Chapter 21

EXTRAOCULAR MUSCLE TRAUMA

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INTRODUCTION

Diplopia (ie, double vision; a symptom) after extraocular muscle trauma following a head injury is not uncommon, and it can be disabling. In addition to the distress diplopia generates, the cosmetic appearance due to ocular misalignment is usually unacceptable. *Traumatic strabismus* (ie, lack of parallelism between the eyes' visual axes; a sign) has three main causes: direct injury to the muscles, orbital injury, and neurological injury. A careful workup, including a complete eye examination and measurements of alignment, is used to evaluate the cause and suggest a treatment. In addition, imaging studies and forced ductions are sometimes required.

Treatment of patients with traumatic strabismus is closely related to the cause, and it varies from waiting for spontaneous recovery to prisms to surgery. The surgical decision process can be quite complex and should be based on an accurate knowledge of the etiology of the misalignment and on the principles of strabismus surgery.

ETIOLOGY OF TRAUMATIC STRABISMUS

Direct Trauma to Extraocular Muscles

Direct injury to the extraocular muscles can cause immediate diplopia with obvious misalignment of the eyes. Although uncommon, it is dramatic when it occurs (Figure 21-1). A report of ocular injuries after the Oklahoma City bombing documented only one rectus muscle transection in 115 injuries.[1] In a series from South Africa of 25 patients with traumatic muscle loss, 81% of the injuries were due to stab wounds and none were associated with significant globe penetration or optic nerve damage.[2] Most injuries that cause strabismus are in the anterior, relatively exposed, segment of the extraocular muscles' tendons. A few patients, however, have a posterior laceration of the muscle or trauma to the trochlea of the superior oblique (Figure 21-2).

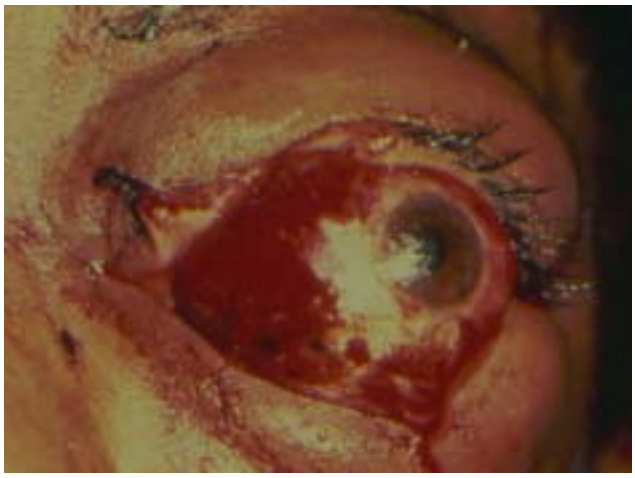

Fig. 21-1. Traumatic laceration of the inferior rectus muscle. This patient received a blow to the eye in a fight; a finger between the eye and the inferior orbital rim cut the inferior rectus. Photograph: Courtesy of Miguel Paciuc, MD, Mexico City, Mexico.

When eyes with an anterior injury are explored surgically, most are found to have a superficial scleral laceration, with the muscle some 5 to 6 mm from its original insertion. The inferior rectus is the most commonly affected muscle, followed by the medial rectus, the lateral rectus, the superior rectus, the inferior oblique, and the superior oblique.[2]

Orbital Fracture

An orbital fracture is one of the most common causes of traumatic diplopia. The classic blowout fracture of the floor of the orbit is the most common, followed by medial wall fractures. The roof of the orbit is uncommonly affected, and the lateral wall is protected by its strong bone structures. Approximately one third of patients with a blowout fracture have diplopia despite early repair of the fracture.[3]

Hypotropia from entrapment of the muscle or of orbital septae is the most common misalignment in cases of an orbital fracture. The muscle itself may be trapped by the sharp edge of the fracture or may be herniated into a sinus. Because the numerous connective tissue septae of the orbit are connected to the muscle sheaths, entrapment of the septae alone give a similar clinical result to muscle entrapment. Not infrequently, the orbital fracture repair itself causes entrapment of the muscle or incomplete release of an entrapped muscle. Forced duction testing generally shows a restriction of the entrapped muscle.

Hypertropia has also been described with posterior fractures.[3,4] The condition is thought to be caused by (*a*) one of the inferior rectus muscles being caught posteriorly on a sharp fracture step-off

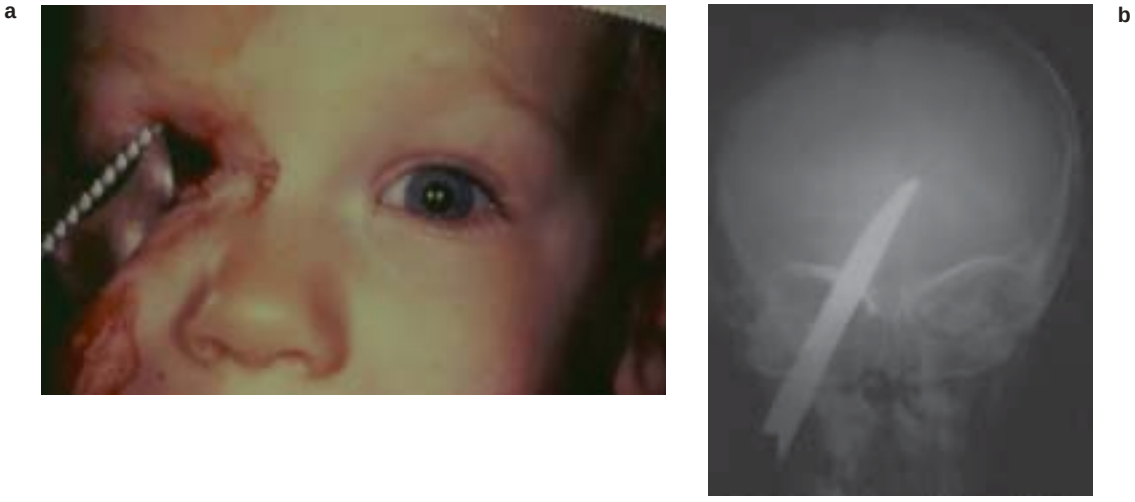

Fig. 21-2. Traumatic laceration of the superior oblique muscle. (**a**) This child picked up a knife from a counter and fell on it while running away from his grandmother. The only significant injury was to the superior oblique tendon, leaving him with a complete superior oblique paresis. (**b**) Plain film radiograph of the same patient. Photograph and radiograph: Courtesy of Julia Stevens, MD, University of Kentucky, Lexington, Ky.

or (*b*) a change in the angle of contact of the inferior rectus with the globe. Patients with traumatic hypertropia have negative forced ductions, and 80% of the conditions are corrected with surgical elevation of the orbital contents to the posterior extent of the fracture.[4]

It is important to realize that nerve and muscle contusion can cause a temporary muscle dysfunction and that orbital swelling can also restrict ocular motility.[5] Although a substantial number of patients with a blowout fracture experience spontaneous resolution of diplopia during the first 2 to 4 weeks after the injury,[3] large fractures should be operated on earlier before scarring makes repair more difficult.

Neurological Injury

Cranial nerve palsies can occur in severe or mild head trauma, but palsy of the third cranial nerve is usually seen only in the setting of severe head injury. However, cranial nerve IV, with its long path, is susceptible to lesser trauma and may be paretic even when the patient had head trauma without loss of consciousness. Palsies of cranial nerve VI are relatively common. In the initial period after an injury to the sixth nerve, the alignment shows an obvious incomitance. With time there is a spread of comitance, however, as the antagonist shortens to match its chronically deviated position.[6]

When dealing with a traumatic diplopia from neurological causes, military ophthalmologists should look carefully for other causes of the nerve damage. Otitis media can inflame the petroclinoid ligament and affect the sixth cranial nerve as it passes through Dorello's canal.[6] Diplopia after relatively mild head trauma also may occur with a previously asymptomatic brain tumor.

DIFFERENTIAL DIAGNOSIS

Underlying strabismus and diplopia from other causes should be excluded. Long-standing strabismus should be considered in any case in which the ocular misalignment does not match the injury, but strabismus can confuse the examiner in the setting of a concussion. In addition to those with a known history of strabismus, patients with an absence of previous symptoms may have mild, congenital, fourth nerve palsies, phorias, and Duane's syndrome. The stress of trauma or illness can cause some patients with phorias to break down into frank strabismus with diplopia, but these cases usually resolve in a few weeks. Careful measurements, old photographs, and occasionally forced ductions or examination under anesthesia may be necessary to differentiate congenital fourth nerve palsies and Duane's syndrome from traumatic nerve injury.

Nonstrabismic diplopia is not uncommon in the setting of trauma and should be differentiated from diplopia-induced ocular misalignment. Usually the diplopia is monocular because of cataract or regular or irregular astigmatism and is eliminated when the patient looks through a pinhole. In addition, a patient who has unilateral traumatic aphakia that is corrected by an anisometropic spectacle lens may see two images due to aniseikonia. This problem is usually easily corrected with a contact lens.

EVALUATION

History

Past ocular history should include specific questions about childhood strabismus, previous muscle operations, and any family history of strabismus. A head posture from an unsuspected congenital superior oblique palsy or Duane's syndrome may be obvious from old photographs such as one appearing on a driver's license.

Military ophthalmologists should inquire carefully about diplopia. A patient with childhood strabismus usually has little or no diplopia. A patient with a resolving muscle contusion or a recovering nerve injury, on the other hand, may describe improving diplopia or an increasing diplopia-free field of gaze.

Ocular Examination

Sensory Tests

When an asymmetrical visual acuity is uncorrectable by refraction and not caused by another obvious source, check for amblyopia with the crowding phenomenon. If the patient complains of diplopia but the eyes appear straight, occlude one eye to rule out monocular diplopia.

The double Maddox's rod test is useful when palsy of the fourth cranial nerve is suspected. Bilateral traumatic fourth nerve palsies are common and usually have more than 10° of excyclotorsion between the eyes on this test.

Stereopsis and the Worth four-dot test (or better, the circularly polarized four-dot test) help to define the binocular status of the patient and can be used to demonstrate improvement after surgery.

Pupils

A careful pupil examination can reveal dilation from a third nerve injury. If a dilated pupil is observed, the pupil should be carefully examined with a slitlamp to rule out traumatic rupture of the iris sphincter or a tonic pupil.

Alignment

Alignment should be measured with the best spectacle correction. Traumatic misalignment can be complex, so measurements should be made in primary position, near-, up-, down-, left-, and right-gaze. In cases with a component of hypertropia or suspected fourth nerve palsies, the alignment should also be measured on head tilt to the left and to the right. In addition to standard prism testing, one of the most useful tests of alignment is the Lancaster red–green test. The Lancaster test gives a standard graphic plot of misalignment and can dramatically demonstrate torsional misalignment.

In cases of incomitant misalignment, the prism should be placed over the apparently paretic or restricted eye and the *primary deviation* measured. If the prism is placed over the apparently normal eye, the resulting measurement is called the *secondary deviation* and is larger than the primary deviation. Because muscle surgery is usually done on the eye with abnormal motility, the primary deviation is the most useful measurement to determine the quantity of recession or resection.

Versions should be tested in all the cardinal positions of gaze. Testing of saccades can be useful to demonstrate a mild nerve paresis that is undetected on version testing: saccades tend to be slow in paresis.

A dilated fundus examination should be done to look for torsion. In straight eyes, the fovea will be observed to be in line with the lower third of the optic nerve head. Patients with fourth nerve palsy usually have observable excyclotorsion of 5° to 15°. Fundus photography can be used to document this torsion with a single photograph that includes both the fovea and the optic nerve.

Refraction

A cycloplegic refraction is important in cases of horizontal misalignment that could have an accommodative component. If an uncorrected hyperopia of greater than 1 diopter is discovered in the set-

ting of concomitant esotropia, then putting this prescription in a trial frame (on another day, when the cycloplegia has worn off) may reduce or eliminate the misalignment.

Clinical Tests

Forced ductions are often useful in the setting of traumatic strabismus and help to confirm a suspected diagnosis of rectus muscle restriction. In the setting of acute orbital injury, soft-tissue swelling by itself can cause restriction, so the results are most reliable 1 week after the injury. Most adults tolerate the procedure well with topical anesthesia alone, but occasionally it must be first done as part of the surgical repair of the misalignment. Caution and gentle technique should be used in patients older than 60 years of age, because the relatively friable conjunctiva of older adults may tear easily. A five-tooth Lester forceps tends to be gentler on the conjunctiva than a three-tooth standard forceps.

The eye is grasped at the limbus nearest the suspected restricted muscle and rotated in the direction of maximum deviation. It is important to avoid depression of the globe while rotating the eye, as this relaxes the muscle being tested. If the muscle is restricted, there usually is an apparent limitation in ocular rotation. Limitation is usually obvious when the restricted eye alone is rotated, but comparisons of the forced ductions of both eyes are sometimes necessary.

Some clinicians use a cotton-tipped applicator to rotate the eye, but I have found this technique to be useful only when the restriction is severe. The applicator must be applied with significant downward pressure, depressing the globe and relaxing the rectus muscle.

The results of clinical forced ductions should be confirmed at the time of surgery. Small amounts of restriction that were not revealed by clinical testing may become apparent. In addition, forced duction testing of the oblique muscles should be done under anesthesia. To test the superior oblique muscle, grasp the limbal conjunctiva nearest the medial rectus muscle. Depress and excyclotort the globe. This exaggerated forced duction puts the tendon on stretch and the examiner should feel the eye roll over the tight tendon. This test is useful to differentiate congenital from acquired unilateral fourth nerve palsy. In congenital cases, the superior oblique tendon is usually quite lax owing to a congenitally anomalous tendon. This test is also useful in diagnosing traumatic Brown's syndrome. The inferior oblique can be tested in a similar fashion, incyclotorting the globe.

Force generation testing is especially useful to differentiate paretic from restrictive misalignment and must be done while the patient is awake. The eye is grasped using the same technique as described for forced ductions, and the patient is instructed to look in the direction of maximum deviation.

Ancillary Tests

Binocular visual fields to determine the field of binocular single vision are especially useful in patients with blowout fractures, for whom the surgical goal may be to shift this field to the most useful areas: primary position and reading position (down-gaze).

Computed tomography (CT) scans with direct axial and coronal views are most useful in the management of orbital-fracture-associated strabismus but can also be used in some cases to evaluate lacerations of the muscle belly (Figure 21-3).

Magnetic resonance imaging (MRI) provides high-resolution imaging of the muscles and is especially useful in evaluating cases of suspected laceration or loss of the muscle. In some cases, MRI

Fig. 21-3. Computed tomography scan. The bottom arrow (pointing right) denotes a slipped left medial rectus, and the top arrow (pointing left) denotes a muscle capsule still attached to the sclera. Reproduced with permission from Murray AD. Slipped and lost muscles and other tales of the unexpected. *J AAPOS.* 1998;2:135.

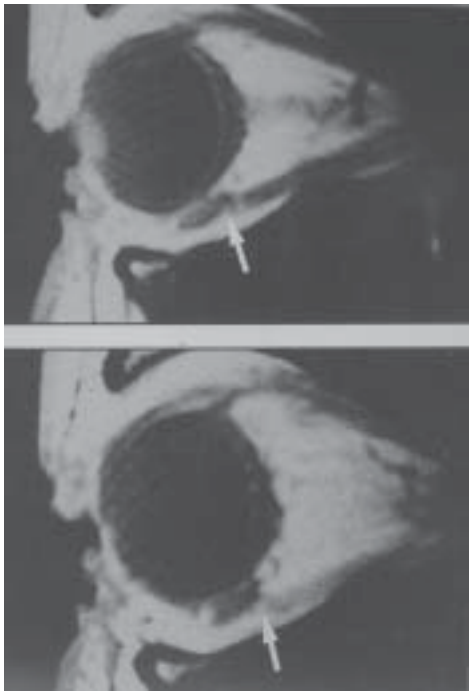

Fig. 21-4. Saggital magnetic resonance imaging scan. The patient is a 31-year-old man who fell onto a standpipe, striking his right lower eyelid and causing a 40-prism-diopter right hypertropia with severe limitation of infraduction due to disinsertion of the inferior rectus muscle. The arrows in both the upper and the lower views point to a defect in the contour of the inferior rectus muscle. A previous computed tomography scan had failed to show the disinsertion. Reproduced with permission from Ward TP, Thach AB, Madigan WP, Berland JE. Magnetic resonance imaging in posttraumatic strabismus. *J Pediatr Ophthalmol Strabismus*. 1997;34:132.

has shown the correct etiology of posttraumatic strabismus prior to surgical exploration and repair (Figure 21-4).[7] High resolution and a reduced signal-to-noise ratio can be obtained by using surface coils. The use of fat-suppression MRI helps reduce artifacts from the otherwise-bright orbital fat. Dynamic MRI (imaging the extraocular muscles during different gaze positions) can be used to differentiate a paretic muscle from a detached, functioning muscle.[8] Muscle bellies with normal contractility thicken when the patient attempts to gaze in the direction of action of that muscle.

MANAGEMENT

Preferred management options to treat the problems caused by extrocular muscle trauma include tincture of time, the use of spectacles and prisms, and occlusive filters in spectacles. In many cases, surgery should be considered only as a last resort.

Medical Options

Cranial nerve paresis often recovers spontaneously over a period of several months, and muscle contusions may recover in a few weeks. One long-term, prospective study[9] of traumatic sixth nerve palsy or paresis showed that spontaneous recovery is common. In this series, 76% of the cases were unilateral and 24% bilateral. Spontaneous recovery at 6 months occurred in 84% of the unilateral cases and in 38% of the bilateral. The prognosis was better if there was some sixth nerve function on the initial examination.

A few patients with concomitant esotropia and significant hyperopia benefit from spectacle correction. Before prescribing lenses, it is wise to evaluate the effect on alignment by putting the corrective lenses in a trial frame.

Prisms can help treat diplopia caused by small amounts of concomitant tropias. In some cases they are the only treatment needed. They are easier to use if the patient already wears spectacles, as small quantities of prism can be obtained simply by displacing the optical center of the lenses. Most patients who did not previously wear spectacles will find those with prisms intolerable. Fresnel prisms are useful as a therapeutic trial and on a short-term basis.

Occasionally a patient has a strabismus that cannot adequately be treated with surgery or prisms, or has incomitance such that the field of binocular single vision is nearly useless (eg, complete third nerve palsies). These patients should be offered the option of cosmetically acceptable occlusive filters. In a few cases, the diplopia is only in one direction (eg, down or laterally) and a partial occluder on the spectacle

lens in the field of diplopia should be considered. In some cases of traumatic nerve paresis, occlusion is also useful while awaiting nerve recovery.

General Principles for Surgical Management

The choice of operation depends on the etiology of the misalignment, clinical measurements, forced duction and force generation findings, and, occasionally, imaging results. Tables of recommended surgical quantities for a given deviation are available in other textbooks, such as the *Color Atlas of Ophthalmic Surgery: Strabismus*.[10]

Military ophthalmic surgeons should bear in mind the following principles for surgical management of patients with extraocular muscle dysfunction:

1. The patient should have realistic expectations. Although muscle surgery is generally successful, some patients will never have useful binocular single vision and should clearly understand this caveat before proceeding to surgery. They should also understand that reoperation may be required.
2. If orbital surgery is planned, do that first. Orbital surgery can relieve strabismus if there is an entrapped muscle, or it can worsen the misalignment.
3. It is wise to delay surgery up to 6 months in cases of traumatic nerve paresis. Spontaneous recovery generally begins by about 3 months, and the alignment is usually stable by 6 months.
4. Optimize the field of binocular single vision. One of the primary goals of surgery in nonconcomitant cases is to increase the field of binocular single vision. This zone should be optimized for the individual patient; most need primary gaze and reading position. Consider the patient's occupation (eg, professional drivers may need single vision in left gaze to avoid diplopia when looking out the driver's-side window).
5. Use adjustable-suture surgery. Adjustment can be made up to 1 week after surgery if hyaluronic acid is placed between the muscle and the sclera.[11]
6. Reduce the risk of anterior segment ischemia. Blood supply to the anterior segment comes from three main sources: ciliary vessels running through the rectus muscles, the limbal conjunctiva, and the long posterior ciliary vessels at 3 o'clock and 9 o'clock. Anterior segment ischemia is rare but can be devastating in severe cases, resulting in chronic iritis, cataract, or even phthisis. To prevent this, avoid performing surgery on all four rectus muscles on one eye, even if the operations are separated in time by years. To preserve the limbal blood supply, use fornix conjunctival incisions in patients younger than age 60. If the patient is known to have compromised blood supply or requires surgery on three muscles, consider the use of vessel-sparing procedures.[12]
7. Recess muscles that are tight on forced duction testing.
8. Operate on the muscle active in the field of greatest deviation. For example, in cases of long-standing fourth nerve paresis, the antagonist inferior oblique muscle is usually shortened, resulting in excyclotorsion and a deviation that is greatest in the action of the inferior oblique muscle. In these cases, the procedure of choice is to weaken the inferior oblique. This dictum must be tempered by the results of intraoperative forced ductions, however. For example, a tight superior rectus muscle will cause the greatest deviation to be in the field of action of the ipsilateral inferior rectus, but the procedure of choice is to weaken the tight superior rectus.
9. Cripple the yoke muscle in nonconcomitant strabismus using either recession of this muscle or a Faden procedure (posterior fixation suture). This intervention increases the field of binocular single vision. For example, a patient with a sixth nerve palsy will have a nonconcomitant esotropia, with greatest deviation in the field of gaze of the flaccid lateral rectus muscle. In this case, a transposition of the ipsilateral vertical recti to the lateral rectus combined with botulinum toxin injected into the ipsilateral medial rectus muscle will help straighten the eye, but a recession of the contralateral medial rectus will increase the field of binocular single vision.
10. Partial nerve palsies are often adequately treated with recession of the antagonist and resection of the weak (but functional) muscle. In some cases, crippling the yoke muscle and injecting botulinum toxin into

the antagonist gives the best results. If the muscle is completely palsied, however, it is not worth resecting, as little effect will be obtained.

11. Transpositions of recti combined with injection of botulinum toxin into the antagonist are generally the best approach to complete isolated rectus muscle palsy (eg, sixth nerve palsy).

Management of Lacerated Muscles

The management of most lacerated muscles is similar to that of slipped or lost muscles. If repaired early, a muscle that has been lacerated at its insertion is usually found 5 to 6 mm away from the original insertion. In one series[2] of such cases, 53% were repaired with reattachment of the muscle to its original insertion, whereas 29% of the muscle insertions could not be found and had to be treated with transpositions (eg, transposing the superior and inferior rectus muscle insertions to the site of a lacerated lateral rectus insertion). With time, the lacerated muscle and its antagonist shorten, making retrieval more difficult and requiring recession or botulinum toxin injection of the antagonist muscle.

When looking for the lacerated muscle, good illumination and exposure using malleable retractors are critical. Loupes and a strong overhead surgical light are usually sufficient, but a headlight or operating microscope may also be useful in some cases. The muscle is often found at its penetration through Tenon's capsule. If the patient has not received systemic atropine or a similar medication as part of anesthesia, then tugging on the muscle may help differentiate it from the surrounding tissue by inducing the oculocardiac reflex.[13] If the muscle cannot be found after diligent efforts, it is not useful to open Tenon's capsule in a usually futile search for the stump: this procedure risks causing a fat adherence syndrome. Instead, the muscle should be declared lost and a transposition procedure performed to align the eyes.

SUMMARY

When a trauma patient complains of double vision, a careful clinical history and examination can in most cases clearly define the etiology, differentiating among direct trauma to the extraocular muscles, fracture of the orbit, and neurological causes. In some cases, imaging of the orbits or the head is necessary to make the final diagnosis. Infrequently, a surgical exploration of the muscles is required.

The examination should include a complete standard eye examination including refraction, confrontation visual fields, pupils, anterior segment, and fundus examination. The motility examination should include, at a minimum, a careful measurement of alignment in relevant positions of gaze, versions, and a fundus examination looking for torsion. In addition, parts of the examination should be carefully tailored to the individual patient, such as alignment in head-tilt positions for patients with vertical deviations, double Maddox's rod testing to measure subjective torsion, and the Lancaster red–green test in cases of complex misalignment. In many cases, forced duction and force generation testing are also required to look for restrictive and paretic causes of misalignment. Many patients with traumatic strabismus need imaging studies to define the course of the muscles, orbital fractures, and central nervous system injury.

The preferred management is determined in part by the motility examination and orbital scan (in the case of orbital fractures). Many cases of diplopia caused by nerve or muscle contusion recover spontaneously in weeks to months; some can be treated with spectacles or prisms. Patients who eventually require surgery to relieve diplopia should be carefully counseled to have realistic expectations, and surgery should be guided by the several principles outlined above.

REFERENCES

1. Mines M, Thach A, Mallonee S, Hildebrand L, Shariat S. Ocular injuries sustained by survivors of the Oklahoma City bombing. *Ophthalmology*. 2000;107:837–843.

2. Murray AD. Slipped and lost muscles and other tales of the unexpected. *J AAPOS* 1998;2:133–143.

3. Good WV, Hoyt CS, eds. *Strabismus Management*. Boston, Mass: Butterworth-Heinemann; 1996: Chap 20.

4. Seiff SR, Good WV. Hypertropia and the posterior blowout fracture: Mechanism and management. *Ophthalmology*. 1996;103:152–156.

5. von Noorden GK. Diagnosis of trauma-related strabismus. In: Freeman HM, ed. *Ocular Trauma*. New York, NY: Appleton-Century-Crofts; 1979: Chap 33.

6. Rubin SE. How to diagnose and manage paralytic strabismus. *Rev Ophthalmol.* 1999;6(10):103–116.

7. Ward TP, Thach AB, Madigan WP, Berland JE. Magnetic resonance imaging in posttraumatic strabismus. *J Pediatr Ophthalmol Strabismus*. 1997;34:131–134.

8. Shin GS, Demer JL, Rosenbaum AL. High resolution, dynamic, magnetic resonance imaging in complicated strabismus. *J Pediatr Ophthalmol Strabismus*. 1996;33:282–290.

9. Holmes JM, Droste PJ, Beck RW. The natural history of acute traumatic sixth nerve palsy or paresis. *J AAPOS*. 1998;2:265–268.

10. Wright KW, ed. *Color Atlas of Ophthalmic Surgery: Strabismus*. Philadelphia, Pa: JB Lippincott Company; 1991: 241–243.

11. Granet DB, Hertle RW, Ziylan S. The use of hyaluronic acid during adjustable suture surgery. *J Pediatr Ophthalmol Strabismus*. 1994;31:287–289.

12. McKeown CA, Lambert HM, Shore JW. Preservation of the anterior ciliary vessels during extraocular muscle surgery. *Ophthalmology*. 1989;96:498–507.

13. Reineke RD. Treatment of ocular motility problems following trauma. In: Freeman HM, ed. *Ocular Trauma*. New York, NY: Appleton-Century-Crofts; 1979: Chap 34.