Principles of Surgical Treatment

The primary goal of strabismus surgery is to eliminate the relative deviation of the visual axes. Surgery is performed for functional reasons, to create comfortable single binocular vision, or, if this cannot be accomplished, to reestablish a normal facial configuration by aligning the eyes. The term “cosmetic surgery” in connection with operations for strabismus in adults should be avoided since this description is not only incorrect but may also be unacceptable to some insurance carriers and managed care providers. Cosmetic surgery is defined as surgery performed to improve the appearance of a normal person. Since strabismus is an abnormal sensory and motor state of the eyes, its surgical correction falls under the category of reconstructive surgery, the goal of which is to eliminate a disease, abnormality, or defect. The term cosmetic surgery is also a misnomer in view of the fact that in many instances functional visual benefits may be expected from correcting strabismus in adults.

Whatever the indication, the effect of an operation is mechanical, since the position of the globe in the orbit is changed, thus altering the effectiveness of extraocular muscle contraction. Surgical procedures cannot directly affect the innervation reaching the eyes. This can happen only indirectly when innervational and sensory factors adjust to the newly created anatomical and mechanical conditions that have created a new stimulus situation.

The purpose of surgery should be to correct the static angle of strabismus. Operations to change the dynamic angle as defined by us (see p. 180) invariably lead to undesirable results. In paralytic strabismus only those patients in whom the deviation interferes with comfortable single binocular vision in the practical field of fixation (see Chapter 4) should be considered for surgical treatment.

History and General Comments

The earliest reference to strabismus surgery can be found in the early eighteenth century in the writings of an itinerant English oculist named John Taylor. “Chevalier” Taylor, as he called himself, traveled through continental Europe to lecture and perform eye surgery. He left a trail of deteriorating sight and blindness behind him and has been called the greatest charlatan of all oculists who ever lived. His self-glorification and shameless publicity stunts would have made even the most aggressive advertising of contemporary “laser surgeons” appear to be exercises in modesty. According to an eyewitness, Le Cat, who later wrote a book about Taylor, strabismus surgery consisted of excising a piece of conjunctiva from the lower fornix. Taylor claimed that by excising some of its nerve supply an overacting muscle was weakened. After surgery the eye not operated on was bandaged and great was the awe and admiration of the spectators when the eye operated on straightened out and remained straight.
... until several days later when the bandage was removed and the squint returned. But by that time Taylor had moved on to the next town and not before collecting a sizable surgical fee. Le Cat, who knew about the nerve supply to the extraocular muscles, expressed his doubts about the effectiveness of this operation in an unusually dramatic and macabre fashion. Once after an excellent lunch he had a covered dessert dish served to Taylor. When the cover was removed it revealed a human head in which the nerves to the extraocular muscles had been carefully dissected. It was obvious that none of the nerves could have been reached with Taylor’s technique and the embarrassed surgeon left town, his local reputation shattered. Despite his unscrupulousness Taylor deserved credit for being the first to mention in his writings that myotomy of a muscle may cure strabismus. However, none of his contemporaries witnessed that Taylor had actually performed this operation himself.

It was not until a century later, on October 26, 1839, at 3 PM to be exact, that Johann Friedrich Dieffenbach, a general surgeon from Berlin and professor at the famous Charité, corrected strabismus by performing a myotomy of a medial rectus muscle in a 7-year-old esotropic child. Dieffenbach was a popular and famous surgeon in his day to whom medicine owes numerous innovations. Many consider him the father of orthopedic and plastic surgery. When he walked through the streets of Berlin the street urchins greeted him with this ditty:

Wer kennt nicht Doktor Dieffenbach,  
den Doktor der Doktoren?  
Er schneidet Arm und Beine ab,  
macht neue Nas’ und Ohren*.

It is highly probable that the rationale for this operation evolved from successfully treating clubfoot with weakening of the Achilles tendon or torticollis with a myotomy of the sternocleidomastoid muscle. Dieffenbach had a considerable personal experience with both operations. Dieffenbach published this case only a few days later, on November 13, 1839, and mentioned in his report that Louis Stromeyer, another German surgeon, had performed this operation on a cadaver.

It so happened that a Belgian ophthalmologist, Florent Cunier, who had also become aware of Stromeyer’s report, performed a myotomy of the lateral rectus muscle in a patient with exotropia only 3 days after Dieffenbach’s feat. Actually, Cunier’s report of his operation in the Annales d’Oculistique preceded Dieffenbach’s publication in the Medizinische Zeitung by 2 weeks. Not surprisingly, an ardent and ugly dispute evolved when Cunier challenged Dieffenbach’s priority. This disagreeable situation was further aggravated when the prestigious and substantial (6000 gold francs!) Montyon Prize of the Royal Academy of Science (Paris) was shared by Stromeyer for first suggesting the operation and performing it in cadavers and by Dieffenbach for being the first to perform it successfully in a patient.

Dieffenbach’s publication in 1839 secured him priority as the father of strabismus surgery, but he may not have been the first to treat esotropia with a myotomy of the medial rectus muscle. In fact, it is quite likely that he was preceded by William Gibson of Baltimore, a noted general surgeon and professor at the University of Maryland. In the sixth edition of his textbook, The Institutes and Practice of Surgery (1841), Gibson reported that he had performed this operation in four patients in 1818, that is, 21 years before Dieffenbach. However, because the results were disappointing (three undercorrections, one overcorrection), Gibson abandoned this procedure. He graciously stated that he did not intend to question Dieffenbach’s glory as the originator of the myotomy but regretted not having persisted and operated on a larger number of patients.

The news of a surgical cure of strabismus spread through Europe and America with telegraphic speed. Only 2 years after his first publication Dieffenbach had done 1200 cases. Ether anesthesia was not discovered until 1846 and several helpers were needed during the operation, one surgeon and two or three assistants whose task it was to immobilize the sitting patient and to pry the lids open. In 1839 only eight such operations had been performed at the Royal Westminster Eye Hospital, but in 1840 over 400 procedures were done, more than 365 of them in less than 7 months by a single surgeon. The French ophthalmologist Fleussu wrote that “never has an operation been accepted with similar enthusiasm as the operation for strabismus. Surgeons snatched patients from each other or chased them like game whose meat would be suited to feed and fatten one’s own reputation.”

The operation was performed in the United

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*aWho does not know Dr. Dieffenbach/The doctors’ doctor?/He cuts off arms and legs./Makes new noses and ears.*
States soon after it became popular in Europe and England. A treatise on strabismus surgery was published in 1842 by James Bolton of Virginia with illustrations of instruments that look not all that much different form those we are using today.

We became aware of one of the first and perhaps most colorful descriptions of muscle surgery in those days in Stephens’s fascinating diary of his 1841 expedition to Yucatan. Stephens was accompanied on this trip by a Dr. Cabot of Boston who performed this procedure on a 14-year-old boy, and Stephens outlined the operation as follows: “The cure discovered is the cutting of the contracted muscle, by means of which the eye falls immediately into its proper place. This muscle lies under the surface; and, as it is necessary to pass through a membrane of the eye, the cutting cannot be done with a broadaxe or a handsaw.” Stephens then went on to describe the operation performed by Dr. Cabot in a “stout lad of about 19 or 20”:

As soon as the doctor began to cut the muscle, however, our strapping patient gave signs of restlessness; and all at once, with an actual bellow, he jerked his head on one side, carried away the doctor’s hook, and shut his eye upon it with a sort of lockjaw grip, as if determined it should never be drawn out. How my hook got out I have no idea; fortunately, the doctor let his go, or the lad’s eye would have been scratched out. As it was, there he sat with the bandage slipped above one eye, and the other closed upon the hook, the handle of which stood out straight. Probably at that moment he would have been willing to sacrifice pride of personal appearance, keep his squint, and go through life with his eye shut, the hook in it, and the handle sticking out; but the instrument was too valuable to be lost. And it was interesting and instructive to notice the difference between the equanimity of one who had a hook in his eye, and that of lookers-on who had not. All the spectators upbraided him with his cowardice and want of heart, and after a round of reproof to which he could make no answer, he opened his eye and let out the hook. But he had made a bad business of it. A few seconds longer, and the operation would have been completed. As it was, the whole work had to be repeated. As the muscle was again lifted under the knife, I thought I saw a glare in the eyeball that gave token of another slaughter, and the whole work had to be repeated. As the muscle or muscles to be operated on must be determined. Only two procedures can affect the action of an extraocular muscle and thereby alter the position of the eyes. The action of a muscle...
can be weakened or the action of the antagonist muscle strengthened; the two procedures can also be combined. We emphasize that we are speaking of weakening or strengthening the action of a muscle rather than of the muscle itself since most of the currently used surgical procedures do only just that.

**Motility Analysis**

**VERSIONS.** An important criterion for choosing the appropriate surgical procedure is based on the study of versions. In most patients with comitant heterotropia, abnormalities of rotations are present. In esotropes, for instance, adduction may be excessive and abduction deficient. In exotropes, abduction may be excessive and adduction deficient, or both conditions may coexist. Surgical procedures on extraocular muscles should normalize the excursions of the eyes and if successful should reduce the deviation automatically.

For example, if movement of the globe is excessive in a particular direction, the action of that muscle should be weakened. If movement is deficient, strengthening the action of the appropriate muscle is indicated. Thus in a patient with esotropia, excessive adduction, and normal abduction, we perform a maximal recession of the medial rectus muscle and only a nominal resection of its antagonist. On the other hand, if deficient abduction is a prominent clinical feature, maximal resection of the lateral rectus muscle is combined with a small recession of the medial rectus muscle. If movement is excessive in one direction and deficient in the opposite direction, a maximal weakening procedure on one muscle may be combined with a maximal strengthening procedure on the antagonist. When the rotations are neither excessive nor deficient, the emphasis should be placed on strengthening rather than on weakening the muscle action.

Weakening the action of a normally functioning muscle tends to restrict movement of the globe in the direction of action of that muscle. Large resections may cause retraction of the globe with narrowing of the palpebral fissure and large recessions may widen the palpebral fissure.

**DIAGNOSTIC POSITIONS.** The results of careful measurements in the diagnostic positions of gaze (see Chapter 12) also must be considered. Increases or decreases of the deviation in the various positions of gaze are important guidelines in selecting the appropriate procedure. This is especially true in exotropes in whom measurements in lateral gaze may indicate a smaller angle of strabismus than in primary position. The amount of recession of the lateral rectus muscles needs to be modified accordingly to avoid overcorrections.

The degree of change in the horizontal deviation with the eyes in elevation and depression provides information regarding the presence or absence of an alphabetic pattern (see Chapter 19), which may influence the choice of operation. When a vertical deviation is present, measurements in the nine diagnostic positions are essential for determining the muscle or muscles involved and, therefore, in choosing the appropriate surgical procedure.

Regardless of its usefulness, the prism cover test in the diagnostic positions does not replace the study of versions. The two tests do not necessarily elicit the same information. For example, an increase of deviation in dextroversion as measured with the prism cover test in a patient with esotropia may be the result of excess adduction in the left eye or limitation of abduction in the right eye. Even if the measurement is performed with either eye fixating, results will remain the same in both situations; the prism cover test does not pinpoint the cause of the anomalous muscle actions in this situation.

**FORCED DUCTION TEST.** In general, the surgical procedure to be performed should be decided on during the preoperative examinations, and the surgical plan should not be changed when the patient is on the operating table and general anesthesia has caused modification of the deviation. When performing the forced duction test on a patient who has been given a general anesthetic, the surgeon must be aware that succinylcholine, a short-acting, depolarizing muscle relaxant used during endotracheal intubation, causes sustained contraction of extraocular muscles. This effect may last for as long as 20 minutes and may interfere with accurate interpretation of the forced duction test. A nondepolarizing muscle relaxant, which does not alter the forced duction test, is suggested as an alternative drug.77

Modification of the original surgical plan is indicated when the forced duction test (see Chapter 20) reveals mechanical obstacles not anticipated preoperatively or when congenital anomalies or structural changes from previous surgery are found on exposure of the muscle that were not
evident on clinical examination. The surgeon must then change the original plan and remove the restrictions. It follows that the forced duction test must be used at the beginning and end of each surgical procedure and at various stages of the operation.

For instance, limitation of abduction in an infant with esotropia may be caused by weakness of the action of the lateral rectus muscle or by contracture of the medial rectus muscles or of the conjunctiva and Tenon’s capsule. In both instances the results of clinical examination will be similar, yet surgical management will differ. In the first instance, the emphasis of the operation should be placed on strengthening the action of the lateral rectus muscle; in the second case, this operation will cause narrowing of the palpebral fissure and little improvement of abduction unless the contracted medial rectus muscle or conjunctiva is first recessed. Another example for application of the forced duction test is the patient in whom a muscle transposition procedure for paralytic horizontal strabismus or a double elevator or depressor paralysis is contemplated. This procedure is successful only if mechanical restriction in the field opposite that of the paretic muscle is eliminated first (see Chapter 20).

Likewise, the position of the eyes after completion of surgery and while the patient is still anesthetized varies considerably between esotropia and exotropia, even though the eyes may be perfectly aligned once the patient is awake. These findings should be considered by those who attach significance, regarding the amount of surgery to be performed, to the eye position while the patient is anesthetized. As a rule, we have found that assessment of the angle of strabismus under this circumstance is without value except in patients in whom strabismus is purely restrictive. In such instances, the eye position is the same under general anesthesia as during the waking state. This information, in conjunction with the forced duction test, is of diagnostic value.

NEAR POINT OF CONVERGENCE. At one time much attention was given to the near point of convergence in determining the proper surgical procedure for esotropia. The concept was that action of the medial rectus muscles should not be weakened if the near point of convergence is remote, an opinion that in turn was based on the erroneous idea that ocular deviations are caused by inadequate strength of the muscles. Actually, with few exceptions the medial rectus muscles are always able to contract sufficiently to cause maximal convergence of the eyes. The missing factor in convergence insufficiency is the nervous impulse to converge. This impulse arises in an area of the brain that is spatially separate from the area subserving the lateroverision movements. These movements are normal in spite of convergence insufficiency, and convergence may be normal, excessive, or defective even though lateroverisions are normal. To be sure, if the medial rectus muscles are recessed unduly far behind their original insertion, a mechanical paresis is created, and convergence and lateroverision will be affected. On the other hand, properly executed operations will alter the relative position of the eyes, regardless of the type of procedure, and thus change the starting position of convergence and divergence movements. Changes in the near point of convergence then will depend on whether the patient exerts the same convergence impulse as before the operation. If so, the near point should be farther away than it was preoperatively in esotropes and closer in exotropes; however, this is not necessarily true because of postoperative adjustments of innervation.

Symmetrical vs. Asymmetrical Operations

Some ophthalmologists place much emphasis on the need for symmetrical operations; that is, the same type of operation (recession or resection) should be done on homonymous muscles of the two eyes. Behind this thought is the belief that asymmetrical procedures (recession of one muscle, resection of the antagonist) often result in an incomitance, although this is by no means always true. However, routine symmetrical operations are just as wrong as the exclusive use of any one type of procedure.

An ophthalmologist who routinely does symmetrical procedures is automatically assuming that all patients have a symmetrical abnormality, a premise that is contrary to the facts. In our opinion, surgery must be planned on an individual basis. Clearly, an incomitance should not be created where one did not exist, but symmetrical operations should not be performed when asymmetry is the primary anomaly. We therefore recommend symmetrizign rather than symmetrical operations; that is, symmetry should be main-
Comitance is desirable, of course, from a functional standpoint. Recession-resection operations are apt to create incomitance, which can be remedied by operating on the fellow eye. A truly functionally harmful incomitance, however, must be defined. It is doubtful whether incomitance in extreme positions of gaze is of major significance, since the eyes rarely if ever move that far during casual conditions of seeing (see Chapter 4). There is no doubt, however, that postoperative incomitance in primary position is functionally detrimental. Such an incomitance is reflected in a change in deviation in primary position with either eye fixating. This may be termed a primary and secondary deviation, but after muscle surgery, it may be referred to also as a differential angle of squint.

Asymmetrical operations on the yoke muscles of the two eyes also may be performed if the deviation toward one side is significantly greater than toward the other. For example, for an esotropia that is 15° or more in levoversion than in dextroversion, one may RECESS the right medial rectus muscle and resect the left lateral rectus muscle. Such procedures have proved useful in our hands by reducing the deviation in primary position and equalizing or reducing the deviation in dextroversion and levoversion.

### Amount of Operation

The results of strabismus surgery are not precisely predictable in terms of prism dioptries correction per millimeter of recession or resection. So-called dose-response curves or tables, derived from retrospective analysis of surgical outcomes and listing the amounts of recession and resections even in fractions of millimeters, can be found throughout the strabismus literature and give the impression of accurate predictability of the surgical effect. We have found such data rather useless because of the common experience that an identical surgical procedure, performed by the same surgeon on several patients with apparently similar conditions, may give different results in each patient. At best, dose-response curves or tables may serve as very general guidelines for the less experienced surgeon. We have included our surgical dosages for the various forms of strabismus in the appropriate sections of this book, being fully aware, however, of the limitations of such information.

The variability of surgical results depends on numerous and only partially known factors. The sensory state of the patient, the operative technique, the manner in which the muscle is exposed, how thoroughly it is freed, its stiffness, whether the check ligaments are severed, the placement of the sutures, the occurrence of intra- and postoperative bleeding, the tendency to form adhesions and scarring, the state of conjunctival elasticity, and the anatomical variations of muscle insertions are just some of the variables that may influence the effect of the operation. Even though it may eventually be possible to standardize most of these aspects, additional factors, as yet unknown, may exist and influence the surgical result. Each surgeon must establish through periodic review of the surgical outcomes the approximate effectiveness of the procedure he or she routinely employs for a certain condition and modify the accustomed dosage whenever so dictated by this learning experience.

Despite the foregoing, there are certain empirical rules that are helpful in determining the amount of surgery to perform in each patient. Assuming that the identical operative technique was used in each case, the larger the deviation and the more abnormal the rotation, the greater the effect will be following a given amount of surgery. In older children and adults in whom presumably secondary anatomical changes of muscles and fascia have taken place, more extensive operations are required than in younger children with a comparable amount of deviation.

After publication of David Robinson’s classic paper on quantitative analysis of extraocular muscle cooperation in strabismus (1975), efforts began to use the aid of a computer to determine the type and dosage of surgery. Initially, these computer predictions were of little value to the practicing ophthalmologist, but recent work in this direction has become more promising. The reason for this is that many of the variables listed above that determine the surgical outcome are now being incorporated into the calculating process. Some of these previously neglected factors are the mechanical influence of orbital structures and geometry, muscle and connective tissue mechanics, stability of the muscle paths, the muscle pulleys, and innervation. The differences between a preoperative computer simulation of a surgical procedure and its actual outcome are becoming increasingly smaller. There is reason to predict that the computer will play some practical, clinical role in the future in deciding on the amount and type of
surgery in complex strabismus cases of innervation origin. For strabismus of mechanical cause, such computer predictions have been disappointing.

The recent emphasis on performing surgery for esotropia during infancy has brought new awareness of the fact that the globe has not reached adult size during infancy (see Chapter 3, Table 3–2). For this reason, a certain amount of recession or resection is more effective in terms of reducing the tangency between muscle and globe than when growth of the eye is completed.1, 147

Weakening the action of a muscle (recession) is more effective in reducing the deviation than is strengthening its action. Relatively larger amounts of resection therefore are required to produce an effect comparable to that achieved by recession of the antagonist.

The sensory state also must be considered. If the patient has a good functional potential for binocular vision, the surgeon should aim for complete alignment of the eyes. In those patients with deep-seated anomalous retinal correspondence and without a functional potential, less extensive surgery is required, since a cosmatically acceptable residual angle is desirable and will enable the patient to maintain single vision and peripheral fusion by means of anomalous retinal correspondence.

Intractable deep amblyopia causes a major problem when one is determining the appropriate amount of surgery to be performed. The amount done under ordinary circumstances may be insufficient and the eye may revert to its original position. In other patients the deviation will be overcorrected. When deep amblyopia is present, therefore, the patient should be informed of the relative unpredictability of the operation and the possibility of more than one operation must be mentioned.

In view of the foregoing, it is obviously impossible to provide for each strabismic condition a recipe by which one can predict the correction to be obtained from a specific amount of recession or resection. Nevertheless, on the basis of clinical experience and with the surgical technique that we use, the following guidelines have been found useful. A minimal amount of combined resection-recession in one eye can be expected to correct 20° to 25°, and a maximal resection-recession procedure may correct 40° to 60° of esodeviation or exodeviation. A minimal recession of both medial or both lateral rectus muscles corrects 15° to 20°, and a maximal recession of these muscles corrects up to 50° of an esodeviation or exodeviation. The minimal and maximal amounts of recession and resection for each muscle are discussed elsewhere in this book in connection with specific conditions. The amount of surgery must be distributed between the muscles according to our concept of symmetrizing their action, as outlined in the preceding discussion, and according to the size of the deviation.

Prism Adaptation Test

It has been observed that the eyes of some patients may return to the preoperative angle after surgical correction on the basis of anomalous retinal correspondence or of anomalous fusional movements (see Chapter 11) or that the preoperative angle of strabismus may increase or reestablish itself after neutralization with prisms. Such patients are said to be “eating up” the prismatic correction. On the basis of these observations some authors advocate deliberate surgical overcorrection when the angle increases significantly after prismatic compensation. Indeed, the preoperative use of prisms to predict the amount of surgery has been advocated since the 1960s.7, 8, 110, 116, 124, 295 Improved surgical results were reported when the increase of the deviation under the influence of correcting prisms (prism adaptation) was taken into account when determining the surgical dosage. A multicenter, prospective, and randomized study was published in 1990229 that reported the efficacy of prism adaptation in the surgical management of acquired esotropia. This study showed that the success rate in patients whose angle increased under the influence of prisms base-out was higher (see also Ohtsuki and coworkers205) after augmented surgery (89%) than when conventional surgery was performed (79%). In a 1-year outcome study of the original patient group, prism responders operated on for the adapted esotropic angle had a satisfactory motor outcome more often (90%) than those operated on for the entry angle (75%).237 However, Greenwald,84 using a different statistical approach, found that the overall motor success rate for the study’s adaptation group was only 75% vs. 74% in the conventionally managed group.

There remain additional questions regarding the prism adaptation study in terms of the nosologic homogeneity of the study group and the influence of the sensorial state of patients undergoing prism adaptation. Moreover, there are no clear directions
as to how much the surgical dosage needs to be augmented when prisms are “eaten up.” No due consideration has been given to the fact that children tend to compensate for stronger prisms than adults, which may affect the long-term outcome of surgery augmented on the basis of prism adaptation. These considerations, as well as the cost of prismatic spectacles in patients who ordinarily do not wear glasses, the general lack of compliance with wearing prismatic spectacles at home, and the necessity for repeated patient visits during which the prismatic power must be adjusted, are reasons why we have not adopted the prism adaptation procedure to determine the dosage of surgery.

Operations to Weaken the Action of a Muscle

As mentioned elsewhere in this chapter, recessions reduce the deviation more per millimeter than do resections of the same amount. Recessions do not disrupt the action of an overacting muscle, but if a muscle does not overact preoperatively or if it is recessed too far, its action may indeed be unduly weakened.

Excessive weakening of the action of a muscle usually is attributed to the loss of rotational force or torque. Torque acts on the tangential point of the muscle, which, in the case of the medial rectus muscle, lies 6.27 mm in front of the equator when the globe is in primary position. The rotational force is most effective when it is applied tangentially. When the muscle is recessed, thus altering its tangential point, the direction of the applied force changes and the muscle loses some of its mechanical effect. Adelstein and Cüppers have shown that the effect of a recession on the arc of contact depends on the diameter of the globe, which varies in patients of different age groups. Moreover, normal variations in the distance between the limbus and insertion of a muscle may add an additional variable to the effect of a standard recession procedure.

Beisner developed a formula by which the loss of torque with various degrees of recession can be determined. He found that this loss, though real, is less than generally assumed. From the family of curves derived by Beisner, one can see that an 8-mm recession of a medial rectus muscle reduces the torque by only 1.5% in primary position and by 10% with 10° adduction. Beisner believes that the loss of torque is a secondary reaction and that the primary cause of postoperative underaction is loss of contractile force caused by shortening of the muscle. This physiologic relationship between muscle force and muscle length is known to exist.

Beisner’s conclusions are well founded, but in addition to torque and muscle length reduction, a third factor must be considered. Not only has the insertion been set back in the operation but the muscle is no longer quite in situ, since many of the dampening and supporting structures have been severed. Their removal indubitably adds to the effect of surgery.

RECESSION OF HORIZONTAL RECTUS MUSCLES. Recessions of the medial rectus muscles for esotropia should be restricted to a maximum of 8 mm. Larger recessions are likely to disturb the balance between opposing muscle forces: the unopposed lateral rectus becomes tight and pulls the eye toward abduction. This effect is sometimes desirable, for instance, when shifting the null position in congenital nystagmus from a peripheral gaze position to the primary position (Chapter 23). However, if both the medial and lateral recti are recessed as much as 12 mm, the balance between the opposing muscle forces remains undisturbed and the resulting motility deficit in lateral gaze is clinically negligible.

If both medial rectus muscles are operated on, they are often recessed the same amount; however, this is not mandatory, and again consideration should be given to the individual problem. If abduction in one eye is significantly more excessive than that in the fellow eye, one may recess the medial rectus of that eye, say, 6 mm, and recess only 3 mm in the other eye. As a rule, a recession of the medial rectus muscle is more effective than the same amount of recession performed on a lateral rectus muscle. Recessions of the vertical rectus muscles are more effective than when they are performed on the horizontal rectus muscles.

Recessions of both lateral rectus muscles of less than 5 mm are of little use in the treatment of exotropia. Unilateral or bilateral lateral rectus muscle recessions of 6 to 8 mm generally are required. In adults with exodeviations exceeding 70°, we recess the lateral rectus muscle as much as 10 to 12 mm behind its insertion and have never had more than moderate restriction of abduction develop postoperatively. One must remember that even though this puts the insertion behind the
anatomical equator of the eye, the lateral rectus muscle will remain in contact with the globe behind the equator (functional equator) and thus continue to exert rotational force on contraction. This is the reason this operation has a greater effect when performed on the medial than on the lateral rectus muscle.

In patients with long-standing strabismus who have a large and especially fixed angle with contracture of the conjunctiva and Tenon’s capsule, the effect of recessing a rectus muscle can be augmented by recessing these tissues as well (see p. 616).

**RECESSION OF VERTICAL RECTUS MUSCLES.** Surgery on the vertical rectus muscles has become a routine procedure in our time and is very effective and free of complications, provided certain precautions are taken and the amount of surgery is not excessive. Great care must be taken in dissecting the inferior rectus muscle from all its fascial attachments to Lockwood’s ligament, since direct fibrous connections exist between the muscle and the tarsus of the lower lid. Failure to meticulously dissect these connections causes ptosis of the lower lid with resection or retraction of the lower lid when a recession of the inferior rectus muscle is performed. According to Jampolsky, recession of the lower lid can be avoided by reattaching the capsulopalpebral head of the recessed inferior rectus to that muscle 15 mm from the limbus. This approach has been modified by others. We have been unsuccessful in consistently avoiding lower lid retraction using these or other methods to reattach the capsulopalpebral head.

The anatomical connections between the levator palpebrae and the superior rectus muscle are less critical in operating on the latter muscle. Relatively large amounts of recession (e.g., 8 to 9 mm for dissociated vertical deviations) or resection of the superior rectus muscle are tolerated well without causing changes of the upper lid position.

Since surgery on the vertical recti is more effective in terms of millimeters recession or resection per prism dioptr correction and more predictable than surgery on the horizontal recti, we infrequently recess or resect the vertical recti more than 5 mm except in dissociated vertical deviations, endocrine ophthalmopathy, or fibrosis of an extraocular muscle.

**SLANTING OF THE RECTUS MUSCLES.** Fink mentioned that “some surgeons” tenotomize the nasal fibers of the superior rectus muscle or advance the superior border and recess the inferior border of the medial rectus muscle to treat ex-cyclotropia. However, he provided no details or case reports to prove the effectiveness of this procedure. Lyle reported, paradoxically, that advancing the temporal and recessing the medial borders of the inferior rectus muscle reduces ex-cyclotropia when, in fact, it should have increased it. Spielmann introduced slanting of the rectus muscle insertions to treat cyclotropia or a head tilt caused by congenital nystagmus with a neutral zone in a tertiary position. For instance, by recessing only the nasal portion of the right superior rectus, the inferior portion of the right medial, the temporal portion of the right inferior, and the superior portion of the right lateral rectus muscles, the right eye is incycloduced by approximately 10°. The same operation performed on the left eye will produce an excycloduction of the same amount. We can confirm the effectiveness of this operation but have abandoned it for simpler approaches, such as a horizontal transposition of the vertical195 or vertical transposition of the horizontal rectus muscle.53

Nemet and Stolovitch suggested resecting the upper border and recessing the lower border of the medial rectus muscles in convergence insufficiency to make the operation more effective at near than at distance fixation.

**POSTERIOR FIXATION SUTURE.** Cüppers in 1974, popularized a new operation termed Fadenoperation. A similar, though not identical, operation was actually described earlier by Peter in 1941, but it found little resonance at that time. With this operation, the action of a rectus muscle is selectively weakened in its primary field of action without disturbing the balance between agonist and antagonist in other positions of gaze. This is accomplished by suturing the muscle to the sclera behind the equator and thus creating a new insertion, posterior to the anatomical insertion (Fig. 26–1).

The word faden is German for “thread” or “suture” and is derived from the use of sutures to attach the muscle to the sclera. But sutures are used for most types of muscle surgery and hence the term Fadenoperation is rather nonspecific. Moreover, it had been used previously in the older German literature to describe traction sutures used to pull an eye operated on temporarily into an overcorrected position.54, 57 We suggested, there-

Therefore, that this operation be designated posterior fixation suture or retropey of an extraocular muscle.\(^{189}\) Even more precise, though considered by some as too ponderous, is retroequatorial myopexy. In view of these more descriptive and precise terms there is no justification for adopting “Fadenoperation” into the English language as has unfortunately become customary in the contemporary literature.

There are several mechanisms that may contribute to the effectiveness of this operation:

1. The ability of a rectus muscle to rotate the eye depends on the leverage existing between the center of rotation (CR) and the line of pull of the muscle at the tangential point (Pt) (Fig. 26–2A). By suturing the muscle behind the equator, the length of the moment arm (m) of this lever system is decreased and more muscle force \((+++\)\) is now required to rotate the globe the same amount (Fig. 26–2B). The further retroequatorially the muscle is fixated, the greater the muscle force must be to maintain the same rotational effect on the globe. This classic explanation of the torque exerted by a rectus muscle has been challenged by Clark and coworkers\(^{39}\) who, in 1999, demonstrated by axial magnetic resonance imaging (MRI), that a significant change in torque of a retroequatorially fixated horizontal rectus muscle actually does not occur. In fact, the angular displacement from tangency is much less than one would predict geometrically. They point out that the classic “arc of contact” concept on which the geometry shown in Figure 26–2 is based may have to be changed since it does not consider the nonlinear paths of the rectus muscles caused by pulleys and during muscle contraction.

2. Since the innervational requirement of a posteriorly fixated muscle for a given rotation of the globe increases and since there is equal innervation of yoke muscles (Hering’s law; see p. 64), the operation increases innervation to the yoke muscle of the fellow eye. For instance, by performing this operation on the superior rectus muscle of the nonparetic eye in a patient with an elevator paresis, the innervational requirements to elevate the eye operated on increase. Increased innervation will also flow to the...

FIGURE 26–2. Mechanical effect of retroequatorial muscle fixation. For explanation, see text.
The innervation required to elevate the fixating nonparetic eye is insufficient to elevate the paretic eye in a patient with elevator paresis of the left eye, A. A posterior fixation of the superior rectus muscle of the fixating right eye increases the innervational requirement to elevate that eye. B. According to Hering’s law of equal innervation, increased innervation will flow also to the yoke muscle in the fellow eye and elevation of the paretic eye improves.

3. A mechanical restriction occurs from a “reverse leash effect”126 (Chapter 20), which is caused by the retroequatorially fixated and shortened medial rectus muscle pushing against the retrobulbar tissues as the eye adducts.198, 213 This restriction of adduction can be demonstrated with the forced duction test and may cause a jerk nystagmus of the abducted fellow eye so that the clinical picture resembles that of an internuclear palsy.198 Clark and coworkers39 have provided further information on the nature of mechanical restriction of ocular rotation following posterior fixation. They suggested that the restriction that also occurs, though to a lesser degree, in abduction after posterior fixation of the lateral rectus muscle occurs because the muscle pulley is deformed and stretched behind the suture.

4. During the operation the muscle is considerably stretched, which causes its elongation proximal to the myopexy.

5. Since the segment of the muscle between its anatomical and new insertions is functionally inactivated, the contractile elements of the muscle are shortened and the effectiveness of a muscle contraction is decreased.

The posterior fixation suture has found a definitive place in our surgical armamentarium.12, 28, 49, 50, 54, 179, 180, 190, 193, 196, 269 In our experience the operation is most effective when performed on the medial rectus, less effective on the vertical rectus, and least effective on the lateral rectus muscle. We use it frequently in the treatment of incomitant strabismus in patients who are orthotropic in primary position but have diplopia in a peripheral position of gaze. For instance, a patient with a mild right abducens paresis will have single binocular vision in primary position and levoversion but experience uncrossed diplopia in dextroversion. A posterior fixation suture applied to the left medial rectus muscles will cause slight limitation of abduction of that eye without compromising normal binocular vision in primary position. This adduction limitation offsets the limitation of abduction, and single binocular vision will be present in all gaze positions. In other words, a paresis is treated by causing a slight and clinically insignificant paresis of the yoke muscle. Other applications
include nystagmus dampening by convergence (nystagmus blockages syndrome), and esotropia with a variable angle.

It was originally thought that the operation has no effect on the position of the eyes in primary position. Although this still holds true in patients who are orthotropic in primary position, posterior fixation of the medial rectus muscles will reduce esotropia in primary position by decreasing the effectiveness of an increased adduction innervation. If a significant deviation exists in the primary position and further weakening of muscle action is desired in the field of action of a medial rectus muscle, the operation may be combined with a muscle recession. We have also recommended this operation as a viable alternative to marginal myotomies of the medial recti in patients with a persistent esotropia in spite of previously performed maximal recession of the medial recti and resections of the lateral recti. Klainguti pointed out that a desirable cyclorotational effect can be obtained by placing the posterior fixation sutures obliquely into the inferior rectus muscle; fixing the nasal aspect of the muscle closer to the limbus than the temporal one reduced excyclotropia, especially in downward gaze.

Since a conventional posterior fixation suture is not adjustable, A. B. Scott suggested resecting a muscle before recessing it by an amount equal or greater than the resection and then placing it on a hang-back adjustable suture. This alternative to a posterior fixation should be kept in mind if for some reason retroequatorial suture placement is technically difficult or for other reasons (e.g., scleral thinning) is inadvisable (see also Bock and coworkers).

WEAKENING THE ACTION OF THE INFERIOR OBLIQUE MUSCLE. Weakening the action of the inferior oblique muscle can be achieved in many ways: the muscle may be myotomized, disinserted, denervated, anteriorly transposed, extirpated, lengthened by marginal myotomy, recessed, or myectomized at its origin or through a conjunctival incision in the temporal inferior quadrant between its insertion and the inferior rectus muscle. With the exception of a myotomy or myectomy near the origin of the muscle—a technique that has been largely abandoned—all other procedures are currently in use, each strabismus surgeon championing one or the other favorite approach.

MYECTOMY. Having tried most of these methods, each of which has its advantages and disadvantages, over the years, the senior author has found that a myectomy through a conjunctival incision in the inferior temporal quadrant, as illustrated in Figure 26–11, consistently gave the most predictable results. This procedure is effective, fast, technically simple, and intra- or postoperative complications are exceedingly infrequent in our experience (see also Mulvihill and coworker). For these reasons the myectomy has evolved for one of us (GKvN) as the procedure of choice for weakening the action of the inferior oblique muscle. Once the presence of a significant increased elevation in adduction has been determined, a myectomy of the inferior oblique muscle may reduce the hyperdeviation in its field of action and also may reduce significantly a hyperdeviation in primary position. Moreover, if the action of the antagonistic superior oblique muscle has been impeded by a tight inferior oblique muscle, the function of the superior oblique muscle may improve after an inferior oblique weakening procedure. The average reduction of a hyperdeviation by inferior oblique myectomy in the field of action of that muscle in primary position and in the field of action of a paretic superior oblique muscle is 11.5° and this effect increases with the size of the preoperative deviation. Weakening the action of the inferior oblique muscle tends to reduce or even eliminate excyclotropia, which is invariably present when this muscle overacts. Because of its abductive effect, a weakening procedure performed on the inferior oblique muscle alters the horizontal position of the eyes in upward gaze (see Chapter 19). The effect of this procedure on the horizontal position of the eyes in primary position is negligible. An overcorrection following surgery on this muscle is rare but tends to occur when a weakening operation is performed on a normally acting muscle or when the upshoot in adduction is only minimal.

In our experience, as well as that of others, a unilateral inferior oblique weakening procedure should be performed only after it is clearly established that elevation of the adducted fellow eye is normal. If this point is overlooked, hypertropia of the eye not operated on invariably will occur postoperatively.

The adherence syndrome described by Parks in 13% of myectomies performed at the insertion and in 2% of disinsertions of the muscle consists of a hypotropia greater in abduction than adduction and restricted elevation with a positive forced duction test. It is caused by a reattachment of the
muscle into "fatty Tenon’s tissue" and "proliferation of the fibrofatty tissue in the inferior temporal area extending up and attaching to the insertion and capsule of the inferior rectus muscle."²²¹ In performing myectomies of the inferior oblique in the inferior temporal quadrant for the past 40 years, the senior author has encountered this complication only once.

**Recession.** Many strabismologists (including the junior author) prefer to recess rather than myectomize this muscle. It has been argued that this operation is reversible in case of an overeffect and causes less bleeding and swelling. As mentioned above, an overcorrection has not been a problem for the senior author, provided this operation was not performed on a normally acting inferior oblique muscle. The ability to modulate the effect of surgery in asymmetrical cases of increased elevation in adduction is a good reason why recession is preferred by some. Interestingly, limitation of elevation in abduction of the eye operated on with secondary upshoot in adduction of the contralateral eye has been reported as a complication not only of anteriorization but also of recession of the inferior oblique muscle.¹⁴² A recession of only the anterior part of the inferior oblique insertion decreases the excycloduction effect of that muscle and an advancement increases it.⁴¹ Likewise, recession of its posterior aspect will decrease elevation in adduction without having an incyclorotatory effect.

**Anteriorization.** Transposing the insertion of the inferior oblique muscle to a position lateral to the insertion of the inferior rectus muscle⁶⁵, ²⁷², ²²³, ²²⁶ has gained some popularity in recent years. However, this procedure is not without its problems as it may produce changes in the palpebral fissure¹⁴⁵a or a limitation of elevation in abduction with secondary contralateral upshoot in adduction that may require additional surgery.¹⁴⁵, ¹⁶⁹, ²²⁷ Mims and Wood²⁷⁰ suggested that this complication can be avoided by attaching the posterior fibers of the inferior oblique muscle not more than 2 mm lateral to the inferior rectus insertion site. In comparing the results of myectomy vs. anterior positioning, one group of authors found the latter procedure more effective.²⁹ On the other hand, such differences were not noted in other studies of a much larger patient group.³⁵, ¹⁷² In view of the efficacy, lack of complications, and ease with which myectomy or recessions are performed, we see no reason to abandon either of these procedures in favor of anteriorization of the inferior oblique muscle.

**Weakening the Action of the Superior Oblique Muscle.** As in the case of surgery on the inferior oblique muscle, numerous surgical procedures have been used to weaken the action of the superior oblique muscle. The tendon may be recessed, lengthened with silicone expander, severed, or a piece excised. The loose tissue surrounding the tendon may be left intact or severed along with the tendon. Over the years, each of these procedures has found its strong proponents. The impression has been created that by including or excluding the sheath (which some authors believe is not a true sheath but rather a reflection of Tenon’s capsule; see p. 467) in the operation, or by performing the tenotomy closer to or farther away from the trochlea, the surgical effect can be modified. In our experience, this has not been so. Once the continuity of the tendon has been completely disrupted, the effect will be the same regardless of where the tenotomy is done or whether the sheath, or whatever one may choose to call it, is sectioned or left intact. For this reason, and after having tried all procedures, we prefer to perform a tenectomy (including the sheath) midway between the insertion and the trochlea in the upper nasal quadrant or a recession.

**Tenectomy.** As is true with weakening procedures on the inferior oblique muscle, it is difficult to predict precisely the amount of correction in terms of prism diopters achieved by tenectomy of the superior oblique muscle. Nevertheless, the operation is extremely effective in reducing the vertical deviation in downward gaze, an A pattern (see Chapter 19), or an incyclotropia. Overcorrections rarely occur, but if they do, they may cause severe functional problems in downward gaze. To avoid overcorrections, perform tenectomy only in those patients in whom a significantly increased elevation in adduction can be demonstrated unequivocally before surgery. The exception to this rule is a tenectomy in a patient with Brown syndrome.

**Recession.** In patients with milder yet functionally significant increased depression in adduction, we prefer, because of its reversibility, to recess the tendon, as proposed by Caldeira.³⁰, ³¹ It is of interest, however, that a comparison of surgical results in patients treated with tenotomy or recession of the superior oblique tendon showed both procedures to be equally effective.²⁷
Recession of the anterior aspect of the superior oblique tendon decreases incycloduction and an advancement increases it. A tenotomy of the posterior fibers selectively weakens the vertical action of the muscle without altering its cycloducting effect. This procedure has been successfully employed to collapse an A-pattern with mild to moderate overaction of the superior oblique muscles.

As an alternative to recession or tenectomy of the superior oblique muscles, Mombaerts and coworkers have advocated surgical luxation of the tendon out of the trochlea or of the trochlea and tendon and reported encouraging results in acquired Brown syndrome and apparent superior oblique overaction. This approach must await further studies to assess its value in comparison with other superior oblique muscle weakening procedures currently in use.

SILICONE EXPANDER. Rather than recessing the tendon, Wright introduced a silicone expander to lengthen it. He reported superior results with this method in Brown syndrome (see p. 471) when compared with tenectomy. Other authors have also reported favorable results with the silicone expander technique in Brown syndrome as well as in superior oblique overaction with an A-pattern. However, this operation is not without its problems. We had occasion to reoperate on several patients for extrusion of the implant. Moreover, the expander does not always protect against a subsequent symptomatic superior oblique paralysis. Mechanically, the lengthening of a tendon with an expander is not much different from performing a large recession of the tendon and the latter is a much simpler procedure. We prefer recession or a tenectomy rather than implanting foreign material near the superior aspect of the globe, an area that in our surgical experience is particularly prone to form adhesions and postoperative reaction.

MARGINAL MYOTOMY. Unlike a recession or posterior fixation suture, which reduces the action of a muscle by decreasing its rotational force on the globe, the marginal myotomy entails actual weakening of the muscle by reducing the number of contractile elements without changing its arc of contact with the globe. This procedure is effective in further reducing the action of an already maximally recessed rectus muscle or one that cannot be recessed because of extremely thin sclera, an implant, exoplant, or an encircling tube placed directly behind its insertion during prior retinal surgery. A review of 18 patients with persistent esotropia after maximal recession of the medial rectus muscle, in whom we performed a marginal myotomy of these muscles as a second procedure, showed a mean improvement of 9 at distance and of 11 at near fixation after a follow-up of 3 years. The wide range indicates that the results of marginal myotomies are rather unpredictable.

A disadvantage of marginal myotomy is its irreversibility. In the case of a patient with persistent esotropia after maximal recession of both the medial rectus muscle and resection of both lateral rectus muscles, we found that application of posterior fixation sutures to the medial rectus muscles was an effective alternative procedure to marginal myotomy of the medial rectus muscles.

Operations to Strengthen the Action of a Muscle

To enhance the action of a muscle, one may shorten its length by tucking or resecting a portion of the tendon or, in the case of the rectus muscles, by advancing the line of insertion toward the limbus. A combined resection and advancement of a muscle is the most commonly performed operation to enhance muscle action. In terms of prism dipters of correction per millimeter of resection, a single resection usually is less effective than a single recession. Advancements, which have been rather neglected in recent years, are effective in increasing and stabilizing the results of a resection. Excessive resection may mechanically restrict movement of the globe in the opposite direction and therefore must be avoided.

HORIZONTAL RECTUS MUSCLES. The minimal amount of resection performed on the medial rectus muscle is 4 mm, and the maximal amount rarely exceeds 7 or 8 mm. We infrequently resect the lateral rectus muscle less than 4 mm or more than 10 mm. When more correction is desired, the muscle is advanced toward the cornea.

VERTICAL RECTUS MUSCLES. In strengthening procedures, as in weakening operations, the relationship of the vertical rectus muscles to the lid structures must be taken into account. We rarely resect the vertical rectus muscles less than 2 mm or more than 5 mm. As mentioned, in terms of prism dipters of correction per millimeter of surgery, a resection of the vertical rectus muscle is more
effective than a comparable procedure on the horizontal rectus muscles.

**INFERIOR OBLIQUE MUSCLE.** Many technical problems occur with the operation to strengthen the action of the inferior oblique muscle. Resection of the inferior oblique muscle at its insertion and advancement, in particular, must be performed with great care to avoid injury to adjacent structures such as the fovea. Moreover, in our experience, this procedure is notoriously ineffective in improving ocular motility in the field of action of this muscle. For this reason, we prefer to weaken the action of the superior rectus muscle in the fellow eye or, in the case of inferior oblique paralysis, to perform a tenectomy of the ipsilateral superior oblique muscle.

**SUPERIOR OBLIQUE MUSCLE.** A tuck of the superior oblique tendon is effective in improving depression of the adducted eye and in countering excyclotropia. One complication of this operation is temporary inability to elevate the adducted eye, similar to Brown syndrome (see Chapter 21). Even though this overeffect normally subsides after several months, we observed permanent restriction of ocular motility in upward gaze in several instances. The length of tendon included in the tuck ranges from 6 to 12 mm and the decision of how much to tuck depends not only on the degree of hypotropia of the adducted eye but also on the tendon’s tightness. As a rule, we perform larger tucks in congenital superior oblique paralysis than in acquired superior oblique paralysis where the tendon is often tight. The tightness of the tendon must be ascertained by the rotationalduction test (see p. 423) and determines the size of the muscle tuck. By keeping these points in mind, a postoperative limitation of elevation in adduction (iatrogenic Brown syndrome) can usually be avoided.

**Combined Recession-Resection Operation**

Weakening of an agonist combined with strengthening the action of the antagonist in the same operative session adds greatly to the effectiveness of each procedure and tends to stabilize the surgical result. Clinical experience supports the concept that each resection operation reduces the amount of contracture that normally occurs in the recessed antagonist. Thus a resection is often added not so much on its own account but rather as a means to ensure the effectiveness of the recession.

The amount of this surgery depends, as always, on the individual case, and one should determine whether a recession supported by a resection or a resection supported by a recession is the more appropriate approach. The answer is determined from the behavior of the rotations and from measurements of the deviation.

In comitant strabismus, we usually do not perform more than a 5-mm recession of a medial rectus muscle combined with an 8- to 10-mm resection of a lateral rectus muscle for esotropia and an 8-mm recession of a lateral rectus muscle combined with a 7-mm resection of the medial rectus muscle for exotropia (for an exception, see p. 573). When a combined operation of the vertical rectus muscles is indicated, we usually recess one vertical rectus muscle 3 mm and resect its antagonist 4 mm. Combined procedures may also be performed on the oblique muscles (e.g., tucking of the superior oblique and a myectomy of the antagonistic inferior oblique muscle) but are indicated only if the hypertropia in the paretic field of gaze exceeds 25° (see p. 449).

**Single vs. Multiple Procedures**

Many exposures to general anesthesia clearly should be avoided, and the eyes should be aligned with a minimum of operations. With this in mind, it is appropriate to operate on more than one set of muscles during one surgical session, and in large deviations we also operate on all four horizontal muscles in the two eyes.

We maximally recess both medial rectus muscles and resect one lateral rectus muscle to correct esodeviations exceeding 50° and operate on all horizontal rectus muscles if the deviation exceeds 75°. Likewise, a recession of both lateral rectus muscles combined with resection of one medial rectus muscle may be considered for an exodeviaton of more than 50°, and all four horizontal muscles can be operated on if the deviation measures more than 75°.

When small incomitant vertical deviations along with comitant horizontal deviations are present, it is undesirable to attempt to correct both deviations at the same time. A relatively small deviation in one direction often is influenced by the surgical correction of the deviation in the other
direction. It is wise therefore to permit some time to elapse between procedures to determine the effect of the correction of the horizontal deviation on the vertical deviation. Small comitant vertical deviations associated with horizontal deviations respond well to vertical transpositions of the horizontal rectus muscles at the time of their recession or resection (see p. 612).

For a large vertical deviation, which may be the cause of the horizontal deviation by impeding binocularity, an attempt should be made first to correct the vertical deviation. If the vertical deviation is smaller than the horizontal deviation, the horizontal deviation is corrected first. Additional operative procedures depend on the outcome of the initial operation.

The presence of an A or V pattern with increased elevation or depression in adduction alters the rule for correcting horizontal and vertical deviations in separate operations. In such cases, we combine horizontal and oblique muscle surgery in one procedure, as described in Chapter 19.

**Preparation of Patient and Parents for Surgery**

A great deal of unnecessary fear and bewilderment can be avoided by appropriate psychological preparation of the parents and patient. The strabismus surgeon must realize that the first mention of surgery to the parents of a strabismic child may cause considerable anxiety, and the subject should be approached gently and in anticipation of the parents' possible reactions, preferably with the child outside the examination area. The operation should be explained briefly (without going into unnecessary details) to dispel fears and the astonishingly frequent notion that the eye is temporarily removed from the orbit during surgery or that surgery is performed with laser beams. We often sense a mild disappointment when we explain that there is no need for lasers. The parents also should be told how much, if any, postoperative discomfort can be expected. One should make a point of mentioning which eye is to be operated on, but qualify this by saying that plans sometimes have to be altered during the operation. In the case of alternating strabismus with equal visual acuity and essentially normal versions, for which it really does not matter which eye is operated on, the surgeon should make a choice before surgery and inform the patient or parents accordingly. Nothing is more difficult to explain to a patient or the parents why, in some conditions, it makes no difference on which eye the surgery is performed, or why the right eye was operated on when the surgeon had previously mentioned it would be the left eye! Just in case unusual findings at the time of surgery, such as extensive scarring from previous operations, unexpected anatomical anomalies, or absence of a muscle, necessitate a change of plans, it is prudent to obtain permission to operate on either eye before surgery.

Finally, it is a grave mistake to be overconfident in predicting the outcome of strabismus surgery. The late Dr. Alan C. Woods, when questioned by an anxious mother about whether he could guarantee the result of strabismus surgery on her child, replied, “Madam, in order to do that I would have to be God or a damned fool, and I am neither.” The possibility of an overcorrection or undercorrection and the need for more than one operation should be mentioned. If this is adequately explained, most parents will maintain confidence in the surgeon rather than question his or her ability if another operation becomes necessary.

**Anesthesia**

**General Anesthesia**

The globe and its adnexa can be completely anesthetized locally, so that operations on the extraocular muscles can be performed painlessly. Every adult should be informed of this possibility and given the choice between local and general anesthesia. Children and apprehensive or nervous adult patients should be given a general anesthetic. We always use general anesthesia for patients who undergo reoperations, surgery on the inferior rectus muscle for endocrine ophthalmopathy, or surgery on the muscles of both eyes.

Most hospitals in which eye surgery is performed have an anesthesiologist available, which relieves the ophthalmologist of a serious responsibility. The surgeon should abide by the suggestions and rules of the anesthesiologist, who should also be acquainted with the patient and suggest the choice of anesthetic. However, the ophthalmologist must be aware of the details of the anesthesia. In most hospitals the anesthesiologist will insist on intubating the patient, even the youngest infant.

Needless to say, a patient undergoing elective
surgery must be in good health. A physical examination before the operation is mandatory and in children is best performed by their pediatrician. It has been recommended that at least 1 month be allowed between the last upper respiratory infection and the date of surgery since intra-anesthetic pulmonary dysfunction has been observed when this rule was violated.\textsuperscript{157}

As mentioned on page 570, the position of the eyes during surgical levels of anesthesia is different from that during the waking stage in most patients with strabismus of nonmechanical origin. In esotropes in particular, the eyes appear to be less esotropic or even exotropic when innervation of the extraocular muscles is suspended. The inexperienced surgeon is easily intimidated by this observation and will perform less surgery than originally intended. This will produce an undercorrection, of course, and reoperation will become necessary.

### Local Anesthesia

To obtain \textit{akinesia} of the lid, we inject 2 mL of 1\% lidocaine over the condyloid process of the mandible, according to the method of O’Brien. Local anesthesia is then induced with several drops of 0.5\% proparacaine hydrochloride (Ophthaine), followed by an injection of 1\% lidocaine underneath Tenon’s capsule in the quadrant in which surgery is performed. The sub-Tenon’s space is entered with the injection needle 3 mm behind the limbus, anterior to the muscle insertion. The injected solution will rapidly spread, ballooning conjunctiva and Tenon’s capsule into all four quadrants. A retrobulbar injection is rarely necessary. If the tissue is handled gently and excess traction of the muscle is avoided, the patient will tolerate muscle surgery under local anesthesia very well. However, for surgery on the oblique muscles and when applying posterior fixation sutures, we insist on general anesthesia to avoid the pain associated with excessive pulling on the muscle. The same applies to the patient with endocrine orbitopathy.

### Instruments, Sutures, Needles

The complete instrument set that we use in strabismus surgery is shown in Figure 26–4. Although

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure26-4}
\caption{Instruments for strabismus surgery. \textit{Upper row from left to right:} Stevens tenotomy hooks (2); Graefe muscle hooks No. 1 (2); Graefe muscle hooks No. 3 (2); Jameson muscle hooks (2); Castroviejo suturing forceps 0.3 (2); Castroviejo suturing forceps 0.5 (2); Castroviejo needle holders, heavy model (2); mosquito hemostats (2); Jameson resection clamps, right and left, child size (2); Jameson resection clamps, right and left, adult size (2). \textit{Lower row from left to right:} Stevens tenotomy scissors, curved (1); Stevens tenotomy scissors, short blades, straight (1); Wescott tenotomy scissors, blunt point (1); smooth tying forceps (2); Castroviejo caliper (1); Lester-Burch speculum (1); Sauer infant speculum (1); Burch tendon tucker, modified by von Noorden (1);\textsuperscript{156} wet field cautery forceps (1); serrrefines (4); Nugent utility forceps (1); Desmarres lid retractors, sizes 1, 2, 3 (3); malleable neurosurgical retractor (1).}
\end{figure}
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not all of these instruments are routinely used for each procedure, we like to have the complete set available for each operation. For the control of minor bleeding we use Visi-Sorb Absorbent Sticks.* Unlike Q-Tips, which after each application leave numerous irritating cotton fibers behind, or Weck sponges, which are too soft for applying pressure on a capillary bleeding site, we have found these cellulose sticks especially suitable for muscle surgery.

For all recessions and resections, we use 6-0 coated Vicryl (polyglactin 910) suture with an S-14 spatula needle. Vicryl is a synthetic, absorbable suture that has practically eliminated acute allergic suture reactions or formation of postoperative granulomas. However, this suture has some tissue drag; therefore it is somewhat difficult for the inexperienced surgeon to tie snugly to the sclera. Vicryl (7-0) on a GS-9 needle is used for conjunctiva closure.

Some surgeons prefer nonabsorbable sutures such as silk, Dacron (polyethylene teraphthalate fiber), nylon, or Mersilene for recession or resection operations. However, unless the knot is buried under the muscle, as advocated by Reinecke,234 such sutures remain visible through thin conjunctiva for many years; for this reason, we have stopped using them.

Attempts have been made to reattach muscle to sclera by means other than suturing and thus to avoid the risks of perforation and intraocular infection. Various tissue glues have been experimented with and Spierer and coworkers271 showed that fibrin sealant was effective in reattaching extraocular muscles in rabbits, provided a muscle recession was large. With small recessions the contractile strength of the muscle exceeded the holding power of the glue. Clearly, this research is still in its exploratory stage and its importance has also been diminished by the much increased safety of muscle surgery and the development of spatula needles. Unlike curved cutting and reversed cutting needles, these needles have a flat back, a thin profile, a sharp tip, and a cutting edge only at the sides. In our opinion, they are preferable to all other needles for strabismus surgery. The improved control of passage of the needle through the superficial lamellae of even the thinnest sclera minimizes trauma and the danger of perforation.

The needle must be passed through the sclera in such a manner that it remains visible through the scleral lamellae at all times. We prefer the same type of needle for traction sutures.

Surgical Techniques

Few ophthalmologic operations have so many variations as surgery of the extraocular muscles. Methods of exposing muscle, passing or tying the suture, and measuring the amounts of recession or resection differ with each surgeon. It follows that a specified number of millimeters of muscle recession or resection will have a different effect on a deviation in the hands of one surgeon than in those of another surgeon. A surgeon’s technique is determined largely by training. With growing experience and exposure to other methods a surgeon is likely to modify procedures and eventually develop an individualized technique. In the following discussion, only those techniques are discussed to which the authors of this book have become accustomed, without implying that our methods are better than the many others in use but not described in this book. We reviewed the surgical techniques of 17 North American strabismus surgeons and found vast differences in their technique of reattaching the muscle to the sclera.187 Several texts dealing with extraocular muscle surgery are available to which the reader is referred for a description of methods other than those discussed here.32, 106, 218, 245, 304

We do not believe that strabismus surgery must be routinely performed under the operating microscope but believe that surgical loupes and optimal illumination, enhanced, if necessary, by a fiberoptic headlight worn by the surgeon, are indispensable aids to optimal surgical technique.

Preparation of the Eye

The periorbital skin is scrubbed for 3 minutes with hexachlorophene (pHis0Hex) after which the skin and the upper and lower fornices are thoroughly rinsed with normal saline. The periorbital skin is then dried with a sterile towel and painted with povidone-iodine (Betadine). Isenberg and coworkers119 advocated rinsing the ocular surfaces with a half-strength povidone-iodine solution routinely for strabismus surgery after having shown an antibacterial effect of this preparation. There is also some evidence that this procedure may decrease

the prevalence of bacterial endophthalmitis,\textsuperscript{266, 267} although additional data based on a randomized prospective study are lacking to further substantiate this claim.

**Fixation of the Globe**

During general anesthesia the eye may rotate inconspicuously around its anteroposterior axis. Unless recognized by the surgeon, this malorientation of the globe may lead to an incision at the wrong place and even to surgery on the wrong muscle. For orientation and for improved exposure, we prefer fixation sutures that permit rotation and fixation of the globe into any desired position during the procedure. These sutures (6-0 Mersilene on an S-14 needle) are inserted through the conjunctiva and superficial sclera close to the limbus in the 12- and 6-o’clock positions for surgery on horizontal muscles and in the 9- and 3-o’clock positions for surgery on vertical rectus muscles. For surgery on the inferior oblique muscle, only one suture is inserted close to the limbus in the inferotemporal quadrant. Before inserting the fixation sutures, the surgeon must verify the position of the globe may lead to an incision at the wrong place and even to surgery on the wrong muscle.

By using this incision, we found that the normal anatomical relationship between Tenon’s capsule and conjunctiva remains undisturbed and that Tenon’s capsule is not traumatized. The limbal conjunctival incision not only provides easy, quick access to the muscle but causes minimal redness and prevents adhesions, leading to an optimal cosmetic and functional result. Another advantage of using this incision is that conjunctival recession or adjustable sutures can be performed with ease and that surgical exposure during muscle transpositions is better than through a fornix-based incision.

The various steps of the limbal conjunctival incision are illustrated in Figure 26–5 in which exposure of the right medial rectus muscle is used as an example. The surgeon sits at the right temporal side of the patient’s head and the assistant at the opposite side. All illustrations used in this chapter to demonstrate surgical techniques show the eye as viewed by the surgeon.

After insertion of the lid speculum, two 6-0 Mersilene sutures are placed with spatula needles through the episclera and the limbus in the 6- and 12-o’clock positions, and the eye is rotated temporally to expose the site of the operation (Fig. 26–5A). Conjunctiva and Tenon’s capsule are united into a single layer close to the limbus. Thus a conjunctival incision in the limbal area provides direct access to Tenon’s space. The conjoined layer is grasped close to the limbus, and a small radial incision is made through these layers perpendicular to the limbus down to the sclera (Fig. 26–5B). The combined layer of conjunctiva and Tenon’s capsule is undermined by spreading the blades of spring-action blunt Wescott scissors (Fig. 26–5C) and is then severed from the limbus (Fig. 26–5D). At this point, slight bleeding from the perilimbal capillaries may be encountered but is easily controlled by pressure with absorbent sponges or an application with the wet field cautery.

The second radial incision is then made (Fig. 26–5E). The radial incisions are 3 to 4 mm in length, but may be extended 5 mm or more when a large recession or a posterior fixation suture is planned. The curved tenotomy scissors are then inserted into the upper and lower nasal quadrant, and the blades are spread gently only once to separate Tenon’s capsule from the episclera (Fig. 26–5F and G). Care must be taken not to advance the scissors directly toward the muscle insertion to avoid injury to muscle fibers, which could cause
bleeding. The conjunctival flap is then retracted, with forceps or a Graefe muscle hook No. 3 and a Jameson muscle hook is then inserted with its tip pointing away from the insertion (Fig. 26–5H).

The muscle is engaged by rotating the hook 180° (arrow in Fig. 26–5H) and exposed by applying traction to the handle of the hook (Fig 26–5J). The assistant exposes the muscle and its inferior and superior fascial connections (falciform folds of Guérin) by lifting conjunctiva and Tenon’s capsule with two Graefe hooks No. 3 (Fig. 26–5J). The inferior border of the muscle is
freed by sharp dissection (Fig. 26–5K), after which the superior border is similarly exposed (Fig. 26–5L) and freed by dissection (not shown).

When one exposes the lateral rectus muscle, especially if this muscle has previously been operated on, it is advisable to pass the tip of the muscle hook under the muscle insertion from above to avoid accidental engagement of muscle fibers from the inferior oblique muscle. Failure to recognize this potential complication results in postoperative hypertropia or deficiency of vertical rotation.

After completion of the procedure the wound is closed with two 7-0 Vicryl sutures on a GS-9 needle passed through the edges of the flap, limbal conjunctiva, and episclera (Fig. 26–5M and N). These sutures should be cut short to avoid irritation. If the perpendicular incisions are larger than
4 or 5 mm, they may be closed with one additional suture. While the wound is being closed, it is important not to leave a conjunctival ridge near the limbus, since this is cosmetically unsatisfactory and causes interruption of the tear film that in turn may produce a corneal delle.

Occasional difficulties may be encountered in identifying the wound edges, and special care must be taken not to grasp and suture Tenon’s capsule, which may prolapse spontaneously from under the conjunctiva during the operation, especially after the tissue has been excessively manipulated. To distinguish between conjunctiva and Tenon’s capsule, it is helpful to remember that, unlike conjunctiva, Tenon’s capsule is an avascular structure. For the less experienced surgeon we recommend placement of a small suture knot at each edge of the conjunctival flap to identify the corners at the conclusion of the operation.

Recession of a Rectus Muscle

After exposure of the rectus muscle, as shown in the preceding discussion, the surgeon must determine whether the muscle is completely engaged by passing a second hook repeatedly from above and from below or, in the case of the vertical rectus muscle, nasally and temporally under the insertion. During a recession operation, we always cut the check ligaments, although some surgeons believe that this does not enhance the effect of surgery. During surgery on the superior rectus muscle, accidental inclusion of the superior oblique tendon on the muscle hook must be avoided. When recessing the inferior rectus muscle, one should take special care to dissect the intermuscular membrane and all fascial attachments between the inferior rectus muscle and Lockwood’s ligament as far posterior as possible to prevent postoperative changes in the position of the lower lid. When isolating the inferior rectus muscle, one should remember that the nerve supply to the inferior oblique enters this muscle just as it passes the lateral border of the inferior rectus muscle, 12 mm posterior to the inferior rectus insertion.

After the muscle has been thus prepared, two single-armed sutures are inserted and locked to the lower and upper edges of the muscle close to the insertion (Fig. 26–6A–D). As mentioned earlier, we prefer a 6-0 coated Vicryl suture with spatula needles for all recession operations. Care is taken to include all anterior ciliary arteries in the suture lock. Serre needles are clamped to the armed end and the free end of each suture for later identification. The surgeon then applies tension to the muscle hook and the sutures (Fig. 26–6E) while the muscle tendon is dissected from the sclera using curved Stevens tenotomy scissors (Fig. 26–6F). Bleeding from the capillaries on the muscle stump is controlled by applying pressure or using wet field cautery. While the stump of the insertion remaining on the sclera is grasped with a forceps, the assistant places one prong of the preset caliper next to the forceps and indents the sclera with the other end (Fig. 26–6G) to provide a mark to identify the site of reinsertion. Keech and coworkers pointed out that the insertion site may be displaced anteriorly more than 1 mm during disinsertion of the muscle and while pulling it with a fixation forceps to stabilize the globe during determination of the reattachment site. This
factor needs to be considered if the insertion site is used as a point of reference. The needles are then inserted through the sclera, entering the tissue at the mark and emerging slightly lateral and parallel to the limbus (Fig. 26–6H and I). The needle should be visible at all times while passing through superficial scleral lamellae, and deep passage, especially perforation, must be avoided. The sutures are then tied and cut, and the new insertion is carefully inspected before closing the wound (Fig. 26–6J).

Some authors prefer to hang back the muscle routinely on a suture loop from the original insertion rather than suture it to the sclera.64, 85, 167, 238, 236 This technique is used by us only in patients with very thin scleras, those with scleral exoplants after retinal surgery, or when there are mechanical restrictions that prevent adequate exposure of the scleral reattachment site. In most other situations we feel more secure knowing that the muscle is exactly where we put it with sutures. The possibility exists that a suture-suspended muscle may move toward its old insertion once the eye is returned to primary position at the end of the operation. Interestingly, the histologic examination of loop-recessed extraocular muscles revealed that the sutures eventually become replaced by a pseudotendon that resembles real tendon.64

Resection of a Rectus Muscle

Resection of a rectus muscle is illustrated using the right lateral rectus as an example. The surgeon faces the left side of the patient’s head; the assistant is on the opposite side.

After being exposed and placed on a muscle
hook (see Fig. 26–5), the rectus muscle is freed as far as necessary to apply the resection clamp. Fascial structures are left intact as much as possible since their presence may add materially to the effect of the operation. A Jameson resection clamp is then placed on the muscle with its smooth side toward the underside of the muscle belly (Fig. 26–7A). The clamp is placed so that its posterior edge corresponds with the amount of muscle that is to be shortened, as determined with a caliper (Fig. 26–7B). One should not pull excessively on the muscle when making this measurement, since the amount of resection is calculated by the amount of the unstretched muscle.

A common error of inexperienced surgeons during this step of the operation may result in resecting more of the muscle than intended. This occurs when the tendon is plicated as the muscle hook pulls the eye toward the surgeon (Fig. 26–7C). Since this folded part is not included in the caliper measurement, an additional 2 to 3 mm of muscle may thus be unintentionally resected.

After the clamp has been applied and locked, the muscle is severed from the sclera with curved tenotomy scissors at its point of insertion and any footplates or other connections of the tendon to the sclera are removed at that time (Fig. 26–7D). Wet field cautery is used to control bleeding of the muscle stump. Two double-armed 6-0 coated Vicryl sutures are then placed through the stump, one needle of each suture being placed close to the center of the insertion and the other through the corresponding end (Fig. 26–7E–G).

The sutures are then carried through the muscle, which is lifted by the clamp, and the needles are placed through the underside of the belly as closely as possible to the posterior edge of the blade of the clamp (Fig. 26–7H). The central sutures are placed close to the middle of the muscle belly and the outer sutures at the corresponding
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For legend, see p. 588.

edge of the muscle. As the needle emerges on the other side of the clamp, the assistant grasps it with an angled utility forceps (Fig. 26–7I). Each pair of sutures is placed in a serrefine, which is removed only when the suture is being used again, to prevent confusion between the four suture ends (Fig. 26–7J). The assistant then takes hold of the muscle clamp and pulls the muscle forward toward its old insertion while the surgeon ties each suture with a triple knot (Fig. 26–7K). The clamp is loosened slightly, then refastened to grasp the muscle at its end. The muscle is crushed with an angled hemostat (Fig. 26–7L). The muscle segment anterior to the sutures is then removed with scissors (Fig. 26–7M). The muscle is inspected (Fig. 26–7N) and any bleeding at this time is controlled with wet field cautery, after which the wound is closed at the limbus (Fig. 26–7O).

The spring-back balance test introduced by Jampolsky125 may prevent overcorrections from excessive resection of a muscle and is used by us routinely during surgery. After completion of the resection and before closure of the conjunctiva the globe is grasped at the limbus with two forceps in the same manner as during the forced duction test. The eye is rocked back and forth several times in the desired plane and then quickly released. The final position of the globe and the velocity of the spring-back are noted. If, for instance, the lateral rectus muscle has been resected too much, the eye will come to rest in a position of abduction. The surgeon is then well advised to recess the previously resected muscle to avoid an overcorrection that will certainly occur if the test result is ignored. If additional strengthening is desirable, the muscle may be advanced 1 or 2 mm toward the limbus, in which case the muscle should be severed from the sclera as closely as possible to avoid adhesion between the old insertion and the underside of the muscle belly. The benefits derived from an advancement procedure are based on lengthening the arc of contact between the muscle and globe, thus increasing the rotational force of the contracting muscle. This effect will be neutralized if the muscle becomes reattached to its old insertion.
Adjustable Sutures

Interest has been revived in reattaching a recessed or resected muscle to the sclera in such a manner that the effect of surgery can be augmented or decreased during the postoperative period by pulling on or loosening the sutures, which are then retied under topical anesthesia. This technique was described as early as 1885 in the United States and at one time was in vogue in Europe. It has been modified and again made popular in our time by Jampolsky. This approach is based on the assumption that the position of the eye at the end of surgery, hours after surgery or on the first postoperative day, when such adjustments can be made, reflects its position after the postoperative
tissue reaction, photophobia, and ocular discomfort have subsided. This assumption remains unproven. Except for large undercorrections and overcorrections, which tend to persist throughout the postoperative phase, we have not found the immediate postoperative position of the globe to be of much help in assessing the final result of surgery. In fact, in one study the operative result 6 weeks after surgery differed from that 24 hours after surgery in 28 (40%) of 70 patients. Although the direction and magnitude of such changes were unpredictable, most patients showed recurrences in the direction of the preoperative deviation.

Postoperative suture adjustments in children are often difficult, and sedation or even general anesthesia may be required. For these reasons, we do not use adjustable sutures in children. However, we have found them to be of value in patients in whom multiple previous operations or restrictive
forms of strabismus (scarring, contracture) have added a substantial factor of unpredictability to the outcome of the operation. Another indication for their use exists in paralytic strabismus with a good potential for restoration of single binocular vision. Wisnicki and coworkers reported that the use of adjustable sutures reduced the frequency of reoperations in their patients.

The adjustable suture technique in recession of the right medial rectus muscle is shown as an example. A double-armed 6-0 coated Vicryl suture is passed and tied through the center of the tendon and then passed and locked through its upper and lower edges (Fig. 26–8A–C). The muscle has been severed from the sclera, and the sutures have been inserted through the scleral muscle stump (Fig. 26–8D). The muscle has been allowed to recede a desired amount. Moving the sutures back and forth several times (arrows) widens the scleral tunnel created by the sutures and facilitates suture adjustment the following day.

The sutures are tied, first with a single knot, then with a bowknot (Fig. 26–8E). The conjunctiva has been closed with two interrupted 7-0
FIGURE 26–7 Continued. For legend, see p. 591.
Vicryl stitches (Fig. 26–8F), using a bare scleral closure technique. The end of the suture that will open the bowknot is left long for later identification. A traction suture (5-0 Mersilene) may be inserted through the superficial sclera between the limbus and the old tendon insertion to facilitate exposure by rotating the globe during suture adjustment (not shown).

If the eye is in a satisfactory position postoperatively and no adjustment is necessary, the suture bow must be opened and a third knot added to secure the knot. The bowknot is removed (not shown in this figure) by cutting the loop and pulling out the now disconnected suture fragment that has been previously identified by leaving its end long. The remaining double knot is tightened and a third double knot is added before the remaining two sutures are cut. The conjunctiva is left in its recessed position.

For suture adjustment on the first postoperative
day, the knot is opened by pulling on the long end of the suture after the conjunctiva has been locally anesthetized (Fig. 26–8G). To allow the muscle to slide posteriorly, the globe is fixed with forceps (or traction suture) while the patient looks in the direction of the field of action of the recessed muscle (Fig. 26–8H). To move the muscle toward the original insertion, it is pulled forward by means of the sutures while the patient is asked to look in the direction of the pull (Fig. 26–8I). After adjustment is completed, the sutures are permanently tied with a triple surgical knot (Fig. 26–8J) and in a few days the knot will be covered by conjunctiva (Fig. 26–8K).

When there is no conjunctival scarring or contracture of conjunctiva or Tenon’s capsule, this
FIGURE 26–8 Continued. For legend, see p. 595.

No convincing data are available to show that strabismus surgery using adjustable sutures is superior to conventional methods. However, there is no question that the possibility of correcting or at least decreasing a large overcorrection or undercorrection on the first postoperative day is reassuring both to the surgeon and the patient.

Marginal Myotomy of a Rectus Muscle

Of the many techniques used to lengthen a muscle, the marginal myotomy of von Blaskovics and Kreiker has emerged as the most effective. The reason for the less beneficial results of the other methods, such as the tenotomy after O’Connor or Verhoeff, is that unless the central fiber bundles of the muscle are sectioned, only insignificant amounts of lengthening of the insertion are obtained. Hemostasis is obtained by briefly crushing the tissue to be cut with a mosquito hemostat (Fig. 26–9A), after which the myotomy is performed, with at least 70% of the width of the muscle being sectioned from above and below (Fig. 26–9B). If available, we prefer to do the myectomy by using battery-driven thermocautery (not shown), which prevents hemorrhage from the muscle section. After completion of the myectomies, the muscle has been lengthened (Fig. 26–9C). It is important to first make an incision distal to the insertion, followed by a second incision through the muscle or tendon proximal to the insertion. Distortion of the muscle or tendon occurs when the proximal incision is first made, which causes difficulties in gauging the length of the desired section.
of the second incision. Reoperations following marginal myotomies are difficult and should be avoided if at all possible.

**Myectomy of the Inferior Oblique Muscle**

We shall discuss only the technique of myectomy in the lower temporal quadrant, a procedure that in our hands has given the best results. The operation is illustrated using the right inferior oblique muscle as an example. Positions of the surgeon and assistant are shown in Figure 26–10.

The eye is elevated in adduction with a traction suture passed through conjunctiva and episclera near the limbus in the inferotemporal quadrant (Fig. 26–11A). A two-step incision is then made, first through the conjunctiva and then through Tenon’s capsule close to the fornix but on the bulbar side of the conjunctiva to stay clear of the more heavily vascularized tissue in the fornix (Fig. 26–11B). Bleeding from conjunctival capillaries, which obscures the operative field and thus interferes with direct visualization of the inferior oblique muscle, can be avoided by opening conjunctiva and Tenon’s capsule with battery-driven thermocautery (not shown).

The scissors blades are placed in the incision and spread, exposing the sclera (Fig. 26–11C). Care must be taken to avoid injuring the inferotemporal vortex vein, usually located in this region, with the tip of the hook. The wound edges are then retracted with a Desmarres lid speculum to expose the muscle. The muscle can be seen as a salmon-pink, flat structure lying in a pocket of Tenon’s capsule (Fig. 26–11D). Great emphasis is placed on adequate exposure, because many surgeons make the mistake of searching blindly for the muscle with a sharp instrument and thereby run the risk of causing considerable tissue damage or injury to the muscle.

After being exposed, the muscle is engaged under direct visualization on a short Graefe hook (Fig. 26–11E). Closed scissors blades are then placed under the muscle, and Tenon’s capsule is perforated by spreading the scissors blades (Fig. 26–11F). Muscle hooks are placed under the muscle, which is then stretched (Fig. 26–11G). The muscle is clamped with two hemostats approximately 8 mm apart (Fig. 26–11H) and the myectomy is performed by excising the muscle segment between the clamps. One should not cut the mus-
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cle flush with the clamp but should leave a stump for subsequent thorough cauterization (Fig. 26–11I) to prevent postoperative hemorrhage or reattachment of the muscle segment(s) to the sclera or Tenon’s capsule.

The effect of a myectomy can be severely limited if the surgeon leaves even a few strands of intact muscle. It is absolutely essential at this point to ensure that all the muscle fibers have been cut, and the sectioned muscle should be examined to determine whether the muscle sheath is intact posteriorly. The posterior aspect of the muscle may
have slipped off the Graefe hook during its exposure, and the surgeon must search for any missed muscle fibers that must be cut or for an anomalous posterior insertion of the muscle, which is not uncommon. Cadaver studies have shown that multiple insertions occurred in 17% and a bifid insertion in 8% of 100 eyes examined.

The conjunctiva may be closed with one or two interrupted 7-0 Vicryl sutures (Fig. 26–11J), or closure may be omitted, because sufficient coaptation of the wound edges occurs without suture the moment the eye is released from the traction suture. The eye is now grasped with forceps close to the limbus and rotated several times to spread the muscle stumps as far from each other as possible (not shown).

Inadvertent sectioning of the inferior rectus muscle rather than the inferior oblique muscle is a rare complication that can be avoided by fixation of the globe in an adducted and elevated position and by exposing the muscle under direct visualization. Also, the flat inferior rectus muscle differs considerably in appearance from the more oval inferior oblique muscle, the fibers of which run perpendicular to those of the inferior rectus muscle. Before proceeding with the myectomy of the inferior oblique muscle, the less experienced surgeon is advised to identify the inferior rectus muscle by placing a muscle hook under its insertion.

**Recession of the Inferior Oblique Muscle**

For a recession of the right inferior oblique muscle the surgeon and assistant are positioned as shown in Figure 26–10. The eye is elevated and maintained in adduction by means of a traction suture passed through conjunctiva and superficial scleral lamellae near the limbus in the inferotemporal quadrant (Fig. 26–12A) The conjunctiva is opened...
as for a myectomy in the inferior temporal quadrant so as to expose the inferior oblique muscle, which is engaged with a hook under direct visualization (Fig. 26–12B). Care is taken to check with two muscle hooks that all the fibers, particularly the posterior ones, are engaged and that a triangle of bare sclera is visible between the hooks (Fig. 26–12C). As mentioned earlier, anomalies of the insertion of this muscle are not uncommon and must be searched for since recessing only part of a multiple insertion may account for a persistent muscle overaction. A double-armed suture of Vicryl 6-0 is passed through the muscle as close as possible to its insertion and is locked and tied at the edges of the muscle (Fig. 26–12D). The amount of recession is measured from the position of the suture with a caliper (Fig. 26–12E) and an indentation is made into the sclera with the caliper to mark the point of reinsertion. The amount of recession ranges from 5 to 10 mm, depending on the degree of overaction. The muscle is detached from the sclera with scissors (Fig. 26–12F) and reinserted to the sclera at the predetermined site (Fig. 26–12G).
**Tenectomy of the Superior Oblique Muscle**

Improved techniques for exposure and isolation of the superior oblique tendon under direct visualization, as advocated by Parks and Helveston,\(^{219}\) have practically eliminated all complications previously incurred with tenectomy of the superior oblique muscle, such as injury to the medial horn of the levator muscle with subsequent ptosis, injury to the superior rectus muscle, or perforation of the orbital septum with prolapse of orbital fat. The operation is illustrated using tenectomy of the right superior oblique as an example and the positions of the surgeon and assistant are shown in Figure 26–13. We prefer to perform this procedure while standing.

Figure 26–14A shows exposure of the superior oblique tendon. The incision is made through the conjunctiva and Tenon’s capsule between the medial and superior rectus muscles, 4 to 5 mm behind the limbus. As during opening of the conjunctiva and Tenon’s capsule for a myectomy of the inferior oblique, thermocautery may be used to gain access to the sclera (not shown). The wound is gently spread with the tips of blunt tenotomy scissors (Fig. 26–14B).

One muscle hook engages the superior rectus muscle, and the eye is turned downward and outward by applying traction on the muscle hook,
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Recession of the Superior Oblique Muscle

Recession of the superior oblique muscle is shown for the right eye. The positions of surgeon and assistant are depicted in Figure 26–13. The superior oblique tendon has been exposed in the upper temporal quadrant, as for a tuck. In Figure 26–15A the conjunctiva has been opened, close to the temporal border of the superior rectus, and bare sclera and the superior oblique tendon insertion are visible. A hook, inserted under the superior rectus muscle insertion and held by an assistant, has depressed the globe toward the 6-o’clock position. A small Desmarres retractor provides good exposure of the operating field above. Two single-armed sutures have been inserted and locked to the anterior and posterior part of the tendon insertion. After the tendon has been detached with scissors (Fig. 26–15B) the sclera is marked with a caliper, nasal to the superior rectus muscle and as equidistant from the limbus as the original insertion. The tendon is resutured to the sclera at the new insertion (Fig. 26–15C).

Tucking of the Superior Oblique Muscle

Tucking of the superior oblique muscle is illustrated using a tuck of the right superior oblique tendon as an example. The surgeon sits at the right side of the patient’s head, the assistant at the opposite side (Fig. 26–16). The right eye has been rotated downward with two traction sutures inserted near the limbus through conjunctiva and episclera.

An incision is made through conjunctiva and Tenon’s capsule with scissors (Fig. 26–17A) or thermocautery (not shown). Stevens tenotomy scissors have been introduced into the wound, and the blades are spread only slightly to avoid injury to the temporal border of the superior rectus muscle (Fig. 26–17B). A muscle hook has been placed under the superior rectus insertion (Fig. 26–17C). By applying traction to the hook the eye is rotated further downward. The posterior wound edge is pulled upward with a small Desmarres retractor. The temporal border of the superior rectus is lifted with a Graefe muscle hook No. 1 and the superior oblique tendon is exposed with a sweeping motion of a second Graefe hook No. 1 (Fig. 26–17D). A Burch tendon tucker or its von Noorden modification192 has been introduced beneath the superior

Illustration continued on following page
oblique tendon. The folded tendon is drawn into the tucker by turning the screw at the tip of the instrument (screw not shown) (Fig. 26–17E). After achieving the desired amount of tucking, which is determined by tightness or slacking of the tendon (usually between 6 and 12 mm), the cuff of the instrument (large arrow) is brought forward, thus closing the blades of the instrument (Fig. 26–17F). The tuck is fastened beneath the instrument with two 5-0 nonabsorbable sutures, after which the tucker is removed (Fig. 26–17G and H). We do not fasten the tucked portion of the tendon to the sclera as this maneuver may inadvertently pull the tendon anteriorly and thus decrease the vertical effect of the operation and also contribute to postoperative limitation of elevation (pseudo-Brown syndrome). Forced ductions are now performed to determine the degree of restriction when elevating the adducted eye. Mild elastic restriction is desirable and should result in a good effect from the operation. Severe restriction necessitates undoing the tuck and tucking a lesser portion of the tendon. The wound is then closed with one interrupted stitch of 7-0 Vicryl.
Anterior and Lateral Displacement of the Superior Oblique Tendon for Excyclotropia (Harada-Ito Procedure)

Jackson suggested recession and lateral displacement of the superior rectus tendon to counteract excyclotropia in patients with paresis of the superior oblique muscle. We have found the operation described by Harada and Ito to be effective. This procedure involves anterior and lateral displacement of the anterior portion of the superior oblique, thereby increasing the incycloduction ef-
FIGURE 26–17 Continued. For legend, see p. 607.
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fect between 9° and 15° in downward gaze. The operation is illustrated using the right superior oblique tendon as an example.

The lateral aspect of the superior oblique tendon is exposed as for the tucking procedure. A nonabsorbable 5-0 single-armed suture is passed on a spatula needle through the anterior portion of the tendon, 3 mm nasal to its insertion (Fig. 26–18A). The suture is tied firmly with a triple knot. The needle is then passed through superficial scleral lamellae, 3 mm temporally and anterior to the insertion. By tying the suture over its scleral fixation, the anterior portion of the tendon is pulled laterally and anteriorly (Fig. 26–18B). The conjunctiva is closed with one or two interrupted 7-0 absorbable sutures, and the muscle hook is removed.

Fells has modified this operation by splitting the tendon at its insertion and transposing the anterior half anteriorly and laterally, and Metz and Lerner advocated the use of an adjustable suture for this procedure (see also Ohmi and coworkers).

Using the procedure described by Harada and Ito we have noted that the effect of the operation tends to diminish in the course of time. The same has been observed by other authors. Thus, if adjustable sutures are used at all, a slight overcorrection on the first postoperative day should not be reversed by a suture adjustment. Indeed, such initial overeffects are common and do not unfavorably influence the final outcome.

In reviewing our results with the Harada-Ito procedure in nine patients we found that the reduction of the exyclotropia in primary position ranged from 8° to 25°, and in downward gaze, from 12° to 30°.

Posterior Fixation Suture

As an example of posterior fixation suture, posterior fixation of the right superior rectus muscle is used to explain the procedure. A limbal conjunctival incision is made to expose the muscle, and the two incisions perpendicular to the limbus are extended approximately 6 to 8 mm posteriorly. The superior rectus has been secured with two single-armed 6-0 Vicryl sutures (see Fig. 26–6A–D), severed from the globe (see Fig. 26–6E and F), and is held in a Jameson muscle clamp (Fig. 26–19A).

For maximal depression of the globe, two additional traction sutures may be inserted through the sclera at the site of the old insertion (Fig. 26–19B). A Schepens speculum or a similarly shaped retractor (malleable brain retractor, Charles microretinal retractor) is used to expose the sclera retroequatorially while marking the sites of the posterior fixation with calipers (Fig. 26–19C). A curved Scott ruler (not shown) should be used for marking posterior fixation sates exceeding 9 mm since the caliper, measuring the chord rather than the arc, becomes inaccurate beyond this distance. For longer arc measurements the amount of inaccuracy depends on axial length. The Scott ruler can introduce significant measuring errors when measuring.
arc length as small as 12 mm in small eyes and 14 mm in large eyes.

The sutures (5-0 Dacron with a D-1 8-mm needle) are placed 14 mm posterior to the nasal and temporal edges of the superior rectus (Fig. 26–19D). The surgeon must avoid injury to the superior vortex veins (not shown) with the retractor. Both sutures are now in place (Fig. 26–19E) and the speculum has been removed (Fig. 26–19F). The muscle is brought downward (Fig. 26–
19F and G) and reattached to the sclera 4 mm behind its original insertion (Fig. 26–19H). The temporal suture is passed through the muscle from underneath, incorporating one third of the muscle, while the assistant lifts the edge of the muscle and pulls it laterally (arrow) with a Graefe hook No. 1 (Fig. 26–19H). Both sutures, fixing the lateral one third of the muscles, have been tied and cut (Fig. 26–19J). Firm fixation of the muscle is tested with a muscle hook (Fig. 26–19J), after which the wound is closed in the usual fashion (see Fig. 26–5N). When the incisions are gaping, two interrupted sutures are used on each side for closure. When there is no deviation in primary position, the operation is performed without recession as shown in Figure 26–19K and L.
TABLE 26–1. Recommended Distances of Posterior Fixation

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Distance Behind Insertion (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial rectus</td>
<td>12–15</td>
</tr>
<tr>
<td>Lateral rectus</td>
<td>13–16</td>
</tr>
<tr>
<td>Superior rectus</td>
<td>11–16</td>
</tr>
<tr>
<td>Inferior rectus</td>
<td>11–12</td>
</tr>
</tbody>
</table>


The recommended minimal and maximal distances of posterior fixation are shown in Table 26–1.

**Muscle Transposition Procedures**

**HORIZONTAL AND VERTICAL RECTUS MUSCLES IN THE TREATMENT OF A AND V PATTERNS.** The indications and effects of raising and lowering the insertion of the horizontal rectus muscle or nasal or temporal transposition of the vertical rectus muscles are discussed in Chapter 19. Exposure and surgical technique do not differ from the performance of a recession or resection of the rectus muscles; however, the limbal incision should be extended toward the direction in which one plans to move the insertion to gain better exposure, and the muscle should be reinserted parallel to the limbus. The effect may be modified by shifting the insertion between one-half and one full muscle width.

**VERTICAL RECTUS MUSCLES IN THE TREATMENT OF HORIZONTAL STRABISMUS.** Temporal transposition of the vertical rectus muscles for esotropia and nasal transposition for exotropia were also recommended by Nawratzki and Benezra181 for horizontal deviations, when maximal surgery on the horizontal muscles fails to completely align the eyes or if the surgeon is reluctant, for some reason, to operate on the fellow eye. Provided there are no mechanical restrictions, we can confirm the effectiveness of this procedure. However, we recommend only partial transposition of the tendon if previous surgery has been performed on the horizontal recti. Great care must be taken to leave viable anterior ciliary vessels in the part of the muscle segment that remains attached to the globe to prevent anterior segment ischemia. In children a full tendon-width transposition may be performed regardless of whether the horizontal rectus muscles have been previously operated on.

**VERTICAL RECTUS MUSCLES IN THE TREATMENT OF CYCLODEVIATIONS.** Horizontal transposition of one or both vertical rectus muscles corrects cyclotropia (see p. 391) or may be used to induce a cyclodeviation to treat a compensatory head tilt to one shoulder in patients with a nystagmus null zone in a tertiary gaze position (see p. 524). Figure 26–20 shows the direction in which the vertical rectus muscles must be transposed to cause incycloduction or excycloduction of each eye. We perform a full tendon transposition and reattach the nasal and temporal border of each muscle in accordance with their preoperatively measured distance from the limbus. Figure 26–21 shows the direction of the transpositions to cause incycloduction of the right eye. This operation will correct (or induce) a cyclodeviation of $11^\circ$ (range, $8^\circ$ to $12^\circ$) when performed on both vertical rectus muscles.

**FIGURE 26–20.** The cyclotorsional effect of horizontal transposition of the vertical rectus muscles. For explanation, see text. RSR, right superior rectus; LSR, left superior rectus; RIR, right inferior rectus; LIR, left inferior rectus; nas., nasalward; temp., templeward.
HORIZONTAL RECTUS MUSCLES IN THE TREATMENT OF CYCLODEVIATIONS. This procedure, introduced by de Decker,53 may be used for the indications outlined in the preceding paragraph as an alternative to horizontal transposition of the vertical rectus muscles in adults who have had previous surgery on the horizontal rectus muscles.

HORIZONTAL RECTUS MUSCLES IN THE TREATMENT OF VERTICAL STRABISMUS. Vertical transposition of the horizontal rectus muscles in the treatment of comitant vertical strabismus was introduced by Foster and Pemberton,75 who lowered or raised the lateral rectus muscle to treat hypertropia or hypotropia. Alvaro3 advocated lowering or raising the insertions of both horizontal rectus muscles and combining this procedure with recession or resection to achieve simultaneous correction of vertical and horizontal deviations. This technique has found acceptance among many ophthalmic surgeons,136, 160, 200, 202, 214 and we found it effective in reducing the hyperdeviation from 8°/10° to 13°/10° when the muscles are transposed by one muscle width. To lower an eye, the insertions are lowered; to raise an eye, they are raised.

HORIZONTAL OR VERTICAL RECTUS MUSCLES IN PARALYTIC STRABISMUS. Resection of a paralyzed muscle does little to improve its function unless the paralysis is incomplete. Some temporary mechanical advantage may be gained by combining resection of a completely paralyzed muscle with recession of its antagonist; however, rotation of the globe into the field of action of the paralyzed muscle cannot be restored and the eye tends to return to its preoperative position. However, muscle transposition procedures may restore some degree of motility to the eye in the field of gaze of the paralyzed muscle.

Jackson121 and Hummelsheim115 are both credited with being the originators of muscle transposition for paralytic strabismus, and most techniques subsequently used111, 200, 130, 137 are derived from the procedure of Hummelsheim, in which the lateral part of the superior and inferior rectus muscles is transposed to the lateral rectus insertion for abducens paralysis. The numerous modifications of this procedure, all of which are based on the same principle, were reviewed by Helveston104 and Metz.161, 162

The question has been debated whether innervational adjustment takes place so that the transposed muscle can carry out coordinated movements in different directions from its original field of action19, 20 or whether the effect of muscle transpositions is merely mechanical.287 We favor the view that muscle transpositions have only a mechanical effect, which was substantiated by EMG studies of Metz and Scott.164

Before considering a muscle transposition, the surgeon must determine that ocular motility is not impeded by mechanical factors by using the forced duction test (see p. 423). Such restrictions must be removed first, usually by maximal recession of the contractured antagonist of the paretic muscle and, if necessary, by conjunctival recession. We state categorically that a muscle transposition should never be performed unless passive movement of the eye is unrestricted in the paretic field of gaze.

Many of the muscle transposition procedures in use, especially those performed in combination with resection of the paretic muscle and recession of its antagonist, have the disadvantage that the integrity of the insertion of more than two rectus muscles is disturbed. Although many adult patients tolerate well such interference with the blood supply from the anterior ciliary arteries, we have seen in consultation several patients in whom ischemic anterior segment necrosis (see p. 620) occurred after surgery on three or four rectus muscles in one session. The severity of this complication is such that transposition of the entire tendon should be considered only if at least one rectus muscle insertion is intact and has not been previously operated on. Otherwise, partial transposition should be considered.

For double elevator or double depressor paralysis, we transpose the insertion of the horizontal
rectus muscle to that of the superior rectus or inferior rectus muscle, as suggested by Knapp. The operation illustrating transpositions of the horizontal recti in a patient with double elevator paralysis of the right eye is shown in Figure 26–22. The horizontal recti have been exposed with a limbal incision between the 4- and 8-o’clock positions and secured with two single-armed sutures (6-0 Vicryl), after which the muscles are severed from the globe by sharp dissection (Fig. 26–22A). The lateral rectus is transposed to the temporal edge of the superior rectus muscle (Fig. 26–22B). Both horizontal recti are shown in their final position (Fig. 26–22C), after which the conjunctiva is closed near the limbus with two stitches at the 4- and 8-o’clock positions (not shown). The

improved ocular motility in the vertical field of gaze to be obtained with this method is most satisfactory, and horizontal gaze is restricted little, if any.

For cranial nerve VI paralysis, we use a full tendon-width transposition of the vertical rectus muscles to the insertion of the lateral rectus muscle or the procedure described by Jensen, combined with a 6- or 7-mm recession of the medial rectus muscle. To enhance the effect of lateral
transposition of the vertical rectus muscles, Foster\textsuperscript{75} suggested fixation of one fourth of each muscle
to the sclera 16 mm posterior to the limbus with a nonabsorbable 5-0 Dacron suture. The rationale for this approach is based on recent find-
ings with MRI that showed very little retroequatorial lateral displacement of a transposed vertical rectus muscle.\textsuperscript{166} This stability of the posterior muscle path is thought to be the effect of musculo-
orbital tissue connections (muscle pulleys).

The Jensen procedure is illustrated in Figure 26–23 using the right eye as an example. The surgeon has to move around to work on both vertical recti and the lateral rectus and for better mobility should stand during this operation. The right eye is rotated medially by means of traction sutures inserted through episclera near the limbus at the 1- and 5-o’clock positions and a partial peritomy has been performed (Fig. 26–23A). When combining the operation with a recession of the medial rectus, a total peritomy is required to gain access to all rectus muscles. The superior, lateral, and inferior recti have been exposed, and the tendon of the lateral rectus is split in its center with a muscle hook (Fig. 26–23B). The tendons of the lateral, inferior, and superior recti have also been split (Fig. 26–23C). At least one branch of the anterior ciliary vessel should remain in the nasal segment of each of the vertical recti that are not incorporated in the muscle union.\textsuperscript{187} The temporal half of the superior and the superior half of
the lateral rectus muscles have been loosely tied with a nonabsorbable suture (5-0 Mersilene) over the equator, and a similar muscle union has been completed between the temporal half of the inferior and the inferior half of the lateral rectus (Fig. 26–23D). The conjunctiva is closed with two stitches at the limbus (Fig. 26–23E).

Our results with respect to moving the paretic eye from a position of extreme adduction into primary position and restoring abduction from 5\degree to 10\degree have been satisfactory in most instances (Fig. 26–24) (see also Frueh and Henderson\textsuperscript{81}). An overcorrection during the immediate postoperative period frequently occurs but this is usually a transient phenomenon that disappears spontaneously and therefore need not be of concern to the surgeon. Selezinka and coworkers\textsuperscript{257} reported an average reduction of 40\degree esotropia in primary position and an average postoperative abduction of 18\degree in 16 eyes with sixth nerve paralysis after medial rectus recession combined with a rectus muscle union according to Jensen.

Jensen developed this operation to protect the patient against anterior segment ischemia but, unfortunately, this protection is not 100\%. The senior author, after having encountered anterior segment ischemia following the Jensen procedure combined with recession of the ipsilateral rectus muscle in an elderly lady,\textsuperscript{188} no longer uses this operation in older persons. Similar results can be obtained and complications avoided by doing a “partial Knapp” instead, that is, by transposing only the temporal halves of the superior and inferior rectus muscles to the insertion of the lateral rectus muscle, while taking very special care to leave at least one intact anterior ciliary artery in each of the nasal muscle stumps. This is one situation in which the operating microscope may become indispensable during eye muscle surgery.

**SUPERIOR OBLIQUE TENDON IN CRANIAL NERVE III PARALYSIS.** Transposition of the supe-

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**FIGURE 26–24.** Improvement of ocular deviation in primary position and levoversion after Jensen procedure and medial rectus recession for a left sixth cranial nerve paralysis. A, Preoperatively. B, Postoperatively.
rior oblique tendon was suggested first by Dransart, who sutured the resected tendon to the upper part of the lateral rectus insertion in the case of traumatic disinsertion of the tendon. Jackson, Wiener, and Peter described a technique by which the tendon is removed from the trochlea, resected, and reattached to the sclera near the insertion of the medial rectus muscle in cases of oculomotor paralysis. The effect is mechanical; the resected tendon pulls the eye from abduction toward the primary position. The superior oblique tendon is exposed under direct visualization and engaged with a muscle hook, as described earlier in this chapter. A small closed mosquito hemostat is then slid along the tendon until its tip enters the pulley of the trochlea. Opening the hemostat fractures the pulley, and the tendon can be disengaged. The tendon is shortened at least 10 or 12 mm and then sutured to the sclera near the upper border of the medial rectus muscle. This operation is combined with extensive recession (10 to 12 mm) of the lateral rectus muscle and maximal resection of the medial rectus muscle.

Some ophthalmologists have observed that abduction is improved after this procedure, but in our experience this has not always been the case. Our approach to a complete oculomotor paralysis is outlined on page 448.

Recession of Conjunctiva and Tenon’s Capsule

The elasticity of the conjunctiva and Tenon’s capsule may be impaired severely if an eye has been deviated in one position for a long time or if scars have formed from previous operations. This factor must be considered in the etiology of mechanically restricted ocular motility. In such patients, forced closure of the conjunctiva after weakening the action of a muscle will counteract the effect of muscle surgery. Considering for how long conjunctival recession and baring of the sclera have been used in the surgical treatment of pterygium, it is surprising that this technique was seldom used in strabismus surgery until it was popularized by Cole and Cole in 1962. These authors showed that a bare scleral closure after strabismus surgery is effective in eliminating mechanical restrictions of conjunctiva and Tenon’s capsule, that it is uncomplicated, and that reepithelialization occurs in a short time. For obvious reasons the limbal conjunctival approach is especially suitable in muscle surgery if a conjunctival recession is planned at the end of the operation. The conjunctiva is recessed to a point slightly anterior to the new muscle insertion and fastened to the sclera with interrupted 7-0 Vicryl sutures to prevent prolapse of Tenon’s capsule (Fig. 26–25) and to act as a barrier against re-formation of scar tissue. Excess conjunctiva should be excised to achieve a neat closure without leaving an unsightly mass of elevated tissue. We do not routinely use conjunctival recessions but limit their use (1) to patients in whom one or both eyes have remained in a position of extreme adduction, abduction, or depression for a long time and in whom conjunctival tightness must be respected, (2) to those with extensive conjunctival scarring, and (3) to patients whose previously negative traction test after surgical reattachment of a muscle becomes positive after conjunctival closure.

Traction Sutures

If adhesion formation that might counteract the effect of the operation is anticipated, traction sutures may be used to hold the globe in an overcorrected position for several days after surgery. This technique is as old as the beginning of muscle surgery, was used as early as 1848 by Dieffenbach, was mentioned by von Graefe and by Gruening, and was revived by Martinez. Vil-
Use of Plastic Materials

In the prevention of adhesions and preservation of muscle function after isolation from scar tissue during reoperations, plastic sheaths or sleeves were once popular and said to enhance the management of persistent strabismus. We no longer use these materials and have relied instead on reducing trauma to the muscle by using painstakingly gentle surgical manipulation of the tissues and reducing adhesions by meticulously cleaning the sclera.

Complications

Surgical Complications

Hemorrhages during surgery may result from cutting a conjunctival vessel or from accidentally cutting into the muscle during exposure. Sometimes the scleral muscle stump hemorrhages after the muscle has been disinserted. An intraconjunctival or intramuscular hematoma occasionally may develop. Control of bleeding is essential before continuing with the operation, since organization of the clot and subsequent scarring will inevitably result and unfavorably influence the surgical result. Cauterized tissue promotes scar formation; therefore, electrocautery should be used sparingly and only if a bleeding vessel can be directly identified. We have found wet field cautery especially useful in muscle surgery, since it keeps tissue coagulation to a minimum. Most hemorrhages, particularly from a capillary bed, respond well to brief pressure with a cellulose sponge that may be soaked with a drop or two of 1:10,000 epinephrine; however, permission must be obtained from the anesthesiologist to use this drug. The conjunctival incision must never be closed until all hemorrhages have been controlled. Most hemorrhages can be prevented by delicate handling of the tissue and by including the marginal vessels of the extraocular muscles in the sutures.

One of the most distressing complications during strabismus surgery is the loss of a muscle because of inadvertent transection during surgery or as a result of direct trauma, breaking of the sutures, slippage from the muscle clamp, spontaneous disintegration while exerting pull on the muscle hook (“snapped muscle”), or slippage and contracture of the muscle belly within the muscle capsule, which remains attached to the sclera. The last complication usually involves the medial rectus muscle and occurs during the postoperative phase. It must be suspected when a large overcorrection with incomitance suddenly develops after initial alignment. Muscle slippage is caused by superficial suture placement that does not incorporate the entire thickness of the tendon. Neural imaging is indispensable in locating the slipped muscle prior to attempts to retrieve and reattach it.

When the muscle snaps or is lost during the operation, the surgeon, above all, must remain calm. Under bright illumination (headlight or microscope, if necessary), with the help of additional assistants and optimal exposure with malleable retractors, the area in which the muscle loss is suspected should be gently explored by hand-over-hand grasping of Tenon’s capsule, to which posterior fibers of the muscle are usually attached. The direction of exploration should occur in the direction of the muscle, that is, in the case of the medial rectus muscle, along the medial orbital wall, rather than toward the posterior pole where the muscle will rarely be found and injury to the optic nerve is a risk. Irrigation of the operative field with balanced salt solution may cause the pink color of the muscle to contrast with the whitish color of Tenon’s capsule and thus help identification of even a few remaining muscle fibers. These should be immediately secured with a suture. Rather than making later identification of the muscle difficult or even impossible by un-
necessarily traumatizing the tissues, the inexperienced surgeon is well advised to call for consultation or to close the wound and refer the patient immediately to an expert surgeon for reexploration. Neural imaging, especially computed tomography (CT) or MRI, may then be helpful in identifying the location of the muscle and in deciding whether further exploration should be attempted or, in the case of a lost medial rectus muscle retracted too far posteriorly, whether a nasal transposition of the vertical rectus muscles should be performed at this time. In our experience, a muscle can be reattached and will function normally even many months after it was lost during surgery. If the muscle was irretrievably lost, Brown recommended resecting and suturing Tenon’s capsule to the muscle stump, but we consider a muscle transposition to be the more effective procedure.

Inadvertent perforation of choroid or retina may occur when the needle is passed too deeply through the sclera. This complication probably is more common than generally realized but its occurrence has markedly declined since cutting needles have been replaced by spatula needles. The prevalence of chorioretinal perforation after conventional muscle surgery has recently been reported to range from 0.4% to 1.5% on the basis of individual studies of large patient groups. A survey conducted by Simon and coworkers among members of the American Association of Pediatric Ophthalmology and Strabismus showed a prevalence of scleral perforation, as defined to include known retinal damage, in only 0.13% of 553,565 cases. An unusually high prevalence of 15.5% of chorioretinal scarring was reported to occur after posterior fixation sutures at the site of the scleral anchorage. This figure contrasts with a prevalence of only 7% after this operation at Moorfields Eye Hospital.

One must consider the possibility that not all pigmented lesions at muscle reinsertion sites are caused by perforation but may be the result of local tissue reaction to the suture material. In any case, retinal detachment endophthalmitis and phthisis bulbi have been reported as infrequent but extremely serious complications of inadvertent perforation. Thus whenever perforation occurs during surgery, the retina should be examined immediately and the patient placed on systemic antibiotics and referred to a retinal specialist on the following day. Most retinologists will opt for observation without treatment. Such patients should be monitored closely during the immediate postoperative phase with slit-lamp and fundus examinations for signs of intraocular inflammation and infection. We routinely check postoperative patients with a retinoscope for a bright fundus reflex.

A scleral wound made during dissection of the muscle insertion from the globe should be securely sutured and surrounded with diathermy or cryotherapy. The retina should be examined at the time of surgery and at close intervals during the postoperative period. Preventive measures include avoiding excessive pull on the muscle hook, which may force the sclera between the scissors blades when the muscle is being dissected from the globe, and exercising extreme care in patients with thin sclera, such as high myopes.

Transient mydriasis of the eye operated on may occur after detachment of a rectus or oblique muscle and is probably caused by release of neurotransmitters from tissue damage. It disappears soon after surgery and is without clinical significance.

Complications of Anesthesia

Complications arising from anesthesia during muscle surgery are, fortunately, extremely rare, even though anesthesia is never entirely without danger. However minimal the risk may be, the possibility that severe and at times life-threatening situations can suddenly develop during the operation or the recovery period should never be ignored. The ophthalmic surgeon must keep abreast of modern methods of cardiac resuscitation and be able to assist the anesthesiologist in the management of cardiac arrest. The incidence of mortality during general anesthesia for strabismus surgery is not known exactly. Gartner and Billet conducted a survey among North American ophthalmologists and reported a total of 72 deaths during the 10-year period between 1946 and 1956. Over half of these deaths occurred in patients under 7 years of age. A similar survey conducted in Germany by Knobloch and Lorenz, who polled 324 ophthalmologists, revealed 60 deaths, 56 of which occurred during general anesthesia. These authors estimated that the number of operations on which this figure is based was approximately 300,000. J. Cooper and coworkers estimated the mortality rate to be 1.1 per 10,000 cases, which indicates that more people die as a result of tooth extraction (17.42 per 10,000) than as a result of strabismus surgery.
In addition to cardiac arrest and asphyxia from other causes, hereditary or idiopathic malignant hyperthermia is cited as another life-threatening complication of general anesthesia. A careful history and constant monitoring of the rectal temperature during strabismus surgery have become routine in most operating rooms so that this problem may be detected early during the procedure. For details regarding the pathophysiology, diagnosis, and treatment of this fulminant complication of general anesthesia, the reader is referred to the excellent reviews by Gronert and by Marmor, as well as the special bulletin issued by the American Society of Anesthesiologists. We have encountered malignant hyperthermia on only four occasions and not once since we banned the use of succinylcholine in our operating room during strabismus surgery. In each instance, the alert pediatric anesthesiologist noted trismus during the induction phase and anesthesia was stopped before the surgery began. Creatinine phosphokinase (CPK) levels were abnormally high in these children. They were eventually readmitted, treated preoperatively and before induction with intravenous dantrolene, and tolerated anesthesia without further complications.

When taking the patient’s history, the surgeon must always search for information with respect to unusual reactions to an anesthetic agent by members of the patient’s family, since there are several other genetic conditions, such as hepatic porphyria and suxamethonium sensitivity, that cause severe complications during and after general anesthesia. A less harmful complication is bradycardia caused by vagal stimulation, which results from pulling on the muscles, especially the medial rectus muscle. This oculocardiac reflex is a transient phenomenon and the surgeon must immediately stop any operative manipulation of the eye. The cardiac rhythm is usually restored after the pull on the muscle is relaxed, but intravenous injection of atropine is usually given by the anesthesiologist at this point. Injection of atropine is recommended prophylactically in all patients who are to undergo muscle surgery, and an additional dose is administered when the reflex is elicited during surgery.

Milot and coworkers applied a standardized traction force to all extraocular muscles during surgery and reported no difference in the sensitivity of a particular muscle to stretching. However, they noted that quick traction was more likely to elicit the oculocardiac reflex than slow, progressive traction. As mentioned above, patients in whom the oculocardiac reflex can be elicited during surgery become poor candidates for adjustable sutures. There is consensus among anesthesiologists that electrocardiographic monitoring is important during all types of eye surgery to detect potentially dangerous cardiac rhythm disturbances.

**Postoperative Complications**

Postoperative vomiting used to be a most unpleasant sequela of muscle surgery but is rarely a problem now since it can be controlled effectively with droperidol (Inapsine) administered intravenously (0.075 mg/kg) during induction of anesthesia. Infections following strabismus surgery are rare but endophthalmitis is the most dreaded complication after strabismus surgery and nearly always results in phthisis bulbi and blindness. Knobloch and Lorenz reported 87 cases following approximately 300,000 strabismus operations performed in Germany. A higher incidence (1:30,000) was reported by Ing in his survey of 63 North American strabismologists. From these reports the role of inadvertent scleral perforations in the etiology of endophthalmitis is not clear. Most studies indicate that intraocular infections following muscle surgery can be related directly to scleral perforation. Such complications can be prevented by good surgical technique and by routine use of spatula needles during muscle surgery.

**Orbital cellulitis** is rarely mentioned in the literature. Only eight cases have been reported but it might be safely assumed that this severe and potentially life-threatening complication occurs far more frequently than indicated in the literature. Ing reported an incidence of orbital cellulitis and subconjunctival abscess after strabismus surgery of 1 in 1900 cases. In the two patients reported by us, the infection developed on the second and third postoperative days, respectively, accompanied by the characteristic clinical signs of orbital infection, that is, proptosis, swelling of the eyelids, chemosis, and restriction of ocular motility. Both patients responded well to massive intravenous and topical antibiotic treatment and recovered completely. CT is indicated to exclude abscesses that may require draining. Since most surgeons discharge patients who have had extraocular muscle surgery either on the day of surgery or on the first postoperative day, it
is important to recognize that this complication may occur.

A most unusual complication of muscle surgery is a localized suture abscess, which one must assume to be caused by contaminated suture material. We have seen this complication only once and, as one would perhaps expect, in the child of a colleague and close associate. Rapid localized swelling and erythema developed over the insertion of the medial rectus muscle 7 days after a resection operation. The abscess was incised and pus drained from the wound; the organism was later identified as Staphylococcus aureus. Healing was uncomplicated, but subsequent formation of adhesions in the area of the abscess caused mechanical restriction of ocular motility, and reoperation became necessary.

Suture reactions used to be common but have become virtually extinct since the introduction of synthetic absorbable sutures. They occurred either as an acute allergic reaction between 24 hours and 7 days after surgery or as a delayed foreign body reaction 6 to 8 weeks later. During the acute stage the patient complained of ocular discomfort and itching and marked chemosis; hyperemia of the conjunctiva and swelling of the lids also may be present. The reaction could be so fulminating that retractors were necessary to open the lids.

Granulomas have become equally rare. They occur from 2 to 4 weeks after surgery and represent a nonallergic foreign body reaction to the suture material, cotton fibers, glove powder, or an eyelash buried in the wound. Characteristically, a localized, elevated, slightly hyperemic mass will appear over the muscle insertion and at times will form a pedicle type of attachment to the sclera. Treatment consists of topically applied corticosteroid drops, and excision of the granuloma occasionally may become necessary.

Anterior segment ischemia is a more serious complication of muscle surgery, caused by disinsertion of three or four rectus muscles with the inevitable disruption of blood supply to the anterior segment from the anterior ciliary arteries. Several cases are on record in which the patients developed anterior segment ischemia after surgery on just two opposing rectus muscles.66, 232, 248, 263 A survey conducted among the membership of the American Association of Pediatric Ophthalmology and Strabismus (1984) showed an estimated incidence of less than 1 case for each 13,000 procedures.78 Within 24 hours after surgery, microcystic epithelial edema and marked thickening of the cornea may develop. Prominent folds occur in Descemet’s membrane, and nonpigmented keratitic precipitates and a mild cellular aqueous humor reaction are usually present. Segmental iris atrophy,280 a fixed and distorted pupil, and cataract formation are late sequelae of this complication. Treatment consists of intensive systemic and topical administration of corticosteroids, and one patient was successfully treated with hyperbaric oxygen.265 However, there is no evidence that visual outcome or the speed of resolution is influenced by such treatment.250 Severe functional impairment of the eye and even phthisis bulbi have been reported.84, 104

 Apparently the tolerance to a reduction of blood supply to the anterior segment is higher in children than in adults84 but exceptions do occur. Anterior segment ischemia occurred in a child with retinopathy of prematurity after surgery on the horizontal recti66 and in a healthy 10-year-old after a Jensen procedure combined with recession of the ipsilateral medial rectus muscle.18 Anterior segment ischemia has been observed in older patients in whom the Hummelsheim procedure or one of its modifications was combined with surgery on one or both horizontal rectus muscles.59.74, 84, 250, 279 It has been described in a leukemic patient after surgery on the two horizontal rectus muscles122 and in a 66-year-old woman after the Jensen procedure combined with a medial rectus recession.188 Saunders and Sandall249 reported anterior segment ischemia following full tendon transposition of the superior and inferior rectus muscles 9 and 20 years after ipsilateral horizontal rectus muscle surgery. Although fluorescent iris angiography appeared to be a promising method to determine when collateral circulation developed after muscle surgery,103, 210, 211, 245 the “safe” interval after which the second procedure can be planned is unknown and subject to wide individual variations. The probable mechanism of redistribution of blood flow to the anterior segment after disinserting the muscles is via the long posterior ciliary arteries. Routine preoperative angiograms are not recommended. As a general rule, we advise waiting at least 6 months in adult patients after surgery on both horizontal rectus muscles before operating on the vertical recti.

Several methods have been reported for preservation of the anterior ciliary vessels during muscle surgery.79, 141, 159, 246 These range from microdissection of the vessels from the muscle under the operating microscope or loupes to a modified
tucking operation during which the muscle with its vessels is plicated rather than detached from the sclera and resected. Contrary to what one may expect, the vessels in the tucked muscle have been reported to remain patent postoperatively, at least in monkeys.\textsuperscript{251} It is not certain whether the anterior ciliary arteries continue to function after these manipulations in humans. These dissection procedures are time-consuming and technically difficult, especially in the age group at risk for anterior segment ischemia. Moreover, it has been reported that this complication can occur despite the use of blood vessel–sparing surgical techniques.\textsuperscript{174}

Fishman and coworkers\textsuperscript{72} observed in cynomolgus monkeys that a fornix conjunctival incision may provide partial protection against anterior segment ischemia by preserving the perilimbal circulation. Whether the same holds true for humans remains to be established. For additional discussion and literature references on anterior segment ischemia, the reader is referred to a recent review article.\textsuperscript{250} A harmless and rare complication is an amputation neuroma that may develop at the site of the old insertion after tenotomy of a muscle as many as 4 to 8 years after muscle surgery.\textsuperscript{300, 301}

Conjunctival cysts develop when small sections of conjunctival epithelium become buried in the wound during closure. The cyst is filled with clear fluid and can be evacuated with a needle puncture under local anesthesia. If the cyst recurs, excision becomes necessary.

Corneal dellen (plural of the German: Delle, a small depression) are caused by interruption of the corneal tear film and local dehydration of the cornea. This benign complication occurs in the postoperative phase, especially when the limbal incision is used, and must be distinguished from marginal corneal ulcers. Dellen usually respond well to a firm bandage applied to the eye for 24 to 48 hours. They can be prevented by smooth closure of the limbal wound and resection of excess conjunctiva to prevent tissue elevation near the limbus. Scharwey and coworkers\textsuperscript{251} reported a decreased prevalence of corneal dellen if plication of a muscle is used rather than a resection.

A scleral delle after strabismus surgery consisted of a dark, translucent scleral patch that disappeared after hydration and reappeared on dehydration and was managed by covering the bare sclera with a conjunctival flap.\textsuperscript{258} A more serious complication involving the sclera is necrotizing scleritis.\textsuperscript{201} It occurs infrequently after strabismus surgery and seems to affect mostly patients with autoimmune vasculitic systemic disease.\textsuperscript{133, 156, 201} We have observed it only once, 1 month after strabismus surgery in a 60-year-old woman without detectable autoimmune disease.\textsuperscript{304} Inflammation was controlled with topical and systemic corticosteroids and ibuprofen, and good visual acuity was preserved. Interestingly, the patient developed a transient myopia of the involved eye which had not been previously described in connection with necrotizing scleritis. Since there was no axial elongation of the eye on ultrasonography we presume that the anterior segment inflammation produced a transient increase in the refractive index of the lens.

Changes in the refractive error (mostly astigmatism) have been reported after surgery on the extraocular muscles\textsuperscript{55, 59, 227, 232, 264, 283} and are thought to be caused by the effects of a temporary imbalance of muscle forces on the corneal curvature.\textsuperscript{285} One study reported no changes in the corneal topography after routine strabismus surgery\textsuperscript{227} but others have described such changes\textsuperscript{99, 148, 251} Nearly all anomalies of corneal topography return to normal after 3 months, but in rare cases an induced astigmatism may persist.\textsuperscript{252} The practical significance of these findings is that refraction and, if necessary, a change of glasses should be delayed until 3 to 4 months after surgery on the rectus muscles.

Diplopia often occurs when a patient with comitant heterotropia undergoes extraocular muscle surgery and the position of the deviated eye is changed so that the fixated object may no longer fall into the area of the suppression scotoma. Provided there is any vision at all in the eye operated on, such a patient will have postoperative diplopia lasting from a few minutes to a day, a week, or a lifetime. How long it persists depends on the ability of the patient to suppress or to ignore the second image. Since this ability decreases with age, constant diplopia is more common in adults. Although young children as a rule respond readily to the new position of the eye with newly formed suppression, a surprising number actually see double immediately after strabismus surgery. Unlike adults, however, children are rarely distressed by diplopia.

Persistent postoperative diplopia is rare, probably because most patients remain slightly undercorrected after strabismus surgery, and the area of suppression extends from the retinal periphery to the fovea in most forms of horizontal strabismus
and some forms of vertical strabismus. Nevertheless, the danger of persistent, distressing, postoperative diplopia must be pointed out to all adults who desire correction of the deviation. It is then up to the patient to assume the risk. To assess this risk preoperatively and to give the patient a chance to experience diplopia, we fully or nearly fully correct the deviation with prisms placed in a trial frame or fitted frame in front of the glasses. Even if diplopia can be elicited in this way, this does not prove that it will be present after surgery; however, the possibility exists, and the patient at least has been shown what double vision means.

The attitude of a patient with insufferable postoperative diplopia depends on his or her personality. A stolid person will adjust and in time may learn to disregard the second image, though it may not actually be suppressed. More often, the patient knows that the second image should not be there, continually looks for it, and becomes increasingly distressed and hampered in his or her activities. Insufferable postoperative diplopia occurs not only in patients with normal visual acuity in the deviated eye but also occasionally in patients with a deeply amblyopic eye that has been operated on. The second image is then dim, of course, but may cause considerable annoyance to the patient.

Problems arise when treating persistent postoperative diplopia, especially if the eyes are nearly aligned and the images are close together. If this situation can be corrected with prisms, they may be prescribed, or an additional operation may be performed. Some form of occlusion therapy is a final resort when prisms fail or the deviation is too small for reoperation to be considered. Patients who underwent surgery for cosmetic reasons in the first place usually decline the use of a conspicuous occluding device. Occluder contact lenses with a painted iris and pupil are acceptable to some.

Overcorrections

Overcorrections happen in the hands of all surgeons, even the most experienced. They may occur in the immediate postoperative phase or months or even years after surgery. Overcorrections may be accompanied by gross incomitance and inability to move the eye in the field of action of a weakened muscle and may occur in patients in whom the action of the muscle operated on appears perfectly normal.

Marked overcorrection can be attributed to excessive weakening of the action of a muscle or excessive strengthening of its antagonist. Should one note on the day after surgery that a previously esotropic eye is exotropic and that the patient cannot adduct that eye even to the midline, partial or complete disinsertion of the medial rectus muscle must be suspected. Immediate exploration is then indicated, since with the passage of time, location of a disinserted and retracted muscle becomes increasingly difficult. In all other situations, it is advisable to wait at least 6 weeks or longer before considering reoperation. In planning surgery for overcorrection, one should use the forced duction test to determine whether the overcorrection is caused by excessive recession or an excessive resection. The test will be negative if excessive recession has been done. If the muscle has been excessively resected, restriction will be noted on attempts to move the eye in the direction opposite the field of action of the resected muscle, in which case the resected muscle should be recessed.

Cooper suggested that “undoing what was done” is not always the best way to overcome overcorrections. He suggested that the surgical decision be based on the result of the examination, as in other cases of strabismus, and not on the fact that the patient had prior surgery. Thus a patient who has undergone bimedial recession and is left with a divergence excess type of exodeviation is a much better candidate for recession of both lateral rectus muscles than for advancement of the previously recessed medial rectus muscles. With the exception of overcorrections caused by obvious mechanical obstacles, we have adhered to what has become known among North American strabismologists as “Cooper’s law” and find that overcorrections no longer present the problems they once did. The reader is referred to Chapters 16 and 17 for a discussion of the clinical management of overcorrected esodeviations and exodeviations.

Postoperative Care

Length of Hospitalization and Postoperative Checkups

The length of hospitalization for strabismus surgery in recent years has been drastically reduced in most medical centers of this hemisphere. The length of hospital stay is now determined primar-
ily by the time it takes for the effect of general anesthesia to dissipate rather than by concern for the success of the operation. Most patients will be able to leave the hospital in the afternoon if surgery is performed in the morning. For nearly 40 years we have performed muscle surgery on an outpatient basis without a single untoward incident. Laboratory and physical examinations are completed on the day before admission. The patient reports directly to the outpatient surgical suite on the morning of surgery and is discharged from the recovery room on the same day.

It is important to guard against postoperative complications and all patients are examined 24 hours after surgery. We look for large, unexpected overcorrections and external or intraocular infections. The brightness of the retinoscopic light reflex is noted and in older children or adults biomicroscopy is performed. Endophthalmitis may occur after an initial normal examination and not until 3 to 4 days after surgery. Therefore the parents are instructed to return with the child immediately or, when from out of town, to the local ophthalmologist in case of increasing redness of the eye(s), swelling of the eyelids, lethargy, or fever. Adult patients are alerted to watch for dimming of vision in the eye operated on. One week after surgery we again reexamine our patients or, in the case of out-of-towners, have the examination performed by the local ophthalmologist. The final postoperative evaluation, including a complete motility analysis, is done 6 weeks after surgery, at which time the new position of the affected eye usually is stable.

**Dressing**

In some foreign clinics, it is still customary to bandage both eyes for several days even though muscle surgery was performed on only one eye. We are strongly opposed to binocular dressings, since they not only have no effect on the outcome of the operation but also are most distressing to the patient, especially a young child. Even with the best of care, every surgical hospital admission is emotionally upsetting to the patient, and a binocular dressing contributes further to the feeling of isolation and distress. After routine procedures, we do not even apply a dressing to the eye or eyes operated on, and it is our clinical impression that there is less redness, edema, and irritation than when the eye is patched. However, after complicated reoperations, we apply a mild pressure dressing to the eye operated on for 24 hours to control postoperative edema. The eye is also patched when adjustable sutures are used to avoid inadvertent pulling on the sutures.

**Medication**

Most North American strabismus surgeons prefer to treat the eye operated on with an ointment containing corticosteroids and antibiotics for several days after surgery (see also Chipont and Hermosa). No controlled studies are available to support the rationale for such therapy, but from clinical experience it appears to some that there is less secretion from the wound and more rapid whitening of the eye if steroids are used for a few days. It is quite possible that the mechanical lubricating effect of the ointment rather than its pharmacologic action may account for this effect.

Corticosteroid-induced glaucoma has been reported in an adult patient who noted a sudden decrease of vision 3 days after strabismus surgery. Infants and young children are unlikely to report such changes in visual acuity, yet marked intraocular pressure increases after topical corticosteroids are known to occur in this age group. Routine strabismus surgery does not affect the blood-aqueous barrier and in view of the foregoing it appears increasingly doubtful whether postoperative corticosteroids should be prescribed at all.

No ointment is used when adjustable sutures are employed. Medication for postoperative pain is rarely required, since most patients experience only a mild foreign body sensation and some soreness on moving the affected eye after muscle surgery.

Whether a postoperative course of oral antibiotics is indicated is highly debatable. Considering the current litigious climate in the United States, it is perhaps not surprising that many surgeons have switched over in recent years from no medication to treating their patients with oral antibiotics. According to a survey conducted by Ing among North American strabismologists, there is no evidence that either preoperative or postoperative topical or oral antibiotics prevent cellulitis or endophthalmitis after muscle surgery.

**REFERENCES**


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