Adult Strabismus

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Cover. Top: adult with exotropia and left hypotropia. Bottom: adult with right hypertropia. (Images courtesy Erick D. Bothun, MD)
Learning Objectives

Upon completion of this module, the ophthalmologist should be able to:

- Describe the clinical evaluation of strabismus in adults
- Identify ancillary studies that can be performed
- Delineate the options involved in the medical and surgical treatment of strabismus
- Outline potential complications of strabismus surgery and how to recognize, treat, and avoid them
- Describe management of the patient following surgery

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Introduction

It has been estimated that up to 4% of the adult population has strabismus, and strabismus surgery is commonly performed on Medicare-aged patients. Childhood strabismus may persist into or recur in adult life. Adults may also develop new-onset strabismus as a result of such varied conditions as microvascular cranial neuropathies, trauma, thyroid-related ophthalmopathy, cerebrovascular disease, or as a consequence of previous ocular or orbital surgery such as a scleral buckling procedure.

The clinical presentation of strabismus in adults can vary from an asymptomatic intermittent or constant deviation to symptomatic diplopia, asthenopia, and a compensatory head posture. Despite significant signs and symptoms, surgical treatment of strabismus is often delayed. One study has reported that almost half of adult patients delayed surgical treatment for a year or more, with an average delay of 19.9 years (range, 1 to 72 years) between the onset of strabismus and the time of surgery. Often the reason for delaying surgical intervention was misinformation about the success of strabismus surgery in adults.

The most common systemic conditions associated with new-onset strabismus in adults are microvascular diseases such as diabetes mellitus and hypertension. Abducens palsy is the most common cause of acquired cranial neuropathy in adults. Sequential cranial nerve palsies caused by microvascular diseases have been reported. Examples of other medical conditions that can
be associated with strabismus in adult patients include thyroid disease, myasthenia gravis, giant cell arteritis, Parkinson disease, and cerebrovascular disease.

Clinical Evaluation

The ophthalmologist should ascertain the patient’s perception of the problem. Is a single eye crossed or deviated outward? Which eye is involved? Was the onset gradual or sudden, and has the problem occurred before? Is the problem stable, improving, or getting worse? Does the patient have diplopia, asthenopia, headaches, or other symptoms? Are there associated signs or symptoms such as ptosis or variability that might suggest myasthenia gravis? Are there any neurologic concerns? Finally, an understanding of the influence of the condition on activities of daily living is important in helping to counsel the patient regarding treatment recommendations and prognosis. Key areas of discussion may include effect on work, driving, relationships, social life, feeling of well-being, and concern for the future (Table 1). Review of prior treatment records can be helpful, though records from childhood are often not available. Lack of availability of previous records should not preclude treatment, including surgery.

A comprehensive eye examination, with special emphasis on the ocular motility examination, is indicated for any adult patient for whom strabismus surgery is planned. Examination needs will vary from patient to patient and a one-size-fits-all approach is not appropriate.

Ocular motility evaluation should include assessment of binocular alignment in the primary position at distance and near, and evaluation of ocular versions at a minimum. For patients with incomitant strabismus, such as that due to a cranial nerve palsy or restrictive strabismus, assessment of ocular alignment in the secondary and tertiary positions of gaze may be helpful. The ophthalmologist should be aware of the presence of primary and secondary deviations in patients with paralytic or restrictive strabismus (Figure 1). In general, quantification of the size of the patient’s deviation should be done with significant refractive correction in place. The specific techniques of ocular motility evaluation are well known to practicing ophthalmologists, and the reader is referred to standard texts for this information.

The presence of monocular diplopia should be ruled out in any patient who reports diplopia. Monocular diplopia can occur in patients with or without strabismus and can coexist with strabismic diplopia. If diplopia persists with either eye covered, monocular diplopia is present and will persist even after treatment of the patient’s strabismus. Potential causes of monocular diplopia are listed in Table 2.

| Table 1. Key Areas of Potential Discussion With Patients About How Strabismus Affects the Patient’s Life |
| Impact on work |
| Impact on driving |
| Impact on interpersonal relationships |
| Impact on social life |
| Impact on feeling of well-being |
| Concern for the future |

| Table 2. Potential Causes of Monocular Diplopia |
| Diffraction |
| Spectacle reflection |
| Corneal surface irregularity |
| Corneal scars |
| Polycoria |
| Cataract |
| Intraocular lens malposition |
| Foveal distortion |
Ancillary Testing

Numerous ancillary studies can be performed on a patient with strabismus. This section covers some of the more common tests that are readily available in most ophthalmology offices.

Sensory Testing. It is often useful to determine if a patient has the potential to fuse, especially if surgery is anticipated. This can be determined with prism correction of the deviation or with an amblyoscope. In a patient with an intermittent deviation or a small-to-moderate deviation, sensory testing may be particularly helpful. In the standard clinical setting, this most commonly consists of stereopsis testing with the Titmus fly test or Randot stereacuity test. In patients who do not have stereopsis, evaluation with the Worth 4-dot test may be useful to demonstrate the presence of some level of binocular peripheral cooperation. Patients who can achieve binocular peripheral cooperation or stereopsis are more likely to sustain optimal ocular alignment following surgical intervention, and demonstration of this ability prior to surgery may aid in preoperative planning and patient education. However, the absence of ability to fuse is not a contraindication to strabismus surgery.

Motor Fusional Amplitudes. Evaluation of motor fusional amplitudes can be helpful in selected patients. Knowledge about the diplopic patient’s convergence and divergence amplitudes, for example, can facilitate preoperative discussions about the risk of postoperative diplopia should an over- or undercorrection occur following surgery for horizontal strabismus. Patients with good motor fusional amplitudes are more likely to be able to fuse following surgery.

Testing for Cyclotorsion. Each of the cyclovertical muscles has a complex set of primary and secondary actions including torsional ocular movements. Therefore, testing for the presence of a concurrent cyclotropia is important in the management of a patient with vertical strabismus. Cyclotorsion can be estimated objectively by evaluation of the fundus for evidence of cyclotorsion (Figure 2) and can be measured subjectively with double Maddox rods. For the test, vertically oriented Maddox rods are placed in trial frames. With the room lights dimmed, the patient rotates the Maddox rod before each eye while viewing a light source, such as a muscle light, until the linear image of the light created by the Maddox rods in each eye is parallel with the horizon. The size and direction of cyclodeviation present in each eye can be quantified in degrees using the scale on the trial frame.

Binocular Visual Field Testing. This test can be useful in quantifying the size and location of the field of single binocular vision in a patient who is able to achieve fusion in some positions of gaze. For the test, the patient is seated at the Goldmann perimeter with both eyes open and is asked to follow a target from the binocular to the diplopia field in several meridians (Figure 3). The patient reports when diplopia is noted in each meridian. The treatment plan should seek to expand the field of single binocular vision and maximize this field around the primary and reading positions.
Evaluation of Limited Ductions. When evaluating a patient with limited ocular ductions, the ophthalmologist must determine if the duction limitation is due to restriction of the antagonist or to paresis of the agonist muscle. Clinical evaluation of saccadic velocity can often help the examiner make this distinction. An attempted saccade by a muscle that is markedly paretic will be characterized by a slow, floating saccade, with most or all of the movement due to relaxation of the antagonist, rather than contraction of the weak agonist muscle. It may be difficult to distinguish a more subtle paresis from a restriction through observation alone. Forced duction testing and force generation testing can be useful in this setting.

Forced duction testing can be performed in the office with the patient awake or in the operating room prior to the start of surgery. For the test, the conjunctiva is grasped firmly with forceps (following administration of topical anesthesia in an awake patient) approximately 2 mm from the limbus and the eye is gently rotated along its normal arc of rotation. A full passive duction is not possible when a restriction of the antagonist is present. As a general rule, resection procedures are avoided on muscles that exhibit significant restriction.

If there is no limitation to passive ductions, a paresis must be the cause of the duction limitation. Force generation testing can be performed to grossly quantify the degree of weakness of a paretic muscle. For the test, with the eye in the primary position, the conjunctiva is grasped approximately 2 mm posterior to the limbus 180° away from the agonist muscle (ie, muscle being tested). The patient is asked to look in the direction of the agonist while the ophthalmologist palpates the amount of force generated by the muscle. With experience, the ophthalmologist is able to detect the presence of a mild, marked, or severe paresis. In the presence of a total paralysis or a severely paretic muscle, saccadic velocity testing is often distinctly abnormal, precluding the need for force generation testing.

Laboratory, Medical, and Radiographic Testing. Laboratory testing is indicated when the ophthalmologist believes that the patient’s strabismus is either caused by or complicated by the presence of systemic disease. The onset of an acute cranial nerve palsy, for example, should prompt consideration for evaluation of the patient for diabetes, hypertension, and/or other microvascular disease. Testing for myasthenia gravis should be considered for patients with variable strabismus, especially if associated with ptosis and/or evidence of systemic muscle weakness. The presence of other concurrent neurological signs or symptoms should prompt consideration of neuroimaging and/or neurological evaluation, performed in collaboration with the patient’s primary care physician.

Treatment of Strabismus

Medical Treatment

Medical treatment options for strabismus in adults include spectacle correction, monocular occlusion, orthoptic therapy, or botulinum neurotoxin.

Spectacle Correction. Spectacles can be used in 2 main settings to treat strabismus. Improvement of visual acuity by proper correction of significant refractive errors can result in improved control of an otherwise uncontrolled deviation. Spectacles can also be used to introduce prism before the eyes to correct small deviations. Opinion varies on how much prism a given patient can tolerate, but in general, total deviations of greater than 15 prism diopters are not adequately treated with prism. Fresnel press-on prisms are valuable for short-term treatment of diplopia and occasionally prove to be an effective long-term strategy. Fresnel prisms should generally be placed before the nondominant eye.

Monocular Occlusion. Full-time monocular occlusion as a treatment for diplopia is poorly tolerated by most patients and is rarely a good long-term treatment strategy. Full-time occlusion is often reasonably tolerated when used as a temporizing measure as a patient awaits anticipated spontaneous improvement or awaits surgical correction. Part-time occlusion, on the other hand, can be an effective long-term strategy for patients who have diplopia only during certain visual tasks such as reading. For example, occlusion of the bifocal segment of the nondominant eye is often tolerated well by elderly patients with diplopia due to convergence insufficiency.

Orthoptic Therapy. The role of orthoptic therapy has diminished as the safety of surgery to correct strabismus has improved. In general, orthoptic exercises are most
appropriate for older children and younger adults with intermittent exotropia or convergence insufficiency. Consistent and frequent use of convergence exercises can significantly reduce symptoms of asthenopia and improve control of the deviation in many patients.

**Botulinum Neurotoxin.** While most ophthalmologists prefer standard strabismus surgery to the use of botulinum toxin, some ophthalmic surgeons routinely use botulinum toxin for certain forms of adult strabismus. It is probably most widely used in the treatment of sensory strabismus and for treatment of acute paralytic strabismus due to unilateral sixth nerve palsy. Typical dosing of botulinum in the treatment of strabismus is 1.25 to 5 units into any one muscle. The dosage may be increased up to twofold of the previously injected dose if the dose needs to be repeated. The frequent need for repeated treatment is a limiting factor in its acceptance.

**Strabismus Surgery**

The traditional role of surgery for strabismus has been to realign the visual axes in an effort to eliminate or reduce diplopia or to produce, maintain, or restore binocular vision (Table 3). Improvements in both the safety and effectiveness of strabismus surgery have expanded these traditional roles of strabismus surgery to include treatment of asthenopia, compensatory head postures (such as in a patient with restrictive or paralytic strabismus), anomalous eye movements (such as upshoots in Duane syndrome), nystagmus, expansion of the field of vision in patients with esotropia, and improvement in psychosocial functioning and vocational prospects. In the end, while most patients with strabismus have one or more of the above indications, it is completely reasonable to offer strabismus surgery solely for the purpose of restoring binocular alignment; such treatment should not be considered cosmetic in nature because its distinct purpose is to correct anomalous ocular alignment.

A treatment plan is devised based upon the needs and diagnosis of the individual patient. The details of surgical planning are beyond the scope of this module; however, Table 4 includes some general considerations.

**Surgical Approaches.** All strabismus surgery requires an incision through the conjunctiva and Tenon’s capsule to expose the episcleral space. There are 2 common surgical approaches (limbal and fornix) used for strabismus surgery, and most other approaches are variations of these techniques. The conjunctival incision should provide adequate exposure of the surgical site and minimize the formation of adhesions postoperatively. There is no clear advantage of one approach over the other, and the choice of incision depends primarily upon surgeon preference.

A limbal incision involves creation of a conjunctival flap over the muscle to be operated, beginning at the limbus (Figure 4). A fornix incision involves creation of an incision of the bulbar conjunctiva adjacent to the muscle to be operated, starting approximately 8 to 10 mm posterior to the limbus (Figure 5). In general, fornix incisions on the inferior rectus muscle are preferred to fornix incisions superiorly where possible.

**Indications for Adjustable Sutures.** The use of adjustable sutures may enable the surgeon to alter the ocular alignment in an alert patient following surgery, prior to permanently securing the muscle sutures. The

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**Table 3. Indications for Strabismus Surgery**

<table>
<thead>
<tr>
<th>Indications for Strabismus Surgery</th>
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<tr>
<td>Develop, restore, or maintain binocular vision</td>
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<tr>
<td>Resolution or improvement of diplopia</td>
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<tr>
<td>Resolution or improvement of asthenopia</td>
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<tr>
<td>Resolution or improvement of a compensatory head posture</td>
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<tr>
<td>Improvement of anomalous eye movements</td>
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<tr>
<td>Improvement of vision in a patient with nystagmus</td>
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<tr>
<td>Expansion of visual field in a patient with esotropia</td>
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<tr>
<td>Improvement of psychosocial function</td>
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<tr>
<td>Improvement of vocational prospects</td>
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<tr>
<td>Improvement of binocular alignment</td>
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Reproduced, with permission, from Coats DK and Olitsky SE. *Strabismus Surgery and its Complications.* Springer-Verlag, 2007, Table 3.4, page 32.

**Table 4. General Considerations in Planning Strabismus Surgery**

<table>
<thead>
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<th>General Considerations in Planning Strabismus Surgery</th>
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<tr>
<td>Surgery on a completely paralyzed muscle will have little or no effect. Thus, transposition surgery on normally functioning muscles is required.</td>
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<tr>
<td>If a significant duction limitation is present, surgery on the contralateral eye may both correct the primary position alignment and match the duction limitation of the involved eye, thus expanding the field of single vision.</td>
</tr>
<tr>
<td>A muscle that is restricted should generally not be resected, as further limitation of ductions may occur.</td>
</tr>
<tr>
<td>Surgery should generally be deferred until the deviation is stable if the deviation is in a state of evolution, such as acute thyroid-related ophthalmopathy.</td>
</tr>
<tr>
<td>Surgery on vertical rectus muscles may produce alteration of eyelid position postoperatively. This is especially true of surgery on the inferior rectus muscle and steps can often be taken intraoperatively to reduce its occurrence.</td>
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indications for the use of adjustable sutures vary depending on individual preferences and training of the surgeon. Some surgeons use adjustable sutures on the majority of adults, while others never use them. The value of these sutures for the treatment of incomitant strabismus, such as thyroid-related ophthalmopathy, is recognized by many surgeons who use adjustable techniques. Adjustable sutures can be utilized with both fornix and limbal conjunctival incisions. One simple technique for adjustable sutures involves the use of a bow-type suture as illustrated in Figure 6.

**Anesthesia Considerations.** The need for laboratory testing of the adult patient prior to strabismus surgery is determined on a case-by-case basis. In general, routine preoperative laboratory testing is not necessary. Preoperative laboratory and other testing may be indicated to identify a disorder that may affect perioperative anesthetic care; determine the status of an already known disorder, disease, or therapy that may affect perioperative anesthetic care; or formulate a plan and alternatives for perioperative anesthetic care.

**Figure 4** Possible locations for placement of a limbal incision. (Reproduced, with permission, from Coats DK and Olitsky SE. Strabismus Surgery and its Complications. Springer-Verlag, 2007, Fig. 8.18 and 8.19, pages 80–81.)

**Figure 5** Possible locations for placement of a fornix incision. Incisions can also be placed parallel to limbus, if preferred. (Reproduced, with permission, from Coats DK and Olitsky SE. Strabismus Surgery and its Complications. Springer-Verlag, 2007, Fig. 8.9, page 74.)

**Figure 6** Bow-type adjustable suture technique. a. After determining initial placement of the muscle, a half bow knot is tied. b. The knot is untied for adjustment and (c) converted to a permanent knot when alignment is satisfactory. (Reproduced, with permission, from Coats DK and Olitsky SE. Strabismus Surgery and its Complications. Springer-Verlag, 2007, Fig. 14.5a–c, page 146.)
The choice of anesthesia for a given patient depends on 1 or more of the following factors: surgeon preference, patient preference, complexity of the planned procedure, general health of the patient, and recommendations of the anesthesiologist.

General endotracheal anesthesia is the most common choice of anesthesia for adults undergoing bilateral strabismus surgery. Alternatives to general anesthesia include bilateral topical anesthesia (combined with intravenous sedation) or sequential surgery under retrobulbar anesthesia on separate days. Peribulbar anesthesia and sub-Tenon’s anesthesia represent variations of the local anesthesia approaches just outlined.

Unilateral strabismus surgery can be performed using any of the above modalities, and the choice generally depends upon the preferences of the surgeon and patient. The first postoperative visit varies from 1 day to several weeks after surgery, depending on the surgeon’s preference. The most important issues for the surgeon to evaluate during the early postoperative period are assessment of alignment and evaluation for possible complications, including slipped or lost muscles and infectious complications, especially endophthalmitis. Serious infections such as endophthalmitis can occur as early as 1 day to almost 2 weeks after surgery. The surgeon’s judgment and experience should be the predominant factor in making follow-up recommendations. In general, most strabismus surgeons perform the first postoperative assessment within 7 to 10 days after surgery.

Most adults experience only mild discomfort following strabismus surgery, and prescription of mild analgesics can be helpful in the first few days. Severe or sustained pain is so unusual following strabismus surgery that its presence should prompt examination of the patient to assure that a serious complication has not developed.

A significant delay from onset of symptoms of endophthalmitis following strabismus surgery to diagnosis is not uncommon, ranging from days to weeks. Patients should be advised to contact the surgeon’s office immediately if they experience a reduction of vision, onset of new floaters, progressively increasing redness or swelling, or other unexpected signs or symptoms.

Driving and hazardous work should not be resumed until the patient has fully recovered from the effects of anesthesia and feels fully capable of safely performing these activities. Most patients are able to return to these activities within a few days after surgery.

Complications of Strabismus Surgery

Complications of strabismus surgery in adults can be characterized into vision-threatening ocular complications, non-vision-threatening ocular complications, intractable diplopia, or systemic complications.

Ocular complications that threaten vision are rare and include endophthalmitis, retinal detachment, retrobulbar hemorrhage, and anterior segment ischemia. Endophthalmitis and retinal detachment are very rare, and both are most likely to occur in the setting of eye wall perforation during surgery.

Anterior segment ischemia can result in vision loss, and those most at risk include patients with advanced age, previous rectus muscle surgery, and a history of hypertension, diabetes, or other vasculopathy. Simultaneous surgery on multiple rectus muscles in the same eye, surgery on vertical rectus muscles, adjacent rectus muscles, and the use of a limbal incision all potentially increase risk of anterior segment ischemia. Strategies to reduce the risk of anterior segment ischemia include limiting the number of rectus muscles detached from the globe, preservation of the anterior ciliary vessels during surgery (Figure 7), staging surgical procedures over...
such as pyogenic granulomas, epithelial inclusion cysts, and inadvertent advancement of the plica semilunaris to the limbus (Figure 9). Most such complications are easily recognized and can be effectively managed through medical or surgical means.

Persistent diplopia following strabismus surgery is uncommon and has been reported to occur in only 3% and 1.4% of those with and without preoperative diplopia, respectively. Nevertheless, persistent diplopia after strabismus surgery can distress patients. Causes of persistent diplopia include residual strabismus due to over- or undercorrection, untreated deviations, and cyclotorsion. Other potential causes of persistent diplopia following surgery include monocular diplopia, spectacle-induced diplopia, anomalous retinal correspondence, aniseikonia,
Measuring Surgical Success

The success of strabismus surgery can be measured through various subjective and objective parameters. Patients are usually very pleased with accurate alignment of the eyes following surgery, and this alone is a strong measure of success. Asthenopia and headaches related to strabismus are often markedly improved or resolved after surgery. Patients may report better interactions with others, greater eye contact with others, less concern for the future, and improved vocational prospects. Objective measures of success include resolution of diplopia, satisfactory improvement in alignment (often defined as alignment to within 10 prism diopters of orthotropia without overcorrection), improvement of versions, improvement of stereopsis or fusion, enlargement of the field of single binocular vision, improvement of an anomalous head posture, and enlargement of the field of vision in a patient with esotropia.

Conclusion

Strabismus is common in adults and can be treated by both medical and surgical means. The treatment of choice depends upon the problem and is highly individualized. Misunderstandings surrounding the risks of strabismus surgery in adult patients, especially the risk of postoperative diplopia, may result in unnecessary treatment delays. However, strabismus surgery in adults has a high degree of success and serious complications are infrequent.

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Clinicians’ Corner provides additional viewpoints on the subject covered in this issue of *Focal Points*. Consultants have been invited by the Editorial Review Board to respond to questions posed by the Academy’s Practicing Ophthalmologists Advisory Committee for Education. While the advisory committee reviews the modules, consultants respond without reading the module or one another’s responses. — Ed.

1. **What changes do you make in your surgical approach for patients with strabismus who have had previous scleral buckling or glaucoma implant procedures?**

**Dr. Clark:** The single most important difference is the close coordination between the retina or glaucoma specialist and the strabismus surgeon. Often, the implanted devices are the direct cause of the strabismus, either by mechanical restriction or by compromised extraocular muscle function, and the periocular elements need to be removed or repositioned to solve the eye alignment problem. The other specialist should state in writing for the medical record that it is either safe to remove the implanted elements or that an alternative treatment, either replacement or repositioning, is required.

During surgery, careful dissection is required to isolate the extraocular muscles through the scar tissue. Often, the implanted element can actually aid in the dissection because the encapsulated scar provides a space to place muscle hooks and other instruments. Once the extraocular muscles are isolated, repeat forced duction testing is needed to ensure adequate release of restrictions. Also, multiple adjustable sutures can help restore the alignment and balance the range of eye movement.

**Dr. Kodsi:** First I try to identify why the patient needs strabismus surgery. Many of these patients have poor vision in the involved eye, and they want strabismus surgery to restore their facial appearance. If vision is good in the involved eye and they desire surgery to eliminate diplopia, I evaluate their ability to fuse. I avoid operating on patients who developed central disruption of fusion or distortion of the macula and fovea that will prevent fusion postoperatively. I always consult with the retina or glaucoma specialist preoperatively to identify exactly what procedures were previously performed and what, if anything, is planned surgically for the patient in the near future. For a patient with a scleral buckle, I ask if...
the retina specialist thinks the buckle can or cannot be removed in the near future. Whenever possible I would rather wait until the buckle is removed before proceeding with strabismus surgery.

2. What techniques do you use to avoid anterior segment ischemia in adults undergoing strabismus surgery? If anterior segment ischemia occurs, how do you treat it?

Dr. Clark: The best strategy to avoid anterior segment ischemia is to limit the number of rectus muscles tenotomized to 2 previously unoperated muscles per eye. A third rectus muscle can be involved during the same surgery if it was tenotomized in a prior surgery. I avoid a complete tenotomy of the fourth rectus muscle, even using ciliary vessel sparing, whenever possible.

A common scenario is an undercorrected sixth nerve palsy after prior recession/resection surgery. Rather than attempt a vessel-sparing transposition, I typically perform a split-tendon transposition of the vertical rectus muscles with posterior augmentation sutures, with or without re-recession of the medial rectus on adjustable suture. I typically make conjunctival fornix incisions in the inferotemporal and superotemporal quadrants and isolate the vertical recti. I then place the muscles on stretch between two muscle hooks and longitudinally bisect each muscle using Westcott scissors, extending from the insertion approximately 10 mm posteriorly. I then pass the muscle sutures through the lateral half of the muscle tendon, disinsert the lateral half of the tendon while leaving the medial half intact, and transpose each split-tendon to the respective border of the lateral rectus insertion. The posterior augmentation sutures are placed through the sclera adjacent to the posterior lateral rectus belly in the standard fashion, 8 mm posterior to the insertion of the lateral rectus and through the split tendon at a similar distance from the lateral rectus muscle insertion. When tightened, the posterior sutures pull the entire posterior muscle belly of the vertical rectus muscle, not just the split-tendon portion, into alignment with the lateral rectus muscle path. The final effect is a fairly powerful transposition that spares half of the ciliary vessels on each vertical rectus muscle. In other situations, it is often preferable to go back and reposition previously operated muscles rather than sacrifice the ciliary vessels of unoperated muscles.

I treat anterior segment ischemia with topical cycloplegic agents and corticosteroids until the inflammation has subsided.

Dr. Kodsi: I find the most important technique is preoperative planning and assessing the risk of anterior segment ischemia preoperatively. The following medical conditions increase the risk of anterior segment ischemia: diabetes, vascular disease, hypertension, and thyroid disease. In addition, the older the patient, the higher the risk. Also the vertical recti muscles appear to be more important in providing blood flow to the anterior segment than the horizontal muscles. Although Dr. Craig McKeown advocates “ciliary vessels sparing of the muscles,” I have not found this to be an easy technique or a guarantee that the vessels will function normally after they are dissected off the muscle. I personally do not operate on more than 2 recti muscles at a time to limit the risk of anterior segment ischemia in adults. Even then, I have seen 2 cases of mild anterior segment ischemia after operating on only 2 recti muscles in elderly patients with many of the above risk factors. I manage anterior segment ischemia with topical corticosteroids in the mild cases that I have encountered, although subconjunctival and oral corticosteroids have been recommended for severe cases.

3. Discuss the surgical management of traumatic sixth cranial nerve palsies in adults.

Dr. Clark: I typically observe a traumatic sixth nerve palsy for at least 6 months to see if the lateral rectus regains some or most of its function. After 6 months, surgical management depends on whether the lateral rectus has regained any contractility. Because of the esotropia and medial rectus contracture, it may be difficult to determine lateral rectus function, so careful attention to saccades and force generation can be helpful. If the lateral rectus has some contractility, I resect the lateral rectus and recess the medial rectus on adjustable sutures. If the lateral rectus does not have contractility, I leave it intact to preserve some ciliary vessels. I perform a full-tendon vertical rectus transposition with posterior augmentation sutures. This procedure is powerful enough that
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I rarely recess the medial rectus during the same procedure, particularly in an older adult, regardless of the amount of esotropia and medial rectus contracture. The medial rectus can always be recessed during a later procedure, if needed, to fine-tune the primary gaze alignment and expand the binocular visual field.

Dr. Kodsi: I would consider surgical intervention if a year after the injury a patient has persistent diplopia and a significant deviation. The preoperative evaluation of the lateral rectus muscle is the single most important factor in determining which surgical procedure to perform. If the patient has normal saccades with abduction and good lateral rectus function on forced generation testing, I would recess the medial rectus muscle and resect the lateral rectus muscle in the involved eye. If the patient has slow saccades on abduction and poor lateral rectus function on forced generation testing, my surgical choice would be a full tendon transposition procedure of the superior and inferior rectus muscles to the lateral rectus muscle with the "Foster modification." In 1997 Dr. Scott Foster popularized the technique of using 2 nonabsorbable sutures 14 mm posterior to the insertion of the lateral rectus to bring the temporal inferior rectus fibers as well as the temporal superior rectus fibers closer to the lateral rectus muscle. This allows for more abduction effect of the transposition procedure. I find that with the Foster modification, the esotropia is fully corrected and botulinum injection into the medial rectus or a medial rectus recession at a later date is usually not necessary.

Dr. Clark: I typically observe a traumatic fourth nerve palsy for at least 6 months to see if the superior oblique regains some of its function. After 6 months, the surgical management depends on the deviation in primary and secondary gazes and the amount of ocular torsion. As a practical point, if the primary gaze deviation is small, less than 10 to 15 prism diopters, I will operate on only 1 muscle, usually recessing the ipsilateral inferior oblique. If the deviation is larger, I will usually recess the inferior oblique and also recess 1 vertical muscle on adjustable suture, with the vertical muscle chosen based on where the secondary gaze deviation is worse. If the secondary gaze deviation is worse on upgaze, I typically recess the ipsilateral superior rectus. If it is worse on downgaze, I typically recess the contralateral inferior rectus. I may also transpose the vertical rectus muscles to help minimize torsion. I rarely tuck the superior oblique muscle because this procedure cannot be adjusted postoperatively to eliminate the diplopia.

Dr. Kodsi: As with a sixth nerve palsy, I would consider surgical intervention if a year after the injury a patient has persistent diplopia and a significant deviation. Fourth nerve palsies are not as straightforward as sixth nerve palsies because of the vertical and torsional components. Also many traumatic fourth nerve palsies are bilateral in nature. Preoperatively you must identify if the patient is bothered by torsional diplopia, vertical diplopia, or both. If the diplopia is purely torsional in nature, my procedure of choice is the Harada-Ito procedure. This will correct the excyclotorsion without changing the vertical deviation. For patients with vertical and torsional diplopia, you must determine the size of the deviation and in which gaze the diplopia is greatest. Based on your measurements, you must also decide whether or not to recess the ipsilateral inferior oblique muscle or tuck the paretic superior oblique muscle. Two points to remember: the superior oblique tendon is normal (not lax) in a true acquired traumatic fourth nerve palsy, and you will perform a much smaller tuck for an acquired fourth nerve palsy than you would in a congenital fourth nerve palsy.

4. Discuss the surgical management of traumatic fourth cranial nerve palsies in adults.

Dr. Clark: Third nerve palsies are the most difficult to treat surgically because most of the extraocular muscles are involved and multiple axes of misalignment occur. The possibility of successfully restoring any useful binocular vision is directly dependent on the amount of recovery of some third nerve function. I observe these patients for a longer period, 9 to 12 months, in the hopes that the third nerve will show at least partial recovery. After that time, if the third nerve palsy is complete I typically do not offer surgery unless the patient has developed significant suppression of vision in the deviated eye. In my experience, supramaximal lateral rectus...
recessions or globe periosteal fixation in primary gaze do not restore a useful range of binocular vision. If the palsy is not complete, surgery is based on the degree of recovery of the each involved rectus muscle and the deviation in primary gaze. Because these patients often need surgery on multiple rectus muscles to account for the vertical and horizontal deviations, ciliary vessel sparing techniques or partial tendon surgeries can be used to help prevent anterior segment ischemia.

Dr. Kodsi: By far the most difficult cranial nerve palsy to manage surgically is a traumatic third nerve palsy in an adult, especially an adult who still has normal vision in the involved eye. I find it easiest to divide the patients with traumatic third nerve palsies into those with partial third nerve palsies and complete third nerve palsies and those with good vision and poor vision in the involved eye. The patients with poor vision and partial third nerve palsies are the easiest to treat, while those with complete third nerve palsies and good vision are not good surgical candidates in my opinion, since it is extremely difficult to give them a reasonable binocular field with surgery. For patients with poor vision and a complete third nerve palsy, you can transpose the insertion of the superior oblique tendon nasal to the superior rectus muscle and superior to the medial rectus muscle, along with a lateral rectus recession of the paretic eye. Cosmetically the patients will look good with this procedure, and that would be the goal of surgery if the vision is poor in the involved eye. The procedure of choice with partial third nerve palsies depends upon which muscles have recovered the most function and how much of the deviation is horizontal and vertical.

6. Discuss the role of strabismus surgery in patients with incomitant strabismus following traumatic brain injuries.

Dr. Clark: Most of the time, incomitant strabismus after traumatic brain injuries results from an injury to 1 or more of the cranial nerves. The treatment of those injuries is covered above. Some patients will develop an incomitant strabismus in the absence of a true nerve palsy for a variety of reasons. The most important factor to consider before recommending strabismus surgery in those patients is the ability to fuse and eliminate the diplopia after horizontal and vertical prisms have neutralized the deviation. If the patient cannot fuse the 2 images, significant ocular torsion may be present or the patient may suffer from central disruption of fusion. If the patient can fuse with prisms, surgical treatment can be very helpful in restoring and/or expanding the binocular field of single vision. In the absence of cranial nerve palsy, the extraocular muscle function is intact and the treatment typically consists of standard recessions and resections, often using multiple adjustable sutures.

Dr. Kodsi: I would wait a year from the time of the traumatic event before considering strabismus surgery. Again, I would consider strabismus surgery if there is persistent diplopia with a significant deviation. Whenever there is an incomitant deviation, you must inform the patient that the goal of strabismus surgery is to allow the patient to have a reasonable binocular field in primary position and possibly in downgaze for reading. However, the patient will have diplopia in certain fields of gaze. Often these patients require correction of both vertical and horizontal deviations.

7. In which adults with strabismus should strabismus surgery be avoided?

Dr. Clark: These patients would fall into 3 broad categories. The first type of patient has a very complex strabismus where surgery is not likely to achieve successful restoration of useful binocular vision. In patients with central disruption of fusion after brain injury, for example, bringing the 2 images closer together with surgery is actually more disruptive to visual function than leaving the images far apart. The second type of patient has poor general health. Many older adults develop strabismus and diplopia late in life and are unwilling or unable to undergo strabismus surgery. Patients undergoing chemotherapy also fall into this category. I maintain a supply of Fresnel prisms with a large range of values to manage these patients nonsurgically. The third type of patient is excessively demanding with unreasonable expectations for surgery. This patient will come in for a third or fourth opinion regarding a relatively straightforward problem. The person will have many questions, fixate on the risks of surgery, and want some type of assurance that surgery will fix the problem. Regardless of outcome, such patients are not likely to be happy after surgery.
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Dr. Kodsi: I avoid strabismus surgery if there is an unacceptable risk of “harm” associated with the strabismus surgery. For example, if a patient is monocular, I personally would not perform strabismus surgery on the patient’s good eye. If a patient shows central disruption of fusion on preoperative sensory testing, I would also not consider strabismus surgery. Lastly, if a patient’s age, medical history, and previous muscle surgery put that person at a significant risk for anterior segment ischemia, then I also would not perform the surgery.

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