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Adult Strabismus Preferred Practice Pattern®

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PEDIATRIC OPHTHALMOLOGY/ ADULT STRABISMUS PREFERRED PRACTICE PATTERN® DEVELOPMENT PROCESS AND PARTICIPANTS

The **Pediatric Ophthalmology/Adult Strabismus Preferred Practice Pattern Panel** of the American Association for Pediatric Ophthalmology and Strabismus Adult Strabismus Task Force members wrote the Adult Strabismus Preferred Practice Pattern guidelines (PPP). The PPP Panel members discussed and reviewed successive drafts of the document conducting review by e-mail discussion, to develop a consensus over the final version of the document.

Pediatric Ophthalmology/Adult Strabismus Preferred Practice Pattern Panel of the American Association of Pediatric Ophthalmology and Strabismus 2023

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The **Preferred Practice Patterns Committee** members reviewed and discussed the document during a meeting in June 2023. The document was edited in response to the discussion and comments.

Preferred Practice Patterns Committee 2023
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The Adult Strabismus PPP was sent for review in July 2023 to improve the quality of the guideline, to gather feedback on the draft recommendations and to assess feasibility for and applicability to the target audience, including assessing the facilitators and barriers to implementing recommendations (e.g., U.S. ophthalmologists and other important groups, including patients, other physicians, international ophthalmologists, research organizations, ophthalmological organizations, and experts in the field). The PPP was sent for review to the following patient organizations to solicit the views of patients and the public: Consumers United for Evidence-Based Healthcare, American Foundation for the Blind, Foundation Fighting Blindness, Lighthouse Guild, National Federation of the Blind, and Prevent Blindness. All those who were returning comments were required to provide disclosure of relevant relationships with industry to have their comments considered (indicated with an asterisk below). Members of the Pediatric Ophthalmology/Adult Strabismus Preferred Practice Pattern Panel reviewed these comments and determined revisions to the document. The following organizations and individuals returned comments.

<u>Academy Reviewers</u>
Board of Trustees and Committee of Secretaries Council
General Counsel*
Ophthalmic Technology Assessment Committee
Pediatric Ophthalmology/Strabismus Panel
Basic and Clinical Science Course Section 6 Subcommittee*
Practicing Ophthalmologists Advisory Committee for Education*

<u>Invited Reviewers</u>

American Academy of Pediatrics, Section on Ophthalmology*
American College of Surgeons, Advisory Council for Ophthalmic Surgery
American Foundation for the Blind
American Ophthalmological Society*
Association for Research in Vision and Ophthalmology
Association of University Professors of Ophthalmology
Canadian Ophthalmological Society
Consumers United for Evidence-Based Healthcare
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International Council of Ophthalmology
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National Federation of the Blind
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North American Neuro-Ophthalmology Society
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This guideline will be formally re-evaluated and updated on a 5-year cycle in 2028. A Summary Benchmark is a resource to facilitate application of the guideline and to provide criteria that could be used to measure the application of recommendations, which will be available to all at www.aao.org/ppp.

FINANCIAL DISCLOSURES

There is no external funding, including industry/commercial support, for the development of this PPP or for the distribution of the guidelines. The Academy has fully funded the development of this PPP, and the views or interests of the Academy has not influenced the final recommendations which are based on evidence from systematic reviews. All those individuals significantly involved in the guideline development process, including guideline panel members, PPP Committee members, Secretary for Quality of Care, and Academy Staff, have declared competing/financial interests through a financial interest disclosure process as well as on the assessment of the Open Payments website (available at https://openpaymentsdata.cms.gov/). The interests of the guideline panel members are provided at the beginning of each meeting and those with competing interests in a guideline topic do not participate in voting on areas of disagreement. In compliance with the Council of Medical Specialty Societies' Code for Interactions with Companies (available at https://cmss.org/code-for-interactions-with-companies/), relevant relationships with industry are listed. As per CMSS code, direct financial relationships with industry do not include food and beverage, research funds paid to the institution and relationships outside of the topic of the PPP. The Academy has Relationship with Industry Procedures to comply with the Code (available at www.aao.org/about-preferred-practice-patterns). A majority (82%) of the members of the Pediatric Ophthalmology/Adult Strabismus Preferred Practice Pattern Panel 2023 had no direct financial relationships to disclose.

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The disclosures of relevant relationships to industry of other reviewers of the document from January to October 2023 are available online at www.aao.org/ppp

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OBJECTIVES OF PREFERRED PRACTICE PATTERN® GUIDELINES

As a service to its members and the public, the American Academy of Ophthalmology has developed a series of Preferred Practice Pattern guidelines that **identify characteristics and components of quality eye care.** Appendix 1 describes the core criteria of quality eye care.

The Preferred Practice Pattern guidelines are based on the best available scientific data as interpreted by panels of knowledgeable health professionals. In some instances, such as when results of carefully conducted clinical trials are available, the data are particularly persuasive and provide clear guidance. In other instances, the panels have to rely on their collective judgment and evaluation of available evidence.

These documents provide guidance for the pattern of practice, not for the care of a particular individual. While they should generally meet the needs of most patients, they cannot possibly best meet the needs of all patients. Adherence to these PPPs will not ensure a successful outcome in every situation. These practice patterns should not be deemed inclusive of all proper methods of care or exclusive of other methods of care reasonably directed at obtaining the best results. It may be necessary to approach different patients' needs in different ways. The physician must make the ultimate judgment about the propriety of the care of a particular patient in light of all of the circumstances presented by that patient. The American Academy of Ophthalmology is available to assist members in resolving ethical dilemmas that arise in the course of ophthalmic practice.

Preferred Practice Pattern guidelines are not medical standards to be adhered to in all individual situations. The Academy specifically disclaims any and all liability for injury or other damages of any kind, from negligence or otherwise, for any and all claims that may arise out of the use of any recommendations or other information contained herein.

References to certain drugs, instruments, and other products are made for illustrative purposes only and are not intended to constitute an endorsement of such. Such material may include information on applications that are not considered community standard, that reflect indications not included in approved U.S. Food and Drug Administration (FDA) labeling, or that are approved for use only in restricted research settings. The FDA has stated that it is the responsibility of the physician to determine the FDA status of each drug or device he or she wishes to use, and to use them with appropriate patient consent in compliance with applicable law.

Innovation in medicine is essential to ensure the future health of the American public, and the Academy encourages the development of new diagnostic and therapeutic methods that will improve eye care. It is essential to recognize that true medical excellence is achieved only when the patients' needs are the foremost consideration.

All Preferred Practice Pattern guidelines are reviewed by their parent panel annually or earlier if developments warrant and updated accordingly. To ensure that all PPPs are current, each is valid for 5 years from the "approved by" date unless superseded by a revision. Preferred Practice Pattern guidelines are funded by the Academy without commercial support. Authors and reviewers of PPPs are volunteers and do not receive any financial compensation for their contributions to the documents. The PPPs are externally reviewed by experts and stakeholders, including consumer representatives, before publication. The PPPs are developed in compliance with the Council of Medical Specialty Societies' Code for Interactions with Companies. The Academy has Relationship with Industry Procedures (available at www.aao.org/about-preferred-practice-patterns) to comply with the Code.

Appendix 2 contains the International Statistical Classification of Diseases and Related Health Problems (ICD) codes for the disease entities that this PPP covers. The intended users of the Esotropia and Exotropia PPP are ophthalmologists.

METHODS AND KEY TO RATINGS

Preferred Practice Pattern guidelines should be clinically relevant and specific enough to provide useful information to practitioners. Where evidence exists to support a recommendation for care, the recommendation should be given an explicit rating that shows the strength of evidence. To accomplish these aims, methods from the Scottish Intercollegiate Guideline Network[1] (SIGN) and the Grading of Recommendations Assessment, Development and Evaluation[2] (GRADE) group are used. GRADE is a systematic approach to grading the strength of the total body of evidence that is available to support recommendations on a specific clinical management issue. Organizations that have adopted GRADE include SIGN, the World Health Organization, the Agency for Healthcare Research and Policy, and the American College of Physicians.[3]

- All studies used to form a recommendation for care are graded for strength of evidence individually, and that grade is listed with the study citation.
- To rate individual studies, a scale based on SIGN[1] is used. The definitions and levels of evidence to rate individual studies are as follows:

I++	High-quality meta-analyses, systematic reviews of randomized controlled trials (RCTs), or RCTs with a very low risk of bias
I+	Well-conducted meta-analyses, systematic reviews of RCTs, or RCTs with a low risk of bias
I-	Meta-analyses, systematic reviews of RCTs, or RCTs with a high risk of bias
II++	High-quality systematic reviews of case-control or cohort studies High-quality case-control or cohort studies with a very low risk of confounding or bias and a high probability that the relationship is causal
II+	Well-conducted case-control or cohort studies with a low risk of confounding or bias and a moderate probability that the relationship is causal
II-	Case-control or cohort studies with a high risk of confounding or bias and a significant risk that the relationship is not causal
III	Nonanalytic studies (e.g., case reports, case series)

- Recommendations for care are formed based on the body of the evidence. The body of evidence quality ratings are defined by GRADE[2] as follows:

Good quality	Further research is very unlikely to change our confidence in the estimate of effect
Moderate quality	Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate
Insufficient quality	Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate Any estimate of effect is very uncertain

- Key recommendations for care are defined by GRADE[2] as follows:

Strong recommendation	Used when the desirable effects of an intervention clearly outweigh the undesirable effects or clearly do not
Discretionary recommendation	Used when the trade-offs are less certain—either because of low-quality evidence or because evidence suggests that desirable and undesirable effects are closely balanced

- The Highlighted Findings and Recommendations for Care section lists points determined by the PPP Panel to be of particular importance to vision and quality of life outcomes.
- All recommendations for care in this PPP were rated using the system described above. Ratings are embedded throughout the PPP main text in italics.
- Literature searches to update the PPP were undertaken in January 2023 and April 2023 in the PubMed database. Complete details of the literature searches are available in Appendix 3.
- Recommendations are based on systematic reviews, as per the Institute of Medicine (Clinical Practice Guidelines We Can Trust, 2011). In formulating the recommendations, the health benefits, side

effects/harms/risks, and the balance of benefits and risks are reviewed and considered. Final decisions are arrived at through informal consensus techniques. If there are areas of disagreement, a vote will be conducted among the members of the guideline panel. If there are individuals with direct financial relationships in the area of disagreement, these individuals will refrain from the vote.

HIGHLIGHTED FINDINGS & RECOMMENDATIONS FOR CARE

Strabismus in adults can have profound negative effects on quality of life and many aspects of day-to-day function. Patients with diplopia have greatest improvements in quality of life functional domains, and nondiplopic patients have greatest improvements in quality of life psychosocial domains. Instruments such as the ATS20 help measure these changes.

Recessions of restricted muscles are the mainstay of surgical correction in thyroid eye disease. Resection, or plication, is generally avoided in restrictive disease out of concern for further reducing ductions. These options can be a useful adjunct in select cases, particularly when extremely large recessions have not fully corrected the misalignment.

A variant of divergence insufficiency esotropia called sagging eye syndrome results from aging and weakening of circumferential supportive bands between the superior and lateral rectus muscles. The superior rectus shifts medially and the lateral rectus shifts inferiorly, resulting in esotropia with diplopia at distance and, occasionally, very modest vertical misalignment. Facial aging with associated blepharoptosis and deep superior lid sulci are commonly present. Sagging eye syndrome, along with other causes of divergence insufficiency esotropia, is a very common cause of acquired binocular diplopia in patients presenting between 60 and 80 years of age, is more frequent in myopes, and, as with other types of divergence insufficiency esotropia, is well managed with prism or strabismus surgery.

Iatrogenic binocular diplopia after eye surgery is rare but may result from anesthetic toxicity to the extraocular muscles, direct muscle damage during blepharoplasty, local adjacent scarring associated with pterygium excision, or mechanical restriction from implanted hardware (scleral buckles, glaucoma plate reservoirs, plates repairing orbital fracture). Diplopia persisting after several months warrants referral to a strabismus specialist.

Binocular diplopia may occur after cataract or refractive surgery due to the following:
(1) Unrecognized strabismus (check spectacles for prism correction and perform cycloplegic refraction)
(2) Fusional challenge associated with choice of monovision
(3) Fixation switch diplopia in patients with a history of childhood strabismus and suppression, and cataract or refractive surgery. This has resulted in better vision in the *previously* suppressed eye.

A trial of monovision with contact lenses may determine whether surgically induced monovision will result in new-onset diplopia. Asymmetric vision loss from other common diseases such as macular degeneration, epiretinal membranes, myopia with axial elongation in the previously dominant eye, or diabetic retinopathy when the nondominant eye is left with better acuity may also result in fixation switch diplopia.

SECTION I. ADULT STRABISMUS OVERVIEW

INTRODUCTION

DISEASE DEFINITION

Strabismus is misalignment of the eyes and may be congenital or acquired. Although more typically associated with the pediatric population, adult strabismus has an estimated incidence of 4% in this population.[4-6] The causes of strabismus in the adult population are numerous, in part because the challenges to ocular alignment common in the pediatric population persist into adulthood, and because new disorders destabilizing alignment occur secondary to aging, vision loss, myopia, endocrine and neurologic disorders, and iatrogenic and non-iatrogenic trauma to the globe or orbit. Notable causes of strabismus and in many cases binocular diplopia in the adult population include the following:

- Recurrent, decompensated, or unresolved childhood strabismus
- Sensory strabismus
- Convergence insufficiency
- Divergence insufficiency
- Sagging eye syndrome
- Strabismus associated with high axial myopia, including strabismus fixus
- Graves' disease
- Orbital trauma
- Strabismus associated with other ophthalmic surgery
- 4th nerve palsy
- Skew deviation
- 6th nerve palsy
- 3rd nerve palsy
- Myasthenia gravis
- Fixation switch diplopia
- Foveal misregistration (binocular central diplopia)

Accordingly, accurate diagnosis of the etiology of strabismus in an adult requires expertise to recognize associated signs and symptoms and familiarity with studies that may confirm the diagnosis. In addition, the goal(s) of treatment may inform the plan for surgical or nonsurgical intervention. Adult patients often have unique concerns associated with functional vision as well as psychosocial concerns that affect quality of life. In the past, most emphasis was on improving motor alignment, but it is now understood that the goals of treatment should be much broader and include sensory recovery when possible as well as gains in psychosocial and functional domains of vision-related quality of life.[7-9]

Success rates depend on the subpopulation studied and the goals of surgery, but overall they are approximately 80% after one procedure[4, 10, 11] and may exceed 95% if a second procedure is performed on eyes failing the first intervention.[6] Intractable postoperative diplopia in primary gaze for adult patients without diplopia prior to intervention occurs in 1% or fewer cases.[6, 10, 12, 13] Satisfactory resolution of diplopia in *primary* position for those who present for treatment of diplopia may exceed 95% for certain types of adult strabismus, although diplopia in eccentric gaze may persist, particularly in the presence of restrictive disease or neurologic etiology.[4] Patients should be informed that surgical success rates vary widely depending on the type of strabismus, number of dysfunctional muscles, previous ocular and strabismus surgery, orbital or hardware involvement, and associated systemic and neurological conditions.

PATIENT POPULATION

The patient population is adults with strabismus.

CLINICAL OBJECTIVES

- Perform a clinical examination and ancillary testing as indicated to diagnose the cause of strabismus
- Counsel the patient on the diagnosis and treatment options
- Consult other medical providers if the diagnosis indicates the need for multidisciplinary management
- Establish priorities in the goal-directed management of strabismus (improved eye contact and appearance of alignment [reconstructive], enhancement of binocular potential, or reduction or resolution of diplopia and/or compensatory head posture with possible centration or expansion of the field of binocular single vision[14, 15])
- Inform the patient's primary care and other health care providers of the diagnosis, treatment plan, and the value of the intervention whether it is surgical, uses botulinum toxin, or is by prism correction

BACKGROUND

PREVALENCE

Individual practice estimates vary based on setting and provider. Intelligent Research in Sight (IRIS® Registry) data document a prevalence of 2.7% in ophthalmology practices.[4-6, 16]

RATIONALE FOR TREATMENT

In general, the goal of adult strabismus surgery is to optimize the functional visual status of patients while also addressing psychosocial concerns. The potential benefits of strabismus surgery in adults include the following:

- Improvement in binocularity (ranging from simultaneous perception to stereopsis)[6, 10, 17-21]
- Reduction of diplopia or compensatory head position[4, 6, 10]
- Improvement of binocular visual field[22]
- Improvement in binocular summation or resolution of binocular inhibition[23]
- Reduction of asthenopia
- Psychosocial benefits related to restoration of more normal ocular alignment
- Reconstruction of an abnormal facial appearance secondary to ocular misalignment[5, 6, 10, 24-30]
- Acknowledge the desire of many patients to be free from prism glasses

The overall rate of success for achieving satisfactory ocular alignment cannot easily be summarized because of the vast heterogeneity of cases and the lack of consensus on what constitutes success.[6, 10, 31] Functional improvement in binocularity can also be achieved in many patients. Although the highest level of binocularity (high-grade stereopsis) requires good vision in each eye, good alignment, and baseline binocular potential (which may not be evident on preoperative examination), lower levels of binocularity (such as simultaneous perception or peripheral fusion) can often be achieved in patients with poorer vision or long-standing strabismus. Additionally, patients with poor vision in one eye or even infantile-onset strabismus can achieve improvement in binocular summation after surgery.[23] Successful strabismus surgery may also increase the binocular visual field in patients with esotropia.[22] When planning surgery, it is important to note that measurement of strabismic deviations can be strongly influenced by built-up muscle tone (vergence adaptation) for patients that are able to fuse. Whenever such fusion is noted, it is wise to repeat measurement of the deviations after a 30- to 45-minute patch test before allowing any binocular viewing in order to uncover the full underlying deviations. This is most efficiently done with the Lancaster red-green test or a Hess screen test, but prism and alternate cover testing can also be used, concentrating on the particular directions of interest.[32]

For individual patients, a realistic functional goal for surgical success is dependent on their strabismus subtype as well as the duration of strabismus. For example, in patients with strabismus acquired during adulthood, the functional goal of surgery is likely to be significant reduction or resolution of diplopia, or compensatory head position, if present, and restoration of high-grade stereopsis. However, in adults with a long-standing history of

infantile-onset strabismus, achieving bifoveal fixation is not a realistic goal, and functional goals would therefore include normalization of visual fields, improvement in binocular summation, or reduction of diplopia or compensatory head position, if present. It is important to measure and document diplopia in addition to ocular alignment,[33] and there are methods to quantify diplopia. The field of binocular single vision can be plotted on a Goldmann perimeter,[34] a cervical range-of-motion device can be used to record diplopia in specific positions of gaze,[35, 36] and the Diplopia Questionnaire can be used to assess the frequency of diplopia in specific positions of gaze.[37]

Aside from the functional goals of surgery described above, addressing psychosocial concerns is also important. Patients with strabismus can endure both psychosocial and economic hardship, such as difficulty obtaining employment,[38] receiving promotions,[39] and overcoming negative social bias.[29] Assessment of psychosocial aspects of the impact of strabismus is often best achieved using patient-reported outcomes measures (PROMs). These PROMs are typically questionnaires completed by the patient and then evaluated and scored. The Adult Strabismus-20[40] questionnaire was developed using rigorous methods yielding two psychosocial domains (self-perception and interactions) and two function domains (reading function and general function).[41]

Using PROM questionnaires, several studies have reported marked improvement in health-related quality of life after strabismus surgery in both diplopic and nondiplopic patients.[26, 42-44] In some patients, this improvement has been found to correlate with improvement in binocular function.[45] In general, patients with diplopia tend to have greatest improvements in domains related to function, and nondiplopic patients tend to have greatest improvements in psychosocial domains.[43] Nevertheless, even adults with limited binocular potential have been found to have function-related benefits from strabismus surgery.[46] Other facets of mental health such as mood, depression, anxiety, social avoidance, and self-esteem have been found to improve after strabismus surgery in adults.[26, 47-49] Strabismus surgery may also have a positive impact on other aspects of overall health, such as reducing falls in the elderly.[50]

Nevertheless, despite improvements in binocular function and psychosocial issues for most adults undergoing strabismus surgery, there are some patients who do not perceive an improvement in quality of life. Such lack of improvement in quality-of-life scores may be due to insensitivity of existing instruments but may also be due, in part, to symptoms of depression[51, 52] or unrealized expectations of gains likely associated with improved eye alignment.[53] Therefore, it is important for physicians to counsel patients prior to surgery to ensure that there is a clear understanding about realistic goals of surgery.

Although the primary goal of strabismus surgery is ocular realignment,[31] patient-specific surgical success metrics should be based on achieving a goal mutually set by the physician and the patient. This goal should incorporate the patient's primary concerns as well as the physician's determination of which goals are achievable considering the underlying etiology, previous treatment history, and disease duration. Specific, goal-determined metrics for surgical success have been suggested for patients with esotropia and exotropia; these are as follows:[14, 15]

- Improvement in binocular potential
- Reconstruction of ocular alignment
- Resolution or reduction of diplopia
- Reduction of compensatory head position (reduction of ocular torticollis)

In summary, strabismus in adults can have negative effects on quality of life and many aspects of day-to-day function. There is strong evidence that strabismus surgery very often improves quality of life and function, and there are now specific validated questionnaires that can be used for patient evaluation and for planning treatment.

SECTION II. COMMON AND CLINICALLY IMPORTANT MANIFESTATIONS OF ADULT STRABISMUS

SECTION IIA. PERSISTENT, DECOMPENSATED, OR RECURRENT CHILDHOOD STRABISMUS IN ADULTHOOD

INTRODUCTION

DISEASE DEFINITION

Childhood strabismus that persists or recurs in adulthood originated in early childhood before visual maturation (most often defined as before 9 years of age).[4, 10, 11] This type of adult strabismus arises in several different ways:

- Childhood strabismus that was untreated
- Decompensation of previously asymptomatic strabismus
- Recurrence of a previously treated strabismus
- Evolution of consecutive strabismus after childhood treatment

PATIENT POPULATION

The patient population is adults who had onset of strabismus in early childhood.

CLINICAL OBJECTIVES

- Counsel the patient on the diagnosis and treatment options
- Provide goal-directed management of strabismus (to restore eye alignment, restore/improve binocular vision, and reduce diplopia and compensatory head posture, if present)
- Inform the patient's other health care providers about the diagnosis and treatment plan

BACKGROUND

PREVALENCE

Prevalence varies according to setting.

NATURAL HISTORY

The ocular misalignment in adults with persistent or recurrent childhood strabismus will not resolve spontaneously. However, signs and symptoms may range in severity from mild (that is psychosocially acceptable) to large-angle misalignment of the eyes, with or without diplopia.

RATIONALE FOR TREATMENT

Psychosocial concerns are among the many reasons for considering restoration of normal ocular alignment and function in cases of childhood strabismus presenting or recurring in the adult years.[4, 6, 10, 14, 15, 20-23] These include poor self-perception, impaired social interactions, and poor eye contact. The psychosocial benefits of such intervention have been extensively documented.[5, 9, 11, 24-26, 28-30, 54, 55] In addition, increased difficulty in maintaining binocular fusion or the development of increasing compensatory head positioning to maintain binocular fusion, and episodic diplopia are reasons to consider intervention as well.

CARE PROCESS

PATIENT OUTCOME CRITERIA

Treatment in adult strabismus is goal directed, and targeted outcomes may include the following:

- Restoration of normal ocular alignment and appearance
- Improvement in self-image
- Improvement of binocular function
- Reduction of diplopia (if present)
- Reduction of compensatory head position (if present)

DIAGNOSIS

History

The medical history should include the following elements:

- A description of ocular misalignment in an adult with a history of persistent or recurrent childhood strabismus.
- Strabismus angle and direction may be the same as the original presentation in childhood or different as a result of aging of the extraocular muscles or the impact of prior strabismus surgery
- History of chronicity is important. An acute change or newly symptomatic diplopia may warrant evaluation for other causes such as cranial nerve palsy, thyroid eye disease (TED), and myasthenia gravis (See appropriate subsections of this PPP)
- Formal neuro-ophthalmic evaluation may be indicated in some cases where presentation suggests other neurologic or systemic disease
- An attempt should be made to acquire and review past clinical and surgical records as well as any prior imaging studies, although this is not always possible

Examination

The examination should include the following elements:

- A careful review of the current optical correction (glasses) and the presence of any ground-in or overlay prism, and the impact that the current correction might have on alignment
- Dry manifest and cycloplegic refraction, which may reveal anisometropia or high hyperopia, providing clues to original ocular motor disturbance. Consideration should be given to changing the current correction, which might improve or eliminate strabismus.
- Complete motility examination, including cover-uncover, alternate-cover testing, and prism and alternate cover measurements as well as testing for binocular fusion and stereopsis.[56] Assessment of alignment by light reflex testing (e.g., Krimsky) to compare with cover-test measurements and identification of abnormal angle kappa. Evaluation for possible duction deficits suggesting a possible slipped muscle or stretched scar.
- Strabismus patterns suggestive of cranial nerve palsy, skew deviation, or the presence of new-onset nystagmus; and proptosis or inflammatory changes that may indicate central nervous system, orbital, or thyroid conditions (see sections on cranial nerve palsies, skew deviation, and TED). These disorders can, of course, impact the population of patients with unrelated childhood strabismus and warrant

further evaluation and potentially different treatment.

- Inspection of the ocular surface for conjunctival scars (prior incision sites) and exposure of the thinned sclera behind anatomical insertions (evidence of likely previous extraocular muscle recession)
- Inspection of the interpalpebral fissures for evidence of possible prior vertical or rectus muscle resection (smaller interpalpebral fissure) or recession (larger interpalpebral fissure)
- Prism testing to simulate the desired postsurgical alignment and the range of overcorrection and undercorrection comfortably tolerated and unlikely to result in diplopia. With adult strabismus originating in early childhood, however, the response to prism can be misleading owing to frequent coexistent anomolous retinal correspondence, which often changes postoperatively. Often a patient will have diplopia when the misalignment is initially corrected with prism but will adapt to the same correction when induced by surgery, resulting in a very low incidence of new, long-standing postoperative diplopia.[13]
- Assessment for ocular torsion by sensory testing or by anatomic evidence of torsion noted during indirect ophthalmoscopy, particularly in patients with vertical strabismus. Fortunately, it is very rare for torsional diplopia to be problematic in adult patients with early-childhood-onset strabismus due to either suppression or torsional anomalous retinal correspondence, which nearly always adapts postoperatively.
- Orbital imaging using computed tomography (CT), magnetic resonance (MR) imaging, anterior segment ocular coherence tomography (OCT),[57] or ultrasound may aid in localization of previously operated extraocular muscles, although nearly all these cases can be managed without imaging using careful preoperative and intraoperative assessment.

MANAGEMENT

Monitor/Observe

The patient should be monitored/observed if symptoms are mild, occasional, and well tolerated or if the patient is opposed to treatment.

Nonsurgical

For refractive error, consider whether alignment might be improved using all the information gained from dry and cycloplegic refraction, for example, by correcting hyperopia and including appropriate bifocal or progressive lenses for adults approaching presbyopia. Reversal of monovision may be necessary and may resolve symptoms for some patients (see Section IIM. Fixation Switch Diplopia). The impact of this intervention can often be appraised in-office.[6] Prisms to address some forms of diplopia and orthoptic exercises to address some forms of diplopia and asthenopia can also be considered in some cases. In cases of prior surgical failure, or preference against incisional surgery, botulinum toxin may help improve alignment.[58, 59] *(II+, Insufficient, Discretionary)*

Surgical

Correction of childhood strabismus in adults is generally surgical but, because a broad range of conditions may be responsible for the eye alignment noted at presentation in adulthood, the specifics of the surgical treatment vary. However, there are often sequelae of previous surgery (such as underaction of a recessed muscle, restriction of a scarred muscle, or unsightly conjunctival scarring) that should be addressed to optimize the postoperative alignment.

Although there is a vast range of presenting patterns, consecutive exotropia after prior surgery for esotropia is particularly common. Whereas anisometropia, amblyopia, hypermetropia, and dissociated vertical deviation are risk factors for consecutive exotropia in childhood,[60, 61] adduction deficits are more typically associated with consecutive exotropia in the adult population and require a specific surgical approach, typically advancement of previously recessed medial rectus muscles or removal of stretched scars, to obtain a durable result.[62, 63]

It is not always possible to predict which patients will acquire sensory fusion. However, patients with a history of congenital esotropia and a positive response to prism adaptation often demonstrate postoperative fusion along with good motor alignment.[64] In a review of outcomes of strabismus surgery, postoperative

diplopia is a concern but, although transient diplopia after surgery is common,[12] patients can be reassured that persistent diplopia after successful surgery occurs in 1% or fewer patients,[6, 10, 13] including those whose preoperative prism testing suggests that it may occur. Botulinum toxin injections may prove helpful in some cases. Even the rare patients who experience persistent new diplopia after surgery report improved health-related quality of life because improved eye alignment (reconstructive goal) has been achieved.[65]

PROVIDER AND SETTING

Diagnosis and management of persistent or recurrent childhood strabismus require the training and clinical judgment of an experienced ophthalmologist. Working under the supervision of an ophthalmologist, orthoptists can be an asset in the examination, diagnosis, and nonsurgical management of adult strabismus. Surgical treatment of childhood-onset strabismus in adults is often challenging because of pre-existing surgical scarring, uncertainty about extraocular muscle attributes and locations, possible limited fusional ability, and (in rare cases) impaired ability to adapt to new alignment.

COUNSELING AND REFERRAL

The ophthalmologist should discuss the findings, explain the disorder, provide a diagnosis, and discuss management options with the patient and any caregivers.

SECTION IIB. SENSORY STRABISMUS

INTRODUCTION

DISEASE DEFINITION

Sensory strabismus denotes an ocular misalignment in the setting of vision loss in one or both eyes. There are myriad causes of sensory strabismus, which include the following:

- Congenital structural ocular defects (i.e., optic nerve hypoplasia)
- Amblyopia from anisometropia or deprivation (i.e., pediatric cataract)
- Acquired vision loss from ophthalmic disease or trauma (e.g., glaucoma, retinal detachment, optic pathway glioma, and optic atrophy).

PATIENT POPULATION

The patient population is adults with sensory strabismus.

CLINICAL OBJECTIVES

- Counsel the patient on the diagnosis and treatment options
- Restore ocular alignment
- Restore binocular function
- Eliminate diplopia
- Inform the patient's other health care providers about the diagnosis and treatment plan

BACKGROUND

PREVALENCE

About 7% of adults over the age of 60 who have been treated with strabismus surgery have sensory strabismus.[10]

NATURAL HISTORY

Loss of visual acuity in one or both eyes and loss of binocular function often results in compromised eye alignment. Sensory vision loss prior to about 2 years of age is more commonly associated with esotropia, whereas exotropia is more common when the *onset* of sensory vision loss occurs after this age, though exceptions abound.[66] Sixty-nine percent of this population present with exotropia versus 31% who present with esotropia.[67] Coexisting vertical misalignment is not uncommon.[66, 68]

RATIONALE FOR TREATMENT

Although improvements in binocular function are uncommon after the surgical treatment of sensory strabismus, there are significant benefits to patients following ocular realignment. In esotropic patients, ocular realignment can yield improvement in peripheral vision and visual field expansion.[11] Also, enhanced emotional health, self-esteem, employment opportunities, and social interactions have been well documented after the correction of sensory strabismus.[4, 5, 24-26, 28-30] Long-lasting improvement in sensory strabismus is common despite the lack of binocular potential in most patients.[27]

CARE PROCESS

PATIENT OUTCOME CRITERIA

- Restoration of normal ocular alignment and appearance
- Improvement in other psychosocial domains

DIAGNOSIS

History

A detailed medical and ocular history includes specific questions about patient symptoms and perception of ocular misalignment.

Examination

Complete sensorimotor examination should be performed, and misalignment should be measured by prism and alternate cover test, if possible. However, in the setting of significant vision loss, an estimation of binocular alignment is often best accomplished using the Krimsky, modified Krimsky, or Hirschberg tests at distance and near.[56] Misalignment is appraised when the better sighted eye is fixated on an accommodative target, because that is often the angle that warrants repair with surgical intervention. If there is eccentric fixation with the poorer seeing eye, the prism and alternate cover test may be misleading. A modified Krimsky or Hirschberg test, using a muscle light at 1/3 meter, may better guide surgical management.

The presence of treatable causes of vision loss should be determined prior to strabismus surgery and treated as possible or appropriate. Sometimes this will improve the ability to maintain normal alignment as may occur after cataract extraction in a patient with a history of prior excellent binocular fusion. At other times, treatment may only increase symptoms of diplopia and patients may defer or delay this intervention in order to minimize diplopia awareness. In those patients with acquired loss of fusion related to long-standing uncorrected aphakia and related sensory strabismus, it may be possible to assess fusional potential with a contact lens rather than an intraocular lens. If symptomatic diplopia occurs, a trial of realignment with botulinum toxin injection may be considered before intraocular lens (IOL) implantation or strabismus surgery.[69]

MANAGEMENT

Monitor/Observe

The patient should be monitored/observed if symptoms are mild, occasional, and well tolerated or if the patient is opposed to treatment.

Extraocular Muscle Injection

Chemodenervation (botulinum toxin) can yield long-term improvement in ocular alignment in some cases.[70] Periodic injections may be required to maintain this improvement.

Surgical

Surgical treatment for sensory strabismus includes the current strabismus surgical techniques, with some surgeons favoring the use of adjustable sutures.[10, 71] *(II+, Insufficient, Discretionary)* Patients with sensory strabismus may also suffer from asymmetric eyelid or globe position (i.e., ptosis, proptosis, enophthalmos, or exophthalmos). In some cases, these eyelid abnormalities may be iatrogenic and associated with prior orbital or retinal surgery or trauma. In such cases, use of large extraocular muscle recessions can also improve concomitant ptosis or enophthalmos via its effect on globe position within the orbit. Similarly, large extraocular muscle resections can reduce proptosis and exophthalmos by repositioning the globe within the orbit. Such dual benefits can be particularly important to patients who may not have the means to

afford elective oculoplastic surgery.[72] In patients with very large angles of misalignment and strong hesitation to consider surgery on both eyes, botulinum-augmented strabismus surgery on the poorly sighted eye may be helpful.[73, 74]

PROVIDER AND SETTING

Diagnosis and management of sensory strabismus require the training and clinical judgment of an experienced ophthalmologist. Working under the supervision of an ophthalmologist, orthoptists can be an asset with the examination and diagnosis of sensory adult strabismus.

COUNSELING AND REFERRAL

The ophthalmologist should discuss the findings, explain the disorder, provide diagnosis, and discuss management options with the patient and any caregivers. The risks of strabismus surgery in patients with sensory strabismus are like those of any patient undergoing strabismus surgery and include the remote risk of scleral perforation, new-onset diplopia, and (in select cases) disruption of extraocular muscles or dislodging of orbital implants. (See Section IIG. Strabismus Associated with Other Ophthalmic Surgery.)

SECTION IIC. CONVERGENCE INSUFFICIENCY

INTRODUCTION

DISEASE DEFINITION

Convergence insufficiency is a binocular disorder associated with eyestrain, headaches, blurred vision, horizontal diplopia, or a need to close one eye to avoid diplopia while reading or engaged in near activities.[54] Difficulty concentrating, movement of print, and loss of comprehension after short periods of reading are described as well.[54] It is an exophoria or exotropia at near.[75]

PATIENT POPULATION

The patient population is adults with convergence insufficiency.

CLINICAL OBJECTIVES

- Counsel the patient on the diagnosis and treatment options
- Provide goal-directed management of symptoms (reduction of asthenopia, improved reading, binocular vision, and/or reduction of diplopia)
- Communicate with the patient's other health care providers on the diagnosis and treatment plan

BACKGROUND

INCIDENCE

Convergence insufficiency has an annual incidence of 8.4 per 100,000 people and in a 2014 review represented 15.7% of new-onset adult strabismus cases.[75] Though the median age of new-onset adult cases is 69 years old, some adults present after decompensation of convergence insufficiency that began earlier in life.[76,75]

RISK FACTORS

Although most adults do not have an obvious antecedent cause, a history of concussion[77,78] and certain central nervous system disorders such as Parkinson's disease[79] are associated with convergence insufficiency.

NATURAL HISTORY

In general, convergence insufficiency does not improve, but symptoms may vary as demands for near work change over time. Cases of convergence insufficiency secondary to concussion may improve over time.[77,80]

RATIONALE FOR TREATMENT

Treatment for convergence insufficiency is to ameliorate asthenopia and intermittent diplopia at near and to enhance the ability to perform activities requiring binocularity at near.

CARE PROCESS

PATIENT OUTCOME CRITERIA

Treatment of convergence insufficiency in adult strabismus is symptom directed, and targeted outcomes may include the following:

- Resolution of asthenopia or increasing comfort with reading and near work
- Control of diplopia at near
- Improvement in binocular function at near

DIAGNOSIS

The diagnosis of a patient with convergence insufficiency includes a comprehensive examination including the following:

- Detailed sensorimotor evaluation
- Assessment of refractive status
- Dilated fundus examination

History

A detailed medical history should include information/medical records on prior ocular surgery and diseases or trauma to the central nervous system. Assessment and quantification of patient symptoms can be achieved using the Convergence Insufficiency Symptom Survey and/or the Diplopia Questionnaire.[37]

Examination

A sensorimotor examination should be performed in the presence of convergence insufficiency to demonstrate the following: [76, 81, 82]

- Exophoria or intermittent exotropia greater at near than distance
- Insufficient positive fusional vergence at near (<20 PD mean positive fusional vergence blur or failing Sheards' criterion; mean positive fusional vergence measured less than twice the near phoria magnitude)
- Distant near point convergence (>6cm)

It should always be verified that the optical correction is appropriate for near activities.

MANAGEMENT

Monitor/Observe

The patient should be monitored/observed if symptoms are mild, occasional, and not bothering the patient or if the patient is opposed to treatment.

Nonsurgical

Convergence orthoptic exercises are often helpful. Office-based training may be more effective than home-based exercises in children, perhaps because of the ability to control compliance and participation. In young adults (19–30 years old) office-based training was found to be more effective than home-based training at improving positive fusional vergence but was not more effective at improving the near point of convergence or patient symptoms.[54,83] In general, results of convergence training are less consistent in the adult population than in children.[83, 84] *(I+, Good, Strong)* Nonsurgical treatment can also include prism reading glasses[85] and in some cases chemodenervation.[86]

Surgical

Strabismus surgery may be helpful in some cases, particularly when a manifest distance deviation is present, symptoms are consistent, and prism reading glasses are not satisfactory. Lateral rectus recession (based on distance deviation) and/or medial rectus resection (based on near deviation) have been reported

to be successful for surgical management,[87, 88] although other options such as recession with slanting the reattached muscle insertions and augmentation of lateral rectus recessions have been studied and have possible advantages in certain populations.[89] The risk of inducing postoperative diplopia at distance after surgery should be discussed, particularly for those patients absent any exophoria or exotropia, or with poor divergence amplitudes at distance.

PROVIDER AND SETTING

Diagnosis and management of convergence insufficiency require the training, clinical judgment, and experience of an ophthalmologist familiar with this diagnosis, and treatment may benefit from the assistance of an orthoptist or an optometrist.

COUNSELING AND REFERRAL

The ophthalmologist should discuss the findings, explain the disorder, provide a diagnosis, and discuss management options with the patient and any caregivers.

SECTION IID. ACQUIRED STRABISMUS RELATED TO AGING AND MYOPIA

INTRODUCTION

DISEASE DEFINITION

Strabismus related to aging and myopia often results in acquired divergence insufficiency and diplopia sometimes associated with alterations of the extraocular muscle-pulley complex. The most common form of acquired divergence insufficiency may be seen with excessive convergence tone, frequently accompanied by myopia, and causality is still poorly understood. A variant called sagging eye syndrome is specifically associated with aging and well-described alterations in the extraocular muscle-pulley complex.[90] The least common, most severe form of acquired divergence insufficiency is strabismus fixus, or heavy eye syndrome, which results from very marked changes in the extraocular muscle-pulley complex and associated supero-temporal displacement of the globe within orbit seen with degenerative high myopia.[91-95]

Divergence Insufficiency

Divergence insufficiency is defined as an esotropia that increases with distance fixation. Patients present with an acquired comitant esotropia that is typically 10 prism diopters larger at distance than at near[96] although the disparity may be less. Such patients complain about progressive or subacute-onset double vision at distance (e.g., while driving or watching television). They rarely have diplopia at near. Primary divergence insufficiency may be associated with decompensation of a long-standing esodeviation, loss of fusion, or chronically increased convergence tonus with subsequent shortening of medial rectus muscles relative to lateral rectus muscles, and the incidence has been increasing in recent decades.[96, 97] Myopia is common.[98] Hypertension and cardiovascular disease may be risk factors.[99] Secondary divergence insufficiency is associated with neurological disease and typically caused by a lesion to a supranuclear divergence center, subtle 6th nerve palsy, neurologic abnormality associated with pontine tumors, or head trauma.[100,101] (See Section IIJ. Abducens Palsy.)

Sagging Eye Syndrome

Some cases of divergence insufficiency are seen in association with an age-related degeneration of the superior rectus-lateral rectus (SR-LR) connective tissue band and are considered to be sagging eye syndrome.[90] This band typically maintains a fixed distance between the superior rectus and the lateral rectus as they course posteriorly, but age or other degeneration can result in a medial shift of the superior rectus and an inferior shift of the lateral rectus due to failure of this connective tissue band. As the lateral rectus sags downward, abduction becomes impaired and esotropia results. The esotropia is often greater at distance than at near. This downward shift of the lateral rectus muscle may be responsible for an often associated small-angle hypotropia, although other extraocular muscle and pulley abnormalities have been reported in addition to the inferior sagging of the lateral rectus and the disruption of the SR-LR band.[90, 102]

Sagging eye syndrome also shares a few imaging characteristics with myopic strabismus fixus, but in a much milder form. Myopic strabismus fixus results in much more extreme displacement of the lateral rectus, nasal displacement of the superior rectus muscle, and a superotemporal prolapse of the globe not seen with sagging eye syndrome.

Strabismus Fixus (Heavy Eye Syndrome)

Strabismus fixus is progressive large-angle esotropia and hypotropia with a limitation in ocular rotation in patients with long-standing pathological high myopia. As a result of the increased axial length, there is

development of a staphyloma or a staphylomatous-like change in globe dimensions that results in rupture of the SR-LR band. An inferior shift of the lateral rectus muscle[91] and a nasal shift of the superior rectus muscle ensues.[92, 93 94, 95] Globe dislocation (prolapse) into the superotemporal orbit and outside the confines defined by the lateral rectus and superior rectus occurs. Ocular rotations in myopic strabismus fixus are much more severely altered than in sagging eye syndrome; there is a component of mechanical restriction not seen in sagging eye syndrome, likely due to secondary medial rectus contracture as well as globe prolapse into the superotemporal orbit. Not all cases of axial high axial myopia result in strabismus fixus. In some cases, the globe elongation is axial only, superotemporal globe dislocation does not occur, and the patient may be treated as if he or she has classic divergence insufficiency.[94]

PATIENT POPULATION

The patient population is adults with divergence insufficiency, sagging eye syndrome, or strabismus fixus.

CLINICAL OBJECTIVES

- Counsel the patient on the diagnosis and treatment options
- Provide goal-directed management of strabismus (restoration of binocularity and control of diplopia and, when severe, reconstruction of normal-appearing alignment, improved eye contact, and self-image)
- Communicate with the patient's other health care providers about the diagnosis and treatment plan

BACKGROUND

PREVALENCE AND RISK FACTORS

Divergence Insufficiency

The annual incidence of 6.0 per 100,000 people represents 10.6% of new-onset adult strabismus cases.[75] The incidence of divergence insufficiency is increasing.[97] Divergence insufficiency typically presents after 50 years of age and frequency increases with age; the median age of presentation is 74 years.[75] It is significantly more common among Caucasian women.[99]

Sagging Eye Sydrome

The prevalence of sagging eye syndrome as a cause of acquired diplopia in adult patients increases with age from less than 5% under the age of 50 years to 60% over the age of 90. Sagging eye occurs more frequently in females (54%) in myopes, with most patients presenting between 60 and 80 years of age.[90, 103-105]

Strabismus Fixus (Heavy Eye Syndrome)

The prevalence of strabismus fixus globally is unknown but has been estimated to be 2.65% among high myopes in Japan.[106] Progressive strabismus fixus is typically seen in middle or older age, with less severe divergence insufficiency predating this progression.[107, 108] Severe myopia with an axial length of more than 27mm is characteristic.[91, 92, 95]

NATURAL HISTORY

The strabismus and diplopia caused by divergence insufficiency, sagging eye syndrome, and strabismus fixus will not resolve spontaneously. Strabismus fixus is the most progressive in severity.[94, 108]

RATIONALE FOR TREATMENT

Diplopia, the inability to make eye contact, and severe ocular misalignment preventing proper eye examinations or other needed ophthalmic surgery (in the case of strabismus fixus) warrant treatment.

CARE PROCESS

PATIENT OUTCOME CRITERIA

Treatment of adult strabismus is symptom directed, and targeted outcomes may include the following:

- Reduction of diplopia
- Improvement in or restoration of binocular vision and field of binocular vision
- Reconstruction of ocular alignment
- Reduction of compensatory head position (if present)

DIAGNOSIS

History

Patients present with a history of subacute onset of binocular diplopia from esotropia, worse at distance and sometimes associated with modest vertical misalignment. This group of disorders is progressive and may begin to impact alignment at near. A detailed medical history should include the use of prism correction in glasses.[109] Symptoms first become apparent with distant fixation (e.g., while driving) and most commonly after age 50 years for classic divergence insufficiency.[75] Symptoms are similar for sagging eye syndrome, with associated small-angle vertical and torsional diplopia at times; presentation with sagging eye syndrome is more common in the seventh decade of life or older. Associated changes of blepharoptosis (29%), deep superior lid sulcus defect (64%).[90] A history of blepharoplasty, brow lift, or facelift surgery has been noted in some cases.[90] Heavy eye or myopic strabismus fixus is associated with very high axial myopia of more than 27mm. Onset may begin in the earlier decades of adult life with chronic progression of a more extreme esotropia and possible hypotropia often associated with mechanical restriction.[91, 92, 95]

Examination

Divergence Insufficiency

Diagnosis is typically accompanied by the following:

- More esotropia at distance than at near
- Similar esotropia in right and left gaze and the absence of pontine or other neurological pathology or significant abduction nystagmus
- No limitation of forced ductions under anesthesia

Sagging Eye Syndrome

Diagnosis is typically accompanied by the following:

- Esotropia, often greater at distance, and sometimes accompanied by a small vertical deviation and cyclotropia[90, 102]
- Deviations that are nearly comitant, except for the described distance-near disparity
- Mild to no limitation of ocular rotation
- Associated changes of blepharoptosis (29%), deep superior lid sulcus defect (64%) with a previous history of blepharoplasty, brow lift, or facelift surgery in some cases[90]

Strabismus Fixus (Heavy Eye Syndrome)

Diagnosis is typically accompanied by the following:

- Severe myopia, typically -8.00 diopters or more but often much greater
- Axial length of more than 27mm
- Large-angle ocular deviation of esotropia with or without hypotropia
- Limitation of ocular rotations such as abduction or elevation
- An SR-LR dislocation angle of 121° ± 7° (measuring the angle between the centroids of the superior rectus muscle and lateral rectus muscle on quasicoronal orbital imaging)[94]

A complete ocular motility examination for these syndromes should include cover testing at near and distance in primary and secondary gaze positions and evaluation of torsion for patients with vertical

misalignment. In patients with myopic strabismus fixus, there may be limited rotations and measurements can be obtained only with the prism and light reflex (Krimsky) test.

High-resolution orbital imaging is useful for evaluation of patients with likely sagging eye or myopic strabismus fixus to look for evidence of disruption of the SR-LR band. This characteristic is best seen on coronal T1-weighted images obtained without fat suppression. The lateral rectus sags downward, creating a large angle between the lateral rectus and superior rectus (typically 104° ± 11°) for patients with sagging eye syndrome.[94] There is fat prolapse within this potential space.

In contrast, for patients with myopic strabismus fixus (heavy eye syndrome), the angle between the lateral rectus and the superior rectus is much larger (described as 121° ± 7°) and there is frank prolapse of the globe within this space. The globe itself demonstrates axial elongation and often posterior enlargement.[90-92, 94, 102]

Brain imaging and neurologic workup is indicated if the patient presents with significant abduction nystagmus and lateral incomitance suggesting a 6th nerve palsy, or with signs or symptoms of elevated intracranial pressure such as headache, papilledema, or other neurologic decline that may result in 6th nerve palsy. (See Section IIJ. Abducens Palsy.)

Conditions resembling myopic strabismus fixus and presenting with restrictive esotropia with or without hypotropia include orbital trauma, chronic complete 6th nerve palsy, TED, and acquired fibrosis of the extraocular muscles but are readily distinguished based on history and characteristic orbital imaging.

MANAGEMENT

Divergence Insufficiency

Monitor/Observe

The patient should be monitored/observed if symptoms are mild and occasional or if the patient is opposed to treatment.

Nonsurgical

Fresnel or ground-in prisms provide temporary (prior to surgical correction) or long-term treatment options.[109-111] Patients should be counseled that the magnitude of prism correction needed to control diplopia may increase over time and that their ability to control the diplopia when glasses are not used will likely decline. Fusional exercises have not proven beneficial for the treatment of divergence insufficiency.[112]

Surgical

Bilateral lateral rectus muscle resection[113] as well as bilateral medial rectus muscle recessions[113, 114] and unilateral medial rectus muscle recession combined with lateral rectus muscle resection have proven successful at resolving divergence insufficiency esotropia.[111] Surgery can be performed bilaterally or unilaterally.[96, 115, 116]

Typically, a greater surgical dose (than indicated in the standard tables for childhood comitant strabismus) is needed for this type of esotropia, particularly when recessing the medial rectus muscles.[117]

It is useful to check convergence amplitudes at near prior to surgery. The presence of robust convergence amplitudes at near generally protects the patient from developing postoperative diplopia with convergence insufficiency at near.[114]

Sagging Eye Syndrome

Monitor/Observe

The patient should be monitored/observed if symptoms are mild and occasional or if the patient is opposed to treatment.

Nonsurgical

Fresnel or ground-in prisms are helpful for patients with new-onset deviations, including those that are intermittent or constant and small in angle. Prism correction may need to be increased over time.

Surgical

Surgical prognosis for this group of patients is favorable and can be addressed using a variety of techniques, including marginal insertional tenotomies,[104] recessions, resections, and plications[118] and superior and lateral rectus muscle myopexy.[119] Surgical resolution or reduction of diplopia has been particularly beneficial for patients who don't otherwise need glasses for distance vision.[103] As described for patients with divergence insufficiency unrelated to sagging eye syndrome, more than typical recession of the medial rectus muscles is usually needed. [114]

Strabismus Fixus (Heavy Eye Syndrome)

Monitor/Observe

The patient should be monitored/observed if he or she is opposed to treatment.

Nonsurgical

Prisms are not typically an option to correct the baseline strabismus because it is quite large, and the strabismus quite incomitant, but they may be useful postoperatively in patients with a residual deviation.

Surgical

In general, surgery is the best alternative to correct the large-angle esotropia and frequent hypotropia and to normalize ocular rotations.[95] Referral to a retina specialist for preoperative evaluation should be considered to ensure that progressive myopic degeneration is not associated with active retinal pathology requiring treatment prior to strabismus surgery. Measuring the angle between the superior rectus muscle and the lateral rectus muscle (dislocation angle) is helpful in determining the severity of the disease and for planning the surgery.[91-93] A forced duction test to determine if limitation to ocular rotation is the result of a medial rectus muscle restriction or, more rarely, an orbital mechanical restriction resulting from the increased axial length and adjacency of the globe to the lateral orbital wall should be performed at the onset of surgery. If the forced duction test confirms restriction to abducting rotation, the medial rectus muscle should be recessed. However, some orbital mechanical restriction may be present even after medial rectus recession. In such cases, restriction to abduction may persist, limiting the outcome of the surgery.[95, 108, 120, 121] Medial rectus recession is typically accompanied by one of several muscle union procedures that join the superior rectus to the lateral rectus to reposition the muscle paths. The classical approach is the Yokoyama procedure,[119] a vessel-sparing suture union of the superior rectus and lateral rectus 15mm posterior to their insertions, typically accompanied by a medial rectus recession.[95] Many variants have been described, including union by a silicone sleeve[122] and the use of a three-suture SR-LR union to successfully reduce more extreme degrees of esotropia.[123]

In some cases of very long axial myopia and large esotropia, prolapse of the globe beyond the confines of the superior and lateral rectus may not be present. Such cases can be surgically managed the same as for sagging syndrome or basic divergence insufficiency and do not typically require loop myopexy to resolve misalignment and diplopia.[94]

PROVIDER AND SETTING

Diagnosis and management of divergence insufficiency, the sagging eye syndrome, and myopic strabismus fixus benefit from the training and clinical judgment of an experienced ophthalmologist. Working under the supervision of an ophthalmologist, orthoptists can be an asset in the examination, diagnosis, and nonsurgical management when appropriate.

COUNSELING AND REFERRAL

Divergence Insufficiency/Sagging Eye Syndrome

Magnetic resonance imaging and referral for central nervous system evaluation should be considered if other signs, such as abduction nystagmus, papilledema, or neurologic decline, are present.

Strabismus Fixus (Heavy Eye Syndrome)

Magnetic resonance imaging or CT is often helpful in confirming the diagnosis of strabismus fixus. Referral to a retina specialist for preoperative evaluation should be considered to ensure that progressive myopic degeneration is not associated with active retinal pathology that might increase risk of a postoperative retinal tear or detachment if untreated. Exposure keratopathy should be monitored and treated in cases of associated exophthalmos sometimes seen with high axial myopia, or referred to an oculoplastic specialist for more definitive care. The ophthalmologist should discuss the findings, explain the disorder, provide a diagnosis, and discuss management options with the patient and any caregivers.

SECTION IIE. THYROID EYE DISEASE

INTRODUCTION

DISEASE DEFINITION

Thyroid eye disease is an autoimmune disorder characterized by congestion and inflammation of the orbit and surrounding tissues.[124] Typical ocular findings include soft tissue congestion with enlargement of the preseptal fat pads, eyelid retraction, exophthalmos, restrictive extraocular myopathy, and optic neuropathy.[125] Vision can be compromised from corneal exposure or optic neuropathy or as a result of development of diplopia secondary to congestive and restrictive extraocular muscle myopathy.

PATIENT POPULATION

The patient population is adults who have TED and associated strabismus.

CLINICAL OBJECTIVES

- Counsel the patient on the diagnosis and treatment options
- Carefully monitor patients at risk for vision loss secondary to compressive optic neuropathy due to crowding at the orbital apex or severe exposure keratopathy from eyelid retraction with or without exophthalmos
- Manage binocular diplopia, compensatory head posture, and sometimes associated elevation in intraocular pressire (IOP)
- Refer to an orbital specialist if the patient experiences vision-threatening disease, moderate to severe exophthalmos and/or significant orbital pain related to TED
- Inform the patient's other health care providers about the diagnosis and work collaboratively on the treatment plan

BACKGROUND

INCIDENCE

The incidence of TED in an adult Caucasian population is 16 per 100,000 per year in women and 2.9 per 100,000 per year in men.[126]

RISK FACTORS

Thyroid eye disease can occur at any age, but onset is most often in the fourth to fifth decade of life.[127] Thyroid eye disease is much more common among women (8:1).[128] Risk of TED causing restrictive strabismus increases with age.[129, 130] Smoking, diseases resulting in reduced oxygen saturation (such as emphysema), and exposure to ionizing radiation increase the risk for and severity of orbitopathy.[131, 132] A history of prior orbital decompression is associated with an increased risk of strabismus,[133] an association that worsens with age,[129] though it may be less problematic when effort is made to preserve the inferomedial orbital strut during decompression.[134] Radioactive iodine treatment, high anti-thyroid antibody titer and serum vitamin D deficiency, and smoking, are independent risk factors associated with the development of TED.[135, 136]

NATURAL HISTORY

Between 30% and 50% of patients with TED develop restrictive myopathy. Ocular motility is restricted initially by inflammatory edema and later by fibrosis. The most frequently affected muscle in TED is the inferior rectus, followed by the medial rectus,[137] although more global extraocular muscle involvement is quite common. A small percentage of patients with TED have co-existent myasthenia gravis.

RATIONALE FOR TREATMENT

Motility impairment causing diplopia and compensatory head posture is a frequent manifestation of TED. This impacts visual function, affects quality of life, and can have profound socioeconomic consequences.[138]

CARE PROCESS

PATIENT OUTCOME CRITERIA

Treatment of TED is symptom directed, and targeted outcomes may include the following:

- Recognition and prevention of primary vision loss due to optic neuropathy, exposure keratopathy, and elevation in IOP
- Restoration of ocular alignment
- Reduction of diplopia
- Improvement of compensatory head position

The goal of the strabismus surgeon is to re-establish single binocular vision in primary gaze and in reading position, and to facilitate establishment of a substantial, usable, field of single binocular vision when possible.[139] *(II-, Moderate, Discretionary)*

DIAGNOSIS

History

A detailed medical and ocular history should include specific questions about weight gain or loss, tachycardia, and unexplained fatigue potentially secondary to hyperthyroidism or hypothyroidism. Strabismus is likely to be associated with diplopia and, in some cases, a compensatory head posture (i.e., ocular torticollis, often a chin-up position in this population). Because the incidence of myasthenia is increased in patients with TED, assessment for the coexistence of myasthenia is suggested if indicated by findings on clinical examination.

Examination

The examination should include a full sensorimotor examination, noting evidence of mechanical restriction. Forced ductions confirm restriction, but classic features, such as fixation duress (brow elevation and augmentation of eyelid retraction on attempted ocular elevation), may confirm the restrictive nature of the associated strabismus. Hypotropia of the affected eye(s) with esotropia is the most frequent deviation owing to involvement of the inferior and medial rectus muscles, although other rectus muscles are commonly involved, and may result in other strabismus patterns. If at presentation there is minimal external evidence of inflammation, relative hypertropia on a less involved side and excyclotorsion from increased inferior rectus tone on either or both eyes may result in a strabismus pattern typically associated with superior oblique palsy (SOP).[140] More global extraocular muscle involvement may be apparent on orbital imaging or with forced duction testing.[141, 142]

The examination should also include the following elements:

- Measurement of the exophthalmos by exophthalmometer, which is important diagnostically and to follow clinical course
- Surveillance for optic neuropathy, monitoring acuity, color vision, visual fields, pupillary examination, and fundus examination (for disc edema or optic atrophy)

- Optical coherence tomography and automated threshold visual fields, which provide ancillary information and are used to screen for or monitor possible compressive optic neuropathy
- Binocular field testing to map the region of single binocular vision, which can be helpful. Screening and management of possible associated optic neuropathy may fall within the expertise of the co-managing orbital specialist (e.g., neuro-ophthalmologist or oculoplastic surgeon.)

Orbital CT or MR imaging can be performed to confirm the diagnosis and evaluate the size of the extraocular muscles and the volume of orbital fat and response to treatment.[143] Imaging features include tendon-sparing enlargement of one or more of the extraocular muscles and proptosis. Muscle involvement and proptosis are often bilateral but frequently asymmetric.[142] Imaging may also help determine whether the superior oblique is involved and demonstrate the degree of orbital apex crowding, and MR imaging can help determine the disease activity. The size of the rectus muscles as measured by CT does not, however, directly correlate with the degree of muscle dysfunction.[144]

Thyroid function and associated immune studies may be ordered, although this is typically handled by the associated primary care or endocrinology specialist; patients may be hyperthyroid, hypothyroid, or euthyroid at the time of presentation with TED.[145]

MANAGEMENT

Ocular lubricants are almost always needed to combat exposure related to eyelid retraction and proptosis. Punctal plugs can be useful. Patients should be counseled to cease smoking.[128]

Selenium supplementation in patients with selenium deficiency has been shown to reduce some inflammatory symptoms in patients with milder TED,[146] perhaps in part through an antioxidant effect.[147] It does not, however, impact control of hyperthyroidism in populations that are not selenium deficient.[148] Teprotumumab, a human monoclonal antibody inhibitor of IGF-IR, reduces proptosis and the clinical activity score of disease in many patients with active TED.[149] Teprotumumab treatment has been shown to improve subjective diplopia scores in both active and chronic TED[150, 151] and reduce the need for strabismus surgery. Reduction in extraocular muscle size to orbital cross-sectional size after treatment with teprotumumab has been demonstrated,[152] along with general reduction in muscle and fat volume within the orbit.[153] The quantitative effect on strabismus, per se, is under investigation.

Although some of the outcomes reported after teprotumumab infusion have been encouraging, it is not universally available, it is associated with a number of adverse reactions, and it is not suitable for everyone. It is relatively contraindicated in patients with inflammatory bowel disease, absolutely contraindicated in pregnancy, and should be considered with caution in patients with pre-existing hearing loss. It may cause hyperglycemia, muscle spasms, nausea, alopecia, diarrhea, tinnitus and hearing impairment, dysgeusia, headache, weight loss, nail disorders, and menstrual disorders. At this time, other biologics such as Tocilizumab, Rituximab, or Fingolimob are used in Europe.

Although there may be an evolving role for teprotumumab in cases of severe proptosis or compressive optic neuropathy,[154, 155] orbital decompression, high-dose pulse steroid infusion, and, in some cases, orbital radiation treatment are often indicated.[156] Consultation with an orbital disease specialist should be considered in patients with concurrent proptosis and significant strabismus, even in the absence of compressive optic neuropathy. Decompression may alter alignment, and rectus muscle recession can worsen proptosis. If orbital decompression is indicated, strabismus repair should be delayed until after the decompression because of the likely change in ocular alignment post decompression.[157-159] Displacement of the extraocular muscles and the globe into newly available space, or, in some cases, disinsertion and reinsertion of the inferior oblique muscle to improve exposure, can significantly impact ocular motility.[160-162] There is some evidence that preserving the orbital strut may diminish the risk of new-onset strabismus.[134, 157] Surgery on the eyelids is typically delayed until after strabismus repair.

Observation

Patients can be observed if there is no diplopia in primary gaze or reading position.[163] They should be observed if the angle of strabismus is not stable for at least 4 to 6 months and if there are still signs of

active inflammation such as chemosis and injection not related to exposure. Observation is also necessary if the patient requires orbital decompression surgery, as this procedure often changes ocular alignment.[164, 165]

Nonsurgical

Fresnel or ground-in prism can provide temporary relief from diplopia while awaiting definitive treatment or may be suitable for small to moderate residual deviations after surgical and medical intervention.[128] Chemodenervation during the active phase of the disease is advocated by some for temporary relief of diplopia and may possibly reduce the misalignment left after the initial inflammatory stage of the disease.[166-169]

Surgical

Surgery is required in most patients with persistent diplopia in primary or reading positions of gaze. This is usually undertaken when the inflammatory stage has subsided and the angle of deviation has been stable for at least 6 months,[142, 170] but earlier surgery in select patients can also have satisfactory outcomes and shorten the period of disability.[171] Quiescence is usually determined on clinical grounds.[172] Less frequently, MR imaging sequences T2, fast spin echo (FSE), postcontrast T1 (T1Gad) signal intensity ratios, and normalized-apparent diffusion coefficient (n-ADC)[173] and water content on Short TI Inversion Recovery (STIR) sequences may be used to determine if the disease has become quiescent,[174] although the imaging signs of persistent imflammation may sometimes persist in the presence of clinically quiescent disease. Recessions of the restricted eye muscles are the mainstay of surgical correction. Resection is generally avoided in restrictive disease out of concern for further reducing ductions[142] but can be a useful adjunct in select cases,[175] particularly when extremely large recessions have not fully corrected the alignment.

The rectus muscles of the thyroid patient can be severely tight. Thyroid eye disease is the most commonly identified risk factor for development of pulled-in-two syndrome,[176] an unplanned horizontal transection of a rectus muscle that seems to spontaneously occur while it is hooked during surgery. Because this transection takes place typically 4mm to 9mm or farther from the anatomical insertion, recovery of the already taut distal end can prove quite challenging.[176]

Surgery for horizontal deviations is more successful than surgery for vertical strabismus (84% vs. 66% success after the primary surgery).[170] Because the orbitopathy often affects the inferior rectus muscle, vertical deviations are more common.[177] Recession of the inferior rectus muscle is frequently complicated by consecutive hypertropia, in part because of suboptimal contact of the recessed muscle with the globe,[178] ipsilateral superior rectus involvement,[179-181] or imbalanced contralateral disease.[182, 183] Use of a semi-adjustable suture technique may help minimize unanticipated muscle drift,[180] as may intentional undercorrection of the inferior rectus recession[141] with the use of adjustable sutures,[184] wider spreading of the muscle to prevent sagging of the center of the insertion over time,[181] and the use of permanent polyester sutures. Large bilateral inferior rectus recession may result in an A-pattern with unanticipated exotropia in downgaze as well as intorsion. This occurs because the superior oblique becomes the dominant infraductor[128, 133] and may be exacerbated by primary involvement of the superior oblique muscle in the disease process.[185] Because managing vertical deviations in TED is complex, a systematic approach appraising preoperative and intraoperative forced ductions of all extraocular muscles and attention to preoperative and intraoperative ocular torsion may significantly minimize the risk of an undesired postoperative result.[181, 185] Recession of the inferior rectus muscle, even with careful dissection from the lower lid retractors, may result in lower lid retraction. Releasing restriction with recession of rectus muscles may result in increased proptosis of the globe.[186] Preoperative counseling with the patient and communication with the treating orbital surgeon are important in this regard. Recession of Tenon's capsule from overlying conjunctiva may augment the effect of rectus muscle recession and in turn improve postoperative ductions and the range of single binocular vision in select cases, and it may facilitate closure.[187, 188]

Surgeons generally prefer an absorbable suture (6–0 polyglactin) for isolating the muscle and reattaching it to the globe. Some surgeons favor nonabsorbable sutures for large recessions of the inferior rectus muscle because they may reduce the risk of postoperative drift to overcorrection.[145] The role of adjustable suture surgery in TED remains controversial. Some surgeons claim more successful results,[189] whereas others

never use the technique because of concern over late overcorrection and/or muscle slippage.[190] Some surgeons advocate a relaxed muscle positioning technique where the muscles are recessed to a position where they rest freely on the globe without tension.[191] In patients with concurrent proptosis and significant strabismus, the predictable worsening of proptosis following recession of fibrotic muscles may warrant consultation with an orbital specialist for orbital decompression surgery prior to strabismus surgery.[186]

PROVIDER AND SETTING

Diagnosis and management of strabismus in a patient with TED require the training and clinical judgment of an experienced ophthalmologist comfortable with very complex strabismus and with managing severe restrictive disease. Working under the supervision of an ophthalmologist, orthoptists can be an asset with the examination, diagnosis, and nonsurgical management of TED.

COUNSELING AND REFERRAL

A multidisciplinary approach to TED treatment is recommended, combining the expertise of medical specialists in endocrinology, oculoplastics, and neuro-ophthalmology as indicated. The ophthalmologist should discuss the findings, explain the disorder, provide diagnosis, and discuss management options with the patient and any caregivers.

SECTION IIF. STRABISMUS AFTER ORBITAL TRAUMA

INTRODUCTION

DISEASE DEFINITION

Strabismus after orbital trauma is common and may be present along with other ophthalmic, medical, and surgical conditions. Although all life-threatening and vision-threatening conditions need to be addressed before treating strabismus, the presence and pattern of ocular misalignment may indicate other orbital or central nervous system trauma guiding imaging and treatment.

Determining the cause of diplopia after orbital trauma requires a detailed history, examination, and often imaging. The etiology of the strabismus may be multifactorial, including direct damage to the extraocular muscles and their associated nerves, to the surrounding orbital structures or contemporaneous trauma to the central nervous system. Rectus or oblique muscle avulsion, tear, or flap tear,[192, 193] hemorrhage, edema, or paresis may occur in addition to orbital hemorrhage or edema, soft tissue swelling, and fracture of orbital bones, with and without entrapment of muscle, fat, or muscle pulleys. Cranial neuropathies,[194] disorders of accommodation or convergence,[195] disruption of fusion, fusional amplitudes, saccades and smooth pursuit, decompensation of previous heterophoria, and other supranuclear defects may result in diplopia.[196]

Diplopia is very common after blowout fractures.[197-199] Strabismus surgery was required in 7% to 24% of cases in two series of patients with orbital floor fractures.[200, 201] Less commonly, strabismus can occur iatrogenically after sinus surgery[202, 203] or other periocular surgeries, including surgery to the eyelids (see Section IIG. Strabismus Associated with Other Ophthalmic Surgery).[204]

PATIENT POPULATION

The patient population is adults with strabismus following orbital trauma.

CLINICAL OBJECTIVES

- Counsel the patient on the diagnosis and treatment options
- Provide goal-directed management of strabismus
- Restore normal anatomical alignment, restore binocular single vision with reduction of diplopia, and reduce compensatory head posture. These are goals for which surgery is typically performed in this population.
- Inform the patient's other health care providers of the diagnosis and treatment plan

BACKGROUND

PREVALENCE AND RISK FACTORS

In self-reported population studies, the incidence of ocular trauma in adults ranged from 1.7% to 19.8%.[205-207] In all of these studies, younger age and male sex were identified as risk factors.[205-207]

NATURAL HISTORY

Diplopia may be transient following ocular trauma, but if it has not resolved within 6 months it is unlikely that it will resolve on its own.

RATIONALE FOR TREATMENT

Diplopia, loss of binocular vision, compensatory head position, and inability to make eye contact all warrant treatment.

CARE PROCESS

DIAGNOSIS

History

A detailed medical and ocular history, including specific questions about symptoms of diplopia, vision loss, enophthalmos and hypoglobus, and details on the nature and timing of the trauma are helpful.

Examination

A thorough examination in the acute setting should include vision testing, refraction (if possible), pupillary examination, IOP measurement, confrontational visual field testing, slit-lamp examination, a dilated (if safe) or undilated fundus examination (with attention to any fundus torsion), testing of facial sensation, and exophthalmometry. The goal of the primary examination is to rule out any globe injury or sight-threatening injury. Patients with orbital or cranial trauma may also have decreased vision (secondary to corneal trauma, traumatic cataract, optic neuropathy, or other damage to the retina or other ocular structures) or decreased visual fields. Care should be taken to note these limitations, because they may help guide test selection during the examination.

A detailed sensorimotor examination should be performed, with attention to versions, ductions, saccades, pursuit, vergence, and near reflex, along with alignment in multiple gaze positions with attention to primary and secondary deviations.[208] Forced duction and forced generation testing may help distinguish restriction from paresis of the extraocular muscles.[209] Double Maddox rod, Lancaster red-green, Hess screen, or synoptophore (especially if there is concern for disrupted central fusion) may also be helpful. Details of this examination will likely change from the acute setting when edema and hemorrhage may limit ductions and versions, induce proptosis, and obscure enophthalmos. Local as well as central nervous system neurological deficits may be very notable but possibly subject to improvement.

Vital signs looking for any bradycardia or heart block, along with symptoms of dizziness, nausea, vomiting, or loss of consciousness in a patient with orbital trauma may indicate an entrapped muscle causing the oculocardiac reflex.[210] This usually requires urgent medical and surgical intervention.

Imaging studies are frequently indicated. Computed tomography rather than MR imaging is required if there is any concern about a possible ferrous-metallic foreign body and often provides sufficient information about the presence of orbital fracture and entrapment. Magnetic resonance imaging provides more precise imaging of the extraocular muscles and surrounding tissues, including the pulley system, and reduces radiation exposure. It can sometimes be performed dynamically and provides additional useful information for planning an intervention.[211-214] Occasionally, patients with atypical strabismus have occult fractures absent a history of trauma to the patient.[215]

MANAGEMENT

General Guidelines

All life-threatening and vision-threatening conditions need to be treated before treating the strabismus. In one series of 379 patients who underwent surgical repair of facial fractures, 5.5% had complete loss of vision in one eye and 0.8% had complete loss of vision in both eyes.[216] Another series of blowout fractures demonstrated serious ocular injury in 24% of cases.[217]

Timing of surgical repair of orbital fractures has been debated.[198, 199] Current recommendations for timing of repair of isolated orbital floor fractures are as follows.[218]

- Immediate repair:
    - Immediate repair is indicated for patients with CT or MR imaging evidence of an entrapped muscle or periorbital tissue associated with a nonresolving oculocardiac reflex.
    - White-eyed blow-out fracture,[219] a form of trap-door fracture with muscle entrapment and oculocardiac reflex (seen in children) requires urgent repair.
    - Globe subluxation into the maxillary sinus, a rare occurrence, demands immediate surgical repair[220, 221]
- Repair within 2 weeks:
    - Symptomatic diplopia with positive forced ductions or entrapment on CT and minimal improvement over time is best repaired within 1 to 2 weeks, permitting enough time for edema to subside and for the effect on globe position and motility to be re-evaluated. Significant fat or periorbital tissue entrapment can also result in permanent strabismus in the absence of muscle entrapment.[222]
    - Large floor fractures, hypoglobus, and progressive infraorbital hypoesthesia are also best addressed within about 2 weeks.
    - Early enophthalmos or hypoglobus causing facial asymmetry will not resolve and are best addressed within about 2 weeks.
- Delayed repair (after 2 weeks):
    - Restrictive strabismus and unresolved enophthalmos may benefit from delayed repair.
- Observation:
    - Observation may be considered in cases of minimal diplopia (not in primary or downgaze), and good ocular motility without significant enophthalmos or hypoglobus.

Guidelines for Treating Strabismus

Even with repair or observation of orbital fractures, strabismus and diplopia can persist. In a series of 54 patients who underwent repair of orbital blowout fractures, 86% had had diplopia preoperatively and 37% postoperatively.[223]

Monitor/Observe

Some forms of strabismus after orbital trauma will improve with time, and watchful waiting is often a reasonable approach. A short burst of oral steroids can hasten recovery and uncover strabismus that will persist despite resolution of orbital edema/hematoma.

Nonsurgical

Waiting 4 to 6 months after orbital trauma is advised because strabismus may resolve on its own unless there is substantial fat and orbital pulley entrapment for which earlier repair is beneficial.[224] Conservative treatment such as occlusion, filters, Fresnel prisms, botulinum toxin injection, and prism glasses may provide temporary or permanent relief of diplopia.

Surgical

For patients who do not meet the criteria for early surgical intervention, waiting 4 to 6 months after the injury is advised to ensure stability of the misalignment prior to repair.[201] The goals of surgical intervention should be discussed with the patient. Those goals are to eliminate diplopia in the primary position and downgaze and to enlarge the field of binocular single vision. More than one strabismus surgery and long-term use of prism glasses may be required. Every situation is unique, and more than one method of surgical repair is possible.[225] Preoperative forced generation testing and preoperative and intraoperative forced duction testing are very important.

Orbital fat entrapment can prove nearly as challenging as extraocular muscle entrapment, resulting in fibrotic and adhesion syndromes not readily relieved with dissection around the involved muscle.[222] Adhesions and entrapment may extend well into the deeper orbit, out of reach of the strabismus surgeon. Adhesion of extraocular muscles, particularly to porous implants, can be equally problematic at times,[226, 227] as can iatrogenic disinsertion of the inferior oblique at its origin, which may be required to place an implant along the nasal wall of the orbit.[228]

Some general principles include an attempt to recover "lost" muscles whenever possible.[229] If recovery of a muscle proves impossible or if a muscle is determined to be severely paretic, a transposition procedure may be indicated. Matching restriction with the use of posterior fixation sutures or Scott procedures (recess/resect)[230] on the unaffected eye are established methods of expanding the field of single binocular vision. Adjustable sutures are often helpful in these cases.

Because the etiology of the strabismus may be multifactorial and the misalignment incomitant, complete elimination of diplopia is difficult, if not impossible in most cases.

PROVIDER AND SETTING

A multidisciplinary approach may be required and it is applied in different settings—an emergency department or inpatient or outpatient facilities. Diagnosis and management of strabismus caused by ocular trauma require the training and clinical judgment of an experienced ophthalmologist. Working under the supervision of an ophthalmologist, orthoptists can be an asset in the examination, diagnosis, and nonsurgical management.

COUNSELING AND REFERRAL

Consultation or co-management with comprehensive ophthalmology, oculoplastics, neuro-ophthalmology as well as plastics, otolaryngology, emergency department, and neurosurgery may prove necessary, depending on the circumstances of the injury and the timing of the strabismus evaluation.

SECTION IIG. STRABISMUS ASSOCIATED WITH OTHER OPHTHALMIC SURGERY

INTRODUCTION

This section focuses on strabismus acquired after the following procedures:

- Cataract extraction or keratoplasty
- Glaucoma filtering surgery (including trabeculectomy and glaucoma aqueous shunt)
- Scleral buckling surgery
- Pterygium surgery
- Blepharoplasty and eyelid surgery

Strabismus sometimes resulting in diplopia has been reported after virtually any periocular procedure, including major orbital surgery as well as dacryocystorhinostomy. A detailed discussion on management of these causes of strabismus in the adult population is outside the purview of this PPP. However, determining whether muscle or nerve damage is responsible and whether paresis versus restriction is the major cause is a common theme that informs the evaluation and treatment of all forms of strabismus associated with other ophthalmic surgery.[231]

DISEASE DEFINITION

Iatrogenic strabismus can occur following different procedures or treatments.

Cataract Extraction or Keratoplasty

Anesthetic myotoxicity following retrobulbar or peribulbar anesthesia for any ocular procedure including cataract extraction or keratoplasty may occur. Initial presentation is usually transient paresis followed by deviation of the eye into the field of action of the involved extraocular muscle. The hypertropia or hypotropia may result from restriction of the involved extraocular muscle when damage is extensive or as an overaction pattern due to focal contracture or muscle hypertrophy.[232-236] The superior and inferior rectus muscles are the most commonly injured by regional and local anesthesia, in retrobulbar or peribulbar blocks,[237] but any muscle, including the superior and inferior oblique muscles, may be involved as well.[238-241]

Trauma from a bridle suture under a rectus muscle, temporary disinsertion and subsequent reattachment of an extraocular muscle in the course of repairing a globe laceration, or retinal detachment may result in strabismus. Additional causes of binocular diplopia after cataract surgery and keratoplasy include previously undiagnosed TED,[242] pre-existing/unmasked binocular disorders, and fixation switch diplopia and acquired loss of central fusion. These conditions are addressed in other sections of this PPP.

Patients undergoing refractive procedures may develop diplopia as a result of fixation switch to the nondominant eye; longstanding visual deprivation causing central fusion disruption; and postoperative anisometropia, aniseikonia, and meridional aniseikonia.[243-245]

Glaucoma Filtering Surgery (Including Trabeculectomy and Aqueous Shunt Surgery)

Motility disturbances occur from a variety of causes, including mass effect from the implant or associated bleb, scarring, fat adhesion, or incorporation of adjacent extraocular muscles.[246] These complications result in a wide array of motility patterns, including Brown syndrome, partial disinsertion of the superior oblique muscle, and restriction of gaze in the direction of the adjacent muscle.[247-251]

Scleral Buckling Surgery

Following scleral buckling surgery, the root cause of the resulting strabismus may be multifactorial. Patients may develop strabismus secondary to loss of fusion, poor vision, aniseikonia, direct trauma to the muscles, myotoxicity from retrobulbar anesthesia, malposition of a detached muscle, scar tissue formation, muscle slippage or disinsertion, entanglement of the superior oblique tendon, and mass effect.[252-255] Fusional disturbance, aniseikonia, and torsional diplopia may sometimes accompany repair of retinal detachment, even without scleral buckling. These threats to binocular fusion increase the complexity of treating the mechanical aspect of strabismus induced by a buckling procedure.[256]

Pterygium Surgery

New-onset diplopia can occur after pterygium surgery as a result of direct injury to the adjacent medial rectus or florid scaring, including scarring to adjacent plica associated with recurrence.[257-260] This can result in consecutive exotropia from medial rectus damage or restrictive incomitant esotropia from scarring that may, at times, require grafting to address.[257-260] The choice of retrobulbar rather than topical anesthesia increases the risk of diplopia after surgery, as it does with cataract surgery.

Blepharoplasty and Eyelid Surgery

New-onset diplopia can occur after upper lid blepharoplasty, sometimes associated with trochlear damage,[261, 262] and after lower lid blepharoplasty, sometimes due to damage to the inferior rectus.[263] Scarring and hemorrhage in adjacent tissue or fat adherence[264] have been implicated among other mechanisms.

New-onset diplopia can occur after ptosis repair as a result of late recognition of previously existing strabismus. The classic example would be double elevator palsy with a limitation of upgaze that is recognized only after the associated ptosis is repaired.

PATIENT POPULATION

The patient population is adults who have strabismus associated with other ophthalmic surgeries that may disrupt normal extraocular muscle function, the landscape of surrounding fat, Tenon's and pulleys, or sensory fusion.

CLINICAL OBJECTIVES

- Counsel the patient on the diagnosis and treatment options
- Provide goal-directed management of strabismus (to restore binocular vision, or minimize diplopia or compensatory head posture, and, in some cases, for the reconstructive benefit of improving eye alignment, eye contact, and self-image)
- Inform the patient's other health care providers and their ophthalmic specialists of the diagnosis and treatment plan

BACKGROUND

CATARACT EXTRACTION AND KERATOPLASTY

Incidence (Anesthetic Myotoxicity)

Although the incidence varies in different practice settings, a 0.18% incidence of secondary strabismus[265] and a 0.23% incidence of secondary strabismus for cases involving retrobulbar block anesthesia that is used most often for cataract surgery has been reported.[265] The incidence is much lower, though not extinguished, when topical anesthesia is used instead. Diplopia may be transient or persistent.[265]

Risk Factors

Risk factors that increase the incidence of secondary strabismus after retrobulbar or peribulbar block are injection by a non-ophthalmologist, left-eye injection, and the absence of hyaluronidase in the block.[266, 267] Secondary strabismus is more typically associated with other factors that threaten binocular stability, such

as the choice of monovision for cataract surgery, fixation switch diplopia, acquired loss of fusion in cases of long-standing cataracts, or aphakia.[268, 269] Fixation switch diplopia occurs if a previously suppressed eye becomes the dominant eye.

GLAUCOMA FILTERING SURGERY

Incidence

Transient strabismus occurs in 4% of patients after trabeculectomy[231, 270] and in 4% to 25% of patients following aqueous shunt surgery.[231, 270, 271] Persistent motility disorders can range from 2% to 77%[270] following glaucoma plate reservoir surgery depending, in part, on the type of implant used, the length of follow-up, and whether the setting was one that afforded an adequate audit of postoperative alignment. One center reported a prevalence of binocular diplopia of 21% in patients treated with plate reservoir surgery and 3% in those treated with trabeculectomy.[246] Another center reported 4% long-term incidence of persistent diplopia following Ahmed valve implantation.[272]

Risk Factors

Advanced age is a risk factor for the development of binocular diplopia.[270] Superior placement of aqueous shunt versus inferior placement may be associated with less risk of diplopia in the reading position.[231, 270]

SCLERAL BUCKLING SURGERY

Incidence

Ocular motility disturbance is reported after retinal detachment repaired by scleral buckle.[273] The strabismus may be transient and often resolves within 6 months. In a single-center study of 1,030 patients treated with a scleral buckling procedure, only 3.8% had persistent strabismus requiring intervention.[274, 275]

Risk Factors

The risk of strabismus after placement of a radial scleral buckle is substantially less than after placement of an encircling band.[275, 276]

BLEPHAROPLASTY AND EYELID SURGERY

Incidence

The incidence of strabismus is very low; it is estimated at under 3% (three cases in 920 procedures) and is much lower in association with other eyelid procedures.[277]

Risk Factors

Excessive cautery, hemorrhage, and misdirected dissection likely cause strabismus.

NATURAL HISTORY

As noted above, diplopia may be transient following other ocular surgeries, but if it has not resolved or demonstrated improvement within 6 months of the procedure, diplopia is less likely to resolve on its own.

RATIONALE FOR TREATMENT

Diplopia, loss of binocular vision, compensatory head position, and inability to make eye contact with poor eye alignment all warrant treatment.

CARE PROCESS

PATIENT OUTCOME CRITERIA

- Reduction of diplopia

- Improvement in or return of binocular vision
- Reduction of compensatory head position
- Restoration of ocular alignment, improved eye contact, and self-esteem

DIAGNOSIS

History

A detailed medical and ocular history, including specific questions about particular surgical procedures, anesthetic used, and onset of patient symptoms should be obtained.

Examination

A detailed sensorimotor evaluation, assessment of refractive status, and dilated fundus examination should be performed to assess the oculomotor status, including possible ocular torsion impacting fusion. In-office forced ductions, if tolerated, may help determine the significance of the restrictive component. If this is not possible, the impact of mechanical restriction can be determined at the time of surgery.

Strabismus following retrobulbar or peribulbar block is characterized by an initial paresis with underaction of the affected muscle followed by segmental contracture of the affected muscle. The most commonly affected muscle is the inferior rectus muscle (70%).[232] Strabismus following glaucoma plate reservoir surgery usually presents within 3 months of glaucoma implant placement, often within the first month.[251, 271] Superotemporal implants more frequently cause hypertropia and exotropia, and restriction or scarring may create a pseudoresection effect on adjacent muscles.[251, 278] Superonasal implants more frequently cause hypotropia.[248, 250, 251, 271] In patients who present with ocular deviation away from the implant, the mechanical bulk of the implant (e.g., in the superior nasal quadrant) may be responsible.[163, 247, 250, 251]

In patients who have had scleral buckling surgery, strabismus is usually incomitant and restrictive with limitation to ocular rotations. Approximately 50% of the patients with diplopia have a torsional component, usually excyclotropia.[252] Evaluation on the synoptophore is helpful, using fusible targets with square contours, to determine how much torsional correction is needed to restore single vision. Alternatively, Lancaster red-green testing can provide valuable torsional information.

Strabismus may be transient after blepharoplasty or other eyelid surgery. Many cases improve after 8 to 15 months if it is the result of local injury or hemorrhage without permanent loss of function or significant scarring.[277] As diplopia is often incomitant, prism correction is rarely satisfactory in the long run, surgery may be indicated, particularly when diplopia is in primary or reading position.

MANAGEMENT

Monitor/Observe

The patient should be monitored/observed if symptoms are mild, occasional, and not bothering the patient or if the patient is opposed to treatment. If the potential compromise to optic nerve function with removal of the reservoir is too great for patients with a glaucoma plate reservoir, other options such as prism correction, fogging, complete occlusion, and contralateral eye surgery may need to be considered. Close communication with the physician treating the patient's glaucoma often clarifies a course of action that facilitates surgical treatment of the secondary strabismus, along with a method of controlling IOP.

Nonsurgical

Transient strabismus is common, so early treatment with prisms may be offered. Prisms may also be helpful for residual diplopia following strabismus surgery.

Surgical

For patients with persistent strabismus, prisms and surgery are recommended. Patients may require multiple surgeries, including surgery in the non-affected eye. In general, surgery of the affected eye is indicated in patients who have limited ocular rotations in the affected eye. Surgery on the non-affected eye may be considered when, for example, surgery designed to match restrictions seems preferable, or when there is

minimal mechanical strabismus and surgery on the contralateral eye is preferable to reduce the risk of destabilizing the achieved outcome for the involved eye.[251]

For patients with aqueous shunt surgery, if the potential compromise to optic nerve function with removal of the reservoir is too great, other options such as prism correction or occlusion may need to be considered. Close communication with the glaucoma specialist treating the patient's glaucoma clarifies a course of action that facilitates surgical treatment of the secondary strabismus, along with a method of controlling IOP. When operating near a glaucoma implant, the surgeon should be prepared to manage hypotony and the added risk of intraocular infection if an intraocular breach occurs. It is important to consider whether alignment can be sufficiently improved by a procedure that avoids violating the area adjacent to a glaucoma acqueous shunt, as this reduces the risk of hypotony, secondary intraocular infection, and disruption of glaucoma management.

Generally, careful evaluation with forced ductions at the time of surgery will clarify the mechanism of the induced strabismus. High-resolution MR imaging may provide additional insight into the multiple causes of misalignment and thus inform management.[279]

In patients with a scleral buckle, factors associated with better surgical outcomes include small preoperative deviation and minimally restricted ocular rotations. In patients with ocular torsion, exploration of the superior oblique tendon and the inferior rectus muscles should be considered.[252] The benefits of removing a scleral buckle are controversial and removal, if done, is best delayed for a minimum of 6 months after initial placement. Some surgeons believe it is almost never necessary to remove the buckle and they will recess, resect, and transpose muscles and tendons over, under, and around the hardware, whereas other surgeons prefer to remove the buckle at the time of strabismus surgery.[280] [281] The risk of retinal redetachment is about 8% after scleral buckle removal.[282] Preoperative discussion with the specialist who placed the periocular hardware, or another colleague in this subspecialty, should address the risks associated with displacement of this hardware. Some procedures might benefit from having both surgeons present and scrubbed for the strabismus repair.[275]

Chemodenervation (botulinum toxin) of the antagonist muscle has proven successful in some cases.[283] Regardless of the etiology, a careful sensorimotor evaluation with attention to torsional strabismus and incomitance and forced ductions can help with planning. Surgical exploration may be necessary to determine the best approach to repair the strabismus.

PROVIDER AND SETTING

Diagnosis and management of strabismus occurring after other ocular surgery require the training and clinical judgment of an experienced ophthalmologist. Communication, as possible, should be established with the surgeon who is performing the original surgical procedure that is associated with the development or exacerbation of strabismus. Working under the supervision of an ophthalmologist, orthoptists can be an asset in the examination, diagnosis, and nonsurgical management. Optometrists and opticians may add additional support in the management of aniseikonia, or contact lens fitting, as appropriate.

COUNSELING AND REFERRAL

The ophthalmologist should discuss the findings, explain the disorder, provide diagnosis, and discuss management options with the patient, the referring ophthalmic surgeon, and any caregivers. When surgical treatment of the strabismus is considered, consultation with the specialist who performed the initial surgery, or another ophthalmologist with expertise in the relevant subspecialty is recommended. This should include a discussion of the potential impact of removing or disrupting implanted hardware. Review of the surgical record from the index case can provide additional information on the approach to the surgical field.

SECTION IIH. SUPERIOR OBLIQUE PALSY

INTRODUCTION

DISEASE DEFINITION

Superior oblique palsy is due to partial or complete paralysis of the 4th cranial nerve (trochlear nerve), resulting in weakness of the superior oblique muscle. The motility disturbance creates a combination of vertical, torsional, and, to a lesser degree, a horizontal incomitant strabismus pattern. Both congenital and acquired forms exist, with the presumed congenital type often presenting for the first time in adulthood.[284]

Patients will show hypertropia of the involved eye, often accompanied by a compensatory head tilt away from the affected eye. Complaints include diplopia, asthenopia, and/or anomalous head posture. Patients with decompensated congenital SOP may have facial asymmetry, demonstrating a shorter maxilla on the opposite the side of the SOP (and thus reduced distance between the corner of the mouth and lateral canthus).[285] It is becoming increasingly recognized that not all chronic vertical deviations, consistent with the pattern of a SOP, have decreased size of the superior oblique muscle belly on neuroimaging and sometimes only compartmental atrophy is present. These vertical deviations might best be referred to as presumed SOP[284] or masquerading SOP.[286] There are also non-inflammatory post-inflammatory presentations of TED where the predominant pathology is unilateral or bilaterally asymmetric inferior rectus enlargement and present with a three-step test mimicking SOP.[140] Nevertheless, the treatment approach is often the same as when addressing confirmed SOP, customizing the treatment plan to address the vertical, torsional, and possibly horizontal components of the deviation.

Head trauma (including concussion) is one of the most common identifiable causes of both unilateral and bilateral acquired SOP, although in extremely rare cases isolated trochlear schwannomas and giant cell arteritis can result in acquired SOP.[287-289, 284]

Skew deviation has a motility pattern that can resemble the misalignment seen with SOP. Distinguishing characteristics, particularly related to fundus torsion, symptoms of ocular tilt and, at times, the impact of upright versus supine positioning of the patient are described at length in Section III. Skew Deviation.[290] Distinction is important because skew deviation is more frequently associated with less benign etiology and more often warrants neuroimaging.

PATIENT POPULATION

The patient population includes adults with strabismus associated with congenital or acquired SOP.

CLINICAL OBJECTIVES

- Determine if SOP is congenital or acquired, unilateral or bilateral, or whether it might be a masquerading SOP.[286]
- Counsel the patient on the diagnosis and treatment options.
- Provide goal-directed management of strabismus (reconstructive to enhance binocular vision and reduce diplopia or a compensatory head posture). This includes addressing the individual barriers to fusion and comfortable binocular single vision, including incomitance of the vertical deviation, to assess whether torsion is a barrier to fusion and, if so, addressing that torsion and incomitance of any horizontal deviation.
- Inform the patient's other health care providers of the diagnosis and treatment plan.

BACKGROUND

INCIDENCE

Superior oblique muscle palsy is one of the common types of vertical strabismus seen in adults. Annual incidence has been reported to be 6.3 cases per 100,000 people, with a higher incidence among males than females.[75]

RISK FACTORS

Risk factors include head trauma and increasing age (in age-related decompensation of congenital weakness).

NATURAL HISTORY

Patients may experience no diplopia or intermittent diplopia in cases of long-standing and presumed congenital SOP. A long-standing and effective compensatory head position minimizes diplopia awareness by avoiding the field of action of the weak superior oblique muscle. Based on the symptomatic presentation of some cases of presumed congenital SOP in later decades of life,[284] the natural history of presumed congenital SOP is deterioration in some cases.

RATIONALE FOR TREATMENT

Diplopia, compensatory head position sometimes associated with neck pain, and asthenopia warrant treatment.

CARE PROCESS

PATIENT OUTCOME CRITERIA

Treatment in adult strabismus is symptom directed, and targeted outcomes may include the following:

- Restoration of ocular alignment, particularly in straight ahead and downgaze
- Improved binocular vision
- Improved control of diplopia, especially in straight ahead gaze, downgaze, and side gaze
- Reduction in compensatory head position

DIAGNOSIS

History

A detailed medical and ocular history, including specific questions about prior head trauma, diplopia, and compensatory head posture is important. Sometimes a review of prior photos demonstrates a pattern of long-standing and potentially worsening compensatory head posture.

Examination

A sensorimotor evaluation with special attention to measuring torsion and also to measuring the magnitude of misalignment in nine gaze positions to determine the position of gaze with the greatest deviation informs the customized surgical plan. The Parks-Bielschowsky three-step test is often used to confirm the diagnosis. Hypertropia is greatest in lateral gaze to the opposite side and head tilt to the same side. The three-step test may appear to confirm SOP where neuroimaging of the muscle belly fails to confirm involvement; these cases may be referred to as presumed SOP or masquerading SOP,[286] but the surgical approach is the same as when addressing confirmed SOP and the associated vertical, torsional and horizontal deviations. Quantifying the magnitude and direction of torsion enhances surgical planning. Because the superior oblique intorts, extorsion is commonly found and may be quantified using Double Maddox Rods or Lancaster red-green testing, and by noting fundus torsion. Nevertheless, evaluation of

fundus torsion by indirect ophthalmoscopy or with fundus photography (e.g., measuring the disc fovea angle) is less useful because normal values have a wide range, and therefore it is almost always impossible to assess the change from a previous undocumented state to the current state.[291] Also, subjective torsion is often less than objective torsion in cases of long-standing SOP. Assessment of torsion does not require, but is enhanced by, evaluation on a synoptophore using fusible targets with square edges (e.g., the house). That assessment will determine whether torsion is a barrier to fusion and the amount of torsion that needs to be corrected.[291]

Determination of refractive error should be included in the examination. It remains controversial whether a neurological evaluation and neuroimaging are warranted, but they are rarely indicated in cases of isolated unilateral SOP or bilateral cases in which trauma is the known cause. Acquired symptomatic diplopia with poor fusional amplitudes may be an indication for brain and/or orbital MR imaging with contrast, because that presentation may herald a trochlear schwannoma. Neuroimaging should always be performed if there are additional central nervous system signs or symptoms.[292] Occult TED can present as new-onset vertical diplopia with a positive three-step test that resembles SOP.[140] The ophthalmologist should also be aware that acute-onset SOP may be caused by giant cell arteritis.

Intraoperative exaggerated forced ductions often reveal a lax superior oblique tendon in many patients with presumed congenital SOP.[293] Quantitative intraoperative torsion forced ductions are also useful in quantifying lax or tight oblique muscles.[294] Vertical rectus forced ductions performed in office or at the time of surgery may reveal evidence of an ipsilateral limitation of downgaze due to superior rectus contracture or contralateral restriction of elevation resulting from inferior rectus contracture, which many consider important to address in any surgical plan.

MANAGEMENT

Monitor/Observe

The patient should be monitored/observed if symptoms are mild, occasional, and not bothering the patient or if the patient is opposed to treatment.

Nonsurgical

Small vertical deviations may be managed with prism glasses, although lateral incomitance of the vertical deviation, if present, often precludes successful implementation.

Surgical

Torsional surgery will be needed if torsion is a barrier to fusion (typically in bilateral cases or severe unilateral cases due to trauma or cases associated with neurosurgery). Larger and incomitant deviations most often require surgical intervention. Some patients with smaller deviations may consider surgical repair or prism correction. The goal of surgery is to improve the vertical and torsional deviation, improve the head posture, and improve the area (field) of single binocular vision. A variety of surgical choices exist, and the decision for which muscle(s) to operate on depends on the magnitude of deviation in primary gaze, the degree of torsion, and the field of gaze with greatest deviation. The most common procedures used include the following (in combination or alone):

- Inferior oblique weakening by recession or myectomy (ipsilateral)
- Inferior rectus weakening (contralateral)[295]
- Superior oblique strengthening (ipsilateral), for example, tuck (recommended for lax tendons in presumed congenital SOP[293]), advancement for vertical and torsional deviations,[296] or a version of the Harada-Ito procedure, advancing only the anterior superior oblique fibers that affect torsion (ipsilateral).[297, 298] The Harada-Ito can be performed bilaterally for higher degrees of torsion without altering vertical alignment.
- Superior rectus weakening (ipsilateral)[299]

In patients with a small vertical deviation (1–6 PD), vertical rectus pole recessions rather than full tendon recessions may be preferable, because they theoretically minimize the risk of overcorrections, which are very poorly tolerated in this patient population.[300, 301]

Many of the above procedures may be performed using adjustable suture techniques; the target angle should be a small undercorrection because overcorrection, particularly in downgaze, is poorly tolerated. Note that if an inferior oblique weakening procedure has previously been performed, months to years later some patients will develop significant limitation of infracduction in adduction because of progressive tightening of the previously weakened inferior oblique muscle. This has been described as an inverted Brown pattern because the pattern of deviation, especially on a Lancaster red-green plot, looks like an upside-down Brown syndrome. This is best managed by a denervation/extirpation of the inferior oblique muscle.[302]

PROVIDER AND SETTING

Management of SOP, specifically surgery, requires the training and clinical judgment of an experienced ophthalmologist and in some cases a neuro-ophthalmologist.[295] Working under the supervision of an ophthalmologist, orthoptists can be an asset in the examination, diagnosis, and nonsurgical management of SOP.

COUNSELING AND REFERRAL

If the SOP is not isolated or is associated with other neurological signs and symptoms, neuroimaging and referral to a neurologist or neuro-ophthalmologist should be considered. Small vertical fusional amplitudes in a case of isolated SOP, absent a history of trauma, may indicate an acquired cause and should be evaluated with neuroimaging. The ophthalmologist should discuss the findings, explain the disorder, provide diagnosis, and discuss management options with the patient and, as appropriate, with a neuro-ophthalmologist, neurologist, or other specialist, as indicated.

SECTION III. SKEW DEVIATION

INTRODUCTION

DISEASE DEFINITION

Skew deviation is a vertical strabismus associated with disorders of the end-organ vestibular pathways within the ear (such as acute vestibular neuronitis) or associated supranuclear utriculo-ocular pathways within the posterior fossa, including both the brainstem and cerebellum.[303-307] The characteristic vertical strabismus may be comitant or incomitant and results in vertical diplopia associated with ocular torsion, torticollis, and a tilt of the vertical visual field referred to as the ocular tilt reaction.[290, 308] The ocular tilt reaction produces a head tilt towards the shoulder of the hypotropic eye and both eyes rotate in the direction of the head tilt. If the patient experiences tilt of the vertical visual field, it will be in the same direction as the head tilt.[309] With skew deviation, the hypertropic eye will demonstrate fundus incyclotorsion and the hypotropic eye will demonstrate fundus excyclotorsion.[309] This characteristic helps to distinguish it from 4th nerve palsy, where the hypertropic eye is most typically excyclotorted (in the absence of skew deviation, head tilt results in a compensatory fundus rotation opposite the direction of the head tilt, also called ocular counter roll). Ocular torsion in skew may be conjugate or dysconjugate.[310]

It is critical to distinguish skew deviation from 4th cranial nerve palsy because causes of skew deviation (e.g., acute vestibular neuronitis, demyelination, or stroke) demand immediate recognition and sometimes treatment and urgent imaging of the brain and brainstem (MR imaging with and without contrast seeking evidence of demyelination, stroke, or mass lesion) may be needed. Most cases of isolated 4th nerve palsy (discussed in detail in Section IIH. Superior Oblique Palsy) are more benign in etiology. Because vertical misalignment in SOP may become comitant over time and skew may be comitant or incomitant, and because both characteristically demonstrate head tilt away from the hypertropic side, the classic three-step test may not distinguish between the two. The upright-supine test (a fourth step for the three-step test) has demonstrated a reduction in the hypertropia by more than 50% when measured in the supine position for patients with skew deviation (sensitivity, 80%; specificity, 100%), thus would not be positive in the presence of SOP. Subsequent to introduction of the upright-supine test, other investigators demonstrated that this distinctive decrease in hypertropia was not reliably found in patients with acute-onset skew deviation.[311] These authors concluded that the upright-supine test was not a reliable method to distinguish acute skew deviation (onset within 2 months) from SOP, although this test might prove useful in the setting of more long-standing skew deviation.

PATIENT POPULATION

The patient population consists of adults with acute peripheral vestibulopathy (vestibular neuronitis), or demyelination, ischemia, or mass lesions affecting the vestibular supranuclear pathways within the region of the brainstem and cerebellum.

CLINICAL OBJECTIVES

- Recognize skew deviation and institute appropriate ancillary testing and referral to colleagues with expertise in otolaryngology or neurology as indicated for further evaluation and management

BACKGROUND

PREVALENCE

The prevalence of skew deviation is unknown because it is associated with a variety of etiologies.

RISK FACTORS

Because there are multiple disparate causes, risk factors vary for skew deviation. Vestibular neuronitis can occur at any age. Demyelinating disease affects females more than males and both demyelination and trauma are more common in younger adults. Cardiovascular risk factors associated with stroke, such as a history of hypertension, diabetes, hyperlipidemia, and smoking, have a greater impact in the aging population.

NATURAL HISTORY

Vestibular neuronitis may be self-limiting and may respond to medical intervention, and transient ischemia in the posterior fossa may, likewise, cause a transient skew deviation that resolves over time.[290] More profound ischemic damage or mass lesions often result in long-lasting symptoms of skew deviation.

RATIONALE FOR TREATMENT

Control of disabling diplopia and perceived tilt of the subjective visual vertical warrant treatment.

CARE PROCESS

PATIENT OUTCOME CRITERIA

Treatment of skew deviation in adult strabismus is symptom directed, and targeted outcomes may include the following:

- Improved binocular vision
- Improved control of diplopia
- Reduced tilt of the subjective visual vertical

DIAGNOSIS

History

Skew deviation is almost always acute to subacute in onset. However, if the etiology is demyelination or a slow-growing tumor, onset may be more insidious. Skew associated with acute end-organ vestibular neuronitis will likely be associated with severe vertigo, dizziness, nausea, and vomiting, whereas skew in association with brainstem or cerebellar demyelination, stroke, or a mass lesion will demonstrate associated neurologic features (e.g., nystagmus, internuclear ophthalmoplegia (INO), hemiparesis, sensory loss, ataxia, and Horner's syndrome) depending on the locus of the pathology and may be acute to subacute in onset.

A history of neurological symptoms (motor or sensory changes, ataxia, headache) or symptoms of vertigo and nausea, in addition to the classic vertical diplopia and head tilt, may help guide additional evaluation. Vertical diplopia and commonly torticollis and subjective tilting of the perceived visual world are characteristic.[290, 308]

Examination

The examination should include the following elements:

- Complete ophthalmic examination with emphasis on the sensorimotor evaluation, complete three-step test, and consideration of the additional upright-supine test
- A careful check for other neuro-ophthalmic signs and symptoms looking for Horner's syndrome, cranial nerve palsy, INO, nystagmus, and hearing loss
- Fundus examination to check for papilledema or optic atrophy
- Visual field testing, which may provide additional information on the etiology
- Abnormalities in the rostral pons and midbrain (e.g., INO), which will result in contralateral hypotropia and head tilt, whereas abnormalities in the vestibular periphery, medulla, and more caudal pons will result in ipsilateral hypotropia and head tilt[309]

MANAGEMENT

The primary diagnostician should refer the patient for evaluation by indicated neurology or otolaryngology specialists. Initial treatment with prisms may be helpful to manage diplopia while waiting for possible recovery, and botulinum toxin, prism, or strabismus surgery may be considered for cases that do not resolve. The goals of surgery should be customized for the individual patient, who may be bothered to different degrees by diplopia, head tilt, and perceived tilting of the visual vertical. These interventions may help reduce both vertical and torsional diplopia, they may reduce the perceived tilting of the visual field, and in select cases they may prove successful at resolving head tilt.[312-314]

PROVIDER AND SETTING

Diagnosis and management of skew deviation require the training and clinical judgment of an experienced ophthalmologist and in some cases a neuro-ophthalmologist. Working under the supervision of an ophthalmologist, orthoptists can be an asset in the examination, diagnosis, and nonsurgical management of skew deviation.

COUNSELING AND REFERRAL

Referral to specialists in neurology, otolaryngology, or neuro-otology may be indicated based on the likely cause of the skew deviation.

SECTION IIJ. ABDUCENS PALSY

INTRODUCTION

DISEASE DEFINITION

Abducens palsy is also known as 6th nerve palsy. It typically presents with an acute onset of horizontal double vision, worse at distance than at near and worse laterally toward the side of the affected nerve. Most often the double vision is noticed by the patients in primary position, but with partial paralysis, it may only be noted on lateral gaze. Some patients present with a head turn to compensate for the diplopia caused by the paralysis. The incomitant horizontal misalignment can result in disabling diplopia at onset.[315] Symptoms may be less bothersome, or even subtle, if the palsy is partial, gradual, and chronic, permitting the development of horizontal fusional amplitudes. The diplopia may become more apparent with exhaustion or systemic illness, or in extreme horizontal gaze.

The majority of acute 6th nerve palsies in the adult population are vasculopathic, associated with risk factors such as diabetes and hypertension.[316] The onset of double vision is acute, may be accompanied by pain, and does not have any associated neurologic or ocular findings. Most palsies resolve after 6 months, and about one-third resolve within 8 weeks. If no recovery is apparent by 6 months, approximately 40% of patients demonstrate a serious underlying pathology warranting further evaluation.[317] The elderly who present with symptoms of scalp or temporal region tenderness, or pain with chewing (jaw claudication) may have giant cell arteritis, a more serious vasculopathic disorder that can result in permanent visual loss if not promptly diagnosed and treated.

Other common causes of 6th nerve palsy are trauma and neoplasm. Traumatic etiology is usually self-evident and may include a history of head injury, typically involving a basilar skull fracture, or an acute rise in intracranial pressure from an intracranial bleed.[318, 319]

A 6th nerve palsy caused by an intracranial neoplasm may be either insidious or acute. Neurologic changes may include other motor deficits, depending on the topographic location detailed below. Evaluation for facial and extremity motor weakness, 3rd and 4th cranial nerve involvement, visual field defect, and central acuity loss from optic nerve involvement, IOP, and proptosis all help in localization. Bilateral 6th nerve involvement can be seen in the clival chordoma as well as increased intracranial pressure or a meningeal process.[318, 320] A 6th nerve palsy can be associated with demyelinating diseases such as multiple sclerosis. Because lesions typically involve the pons, other neurologic findings are present, most notably a facial palsy, because the 7th nerve curves over the 6th nerve nucleus. However, isolated cranial nerve VI palsy is the most common in adults. Postviral 6th nerve palsy can occur, but it is typically a diagnosis of exclusion.[321] It has been described with COVID-19 infection and post COVID-19 vaccination.[322, 323]

PATIENT POPULATION

The patient population is adults with strabismus caused by 6th nerve palsy.

CLINICAL OBJECTIVES

- Determine the etiology of the 6th nerve palsy
- Counsel the patient on the diagnosis and treatment options
- Provide goal-directed management of strabismus (typically to reduce symptoms of diplopia or secondary compensatory head posture diplopia)
- Inform the patient's other health care providers of the diagnosis and treatment plan

BACKGROUND

INCIDENCE

The annual incidence of new-onset 6th nerve palsy is approximately 11 per 100,000.[316]

RISK FACTORS

Risk factors relate to etiology but, as vascular etiology is the most common, both hypertension and diabetes increase the risk.

RATIONALE FOR TREATMENT

Diplopia, loss of binocular vision, compensatory head position, and inability to make eye contact all warrant treatment.

CARE PROCESS

PATIENT OUTCOME CRITERIA

Treatment in adult strabismus is symptom directed, and targeted outcomes may include the following:

- Reduction of diplopia
- Resolution of torticollis
- Restoration of ocular alignment (reconstructive)
- Improvement of binocular vision

DIAGNOSIS

Understanding the path of the 6th nerve aids localization of the lesion as well as the cause.[324] The 6th nerve originates in the abducens nucleus of the pons. Thus, lesions involving the 6th nerve nucleus often are accompanied by an ipsilateral facial paralysis or a complete horizontal gaze deficit. Within the pons, it courses through the corticospinal tracts, and thus, lesions involving the 6th in this region can lead to a contralateral hemiparesis. The nerve then ascends in the subarachnoid space and passes underneath the petroclinoid ligament to enter into the cavernous sinus. Tethering of the nerve along this pathway make it susceptible to stretching from increased intracranial pressure, cerebrospinal fluid inflammation, infection, infiltration, or compression from clival tumors.

In the cavernous sinus, the 6th nerve is in proximity to the intracavernous carotid artery; ocular sympathetics; and cranial nerves III, IV, and the first division of the trigeminal nerve. Thus, carotid artery aneurysms, inflammatory cavernous sinus processes, or other structural lesions may include a concomitant Horner's syndrome, 3rd nerve palsies and 4th nerve palsies, or facial pain.[325] The 6th nerve then passes through the superior orbital fissure into the orbit.[326] Orbital infections, mass lesions, or inflammation can affect the 6th nerve as well as the lateral rectus muscle itself. Associated proptosis and optic neuropathy may be present. Venous congestion from either an orbital process or back pressure from cavernous sinus lesions can cause chemosis with increased IOP.

History

A detailed medical history should include information and medical records on prior ocular surgery, a history of diabetes or hypertension, and complaints of specific additional symptoms, including facial weakness, motor weakness, headache, fever, proptosis, vision loss, scalp pain or jaw claudication that might reflect the anatomical locus and cause of 6th nerve pathology.

Examination

The examination should include the following elements:

- Complete ophthalmic evaluation with emphasis on best-corrected acuity, a check for afferent defect, and color acuity to screen for orbital and cavernous sinus pathology
- Sensorimotor examination demonstrating incomitant esotropia, typically greater at distance, and possibly associated with abduction nystagmus
- Fundus examination to look for papilledema or optic atrophy as indicators of elevated intracranial pressure

Ancillary Testing

Neuroimaging should be considered in all young patients or in any patient manifesting other cranial neuropathies, other neurologic change or elevated IOP, or if there are no compelling vasculopathic risk factors. Study should seek possible evidence of neoplasm, demyelination, stroke, vascular abnormality, or signs of infectious or inflammatory etiology. Referral to a neuro-ophthalmologist or neurologist for further evaluation may be indicated in some cases.

In an elderly patient with hypertension, hyperlipidemia, or diabetes, and without temporal tenderness, jaw claudication, or scalp pain, evaluation may be limited to determining blood pressure, serum glucose level, and hemoglobin A1c. Follow-up is necessary to determine if the palsy spontaneously resolves. In the absence of resolution or improvement, MR imaging of the brain with and without contrast may be indicated. In the elderly with a history of scalp tenderness, jaw claudication, or pain, the erythrocyte sedimentation rate and C-reactive protein should be checked immediately and a temporal artery biopsy performed if the results indicate possible giant cell arteritis. Consultation with a neuro-ophthalmologist may facilitate a biopsy and initiation of treatment.

Evidence of increased intracranial pressure with papilledema, bilateral 6th nerve palsy, or meningeal signs (stiff neck with headache) suggests a need for lumbar puncture following neuroimaging to measure intracranial pressure and look for meningitis (infectious, inflammatory, or carcinomatous) or demyelination. Systemic serology in this instance should include Lyme and syphilis testing.[327]

MANAGEMENT

A detailed treatment of the 6th nerve palsy is initially directed to the primary cause. Neuroimaging should be considered in all young patients or in any patient manifesting other cranial neuropathies, other neurologic change or elevated IOP, or signs of elevated intracranial pressure, or if there is no compelling vasculopathic risk factor. In the aging population with vasculopathic risk factors, a lack of improvement in 4 to 6 weeks suggests a need for neuroimaging. At onset, a history of scalp tenderness, jaw claudication, or pain should prompt evaluation for possible giant cell arteritis. From the ocular motility standpoint, symptomatic intervention is to reduce diplopia and torticollis and to restore binocular vision.

Monitor/Observe

The patient should be monitored/observed if symptoms are mild or if the patient is opposed to treatment.

Nonsurgical

Nonsurgical treatment for abducens palsy can include occlusion (with a patch over one eye or with a Bangerter filter or satin tape applied to a lens of the glasses) unless a comfortable region of single binocular vision is achieved with minimal compensatory head posture. Prisms can also be used temporarily, and if the deviation remains stable and fusion can be achieved, a ground-in base-out prism can be incorporated into the lenses.[328] Chemodenervation (botulinum toxin) of the medial rectus muscle may help reduce secondary contracture and the severity of compensatory head position and magnitude of the final deviation.[329-331]

Surgical

Strabismus surgical management is generally offered when the deviation persists after 6 months from onset. A small residual deviation with some residual abducting force of the lateral rectus past the midline usually responds well to a medial rectus recession and lateral rectus resection. Other options include a contralateral medial rectus recession, with or without posterior fixation, with or without ipsilateral lateral rectus

resection, to balance ductions. Larger deviations with no abducting force of the lateral rectus (confirmed by force generation testing) usually necessitate some form of transposition procedure of the vertical recti laterally (often combined with medial rectus weakening by recession or injection of botulinum toxin) either initially or subsequently.

Many techniques for vertical rectus transposition have been described, including full-tendon or partial-tendon transfer, of one or both vertical rectus muscles, with or without an augmentation suture.[321, 332-336] Partial tendon transfer, or loop myopexy, may decrease the incidence of anterior segment ischemia, since three extraocular muscles are not operated on at the same time.[335, 337] Superior rectus muscle transposition alone with simultaneous medial rectus recession has similar advantages. When performing transposition of both vertical rectus muscles, staging the procedure by performing transpositions followed months later by medial rectus recession also decreases the risk of anterior segment ischemia.[338] Transposition without muscle splitting or tenotomy may be less invasive, lowering risk of anterior segment ischemia.

PROVIDER AND SETTING

Diagnosis and management of 6th nerve palsy require the training and clinical judgment of an experienced ophthalmologist. Working under the supervision of an ophthalmologist, orthoptists can be an asset in the examination, diagnosis, and nonsurgical management of 6th nerve palsy.

COUNSELING AND REFERRAL

Neuroimaging should be considered in all young patients or in any patient manifesting other cranial neuropathies, other neurologic change or elevated IOP, or signs of elevated intracranial pressure, or if there are no compelling vasculopathic risk factors. In the aging population with risk factors, lack of resolution over time suggests a need for neuroimaging. If the primary diagnosis is uncertain, referral should also be considered to those providers who have expertise in neuro-ophthalmology and adult strabismus for directed treatment. The ophthalmologist should discuss the findings, explain the disorder, provide diagnosis, and discuss management options with the patient and, as appropriate, with a neuro-ophthalmologist or other subspecialist, as indicated. Despite the number of strabismus surgical options for repair, patients should be advised that the goal of treatment is to eliminate diplopia in the primary position and to create a reasonable field of single binocular vision. Patients will most likely continue to have diplopia in extreme lateral gaze because of the difficulty in balancing ductions given the underlying neurological deficit.

SECTION IIK. OCULOMOTOR PALSY

INTRODUCTION

DISEASE DEFINITION

Oculomotor palsy is also known as a 3rd nerve palsy and is the second most common cranial neuropathy.[339] Patients usually present with diplopia secondary to misalignment that has both a horizontal and vertical component, and sometimes with difficulty reading secondary to accommodative deficiency. Because the eyelid can be partially or completely ptotic, the subjective complaint of diplopia may be lessened because the pupil may be occluded.

The presentation is an incomitant deviation. In addition to ptosis from levator dysfunction, paresis of the superior rectus, inferior oblique, medial rectus, and the inferior rectus muscles typically leaves the eye abducted infraducted, and incyclotorted as a result of preserved lateral rectus muscle and superior oblique muscle function. Variants of misalignment may be present, particularly if the location of the inciting pathology is intracavernous or intraorbital, since the nerve has already divided into an upper and lower division. The pupil may or may not be involved, and it is important to note this characteristic because it helps direct the evaluation. Aberrant re-innervation is more common with prior trauma or a compressive lesion, but can be present in association with other etiologies.

PATIENT POPULATION

The patient population is adults with strabismus caused by oculomotor palsy.

CLINICAL OBJECTIVES

- Determine the etiology of the 3rd nerve palsy
- Counsel the patient on the diagnosis and treatment options
- Provide goal-directed management of strabismus (reconstruction, binocular vision, or reduction of diplopia)
- Inform the patient's other health care providers of the diagnosis and treatment plan

BACKGROUND

INCIDENCE

The annual incidence of acquired 3rd nerve palsy is approximately 4 per 100,000.[340]

RISK FACTORS

Patients with hyperlipidemia, hypertension, and diabetes are at greater risk of vasculopathic 3rd nerve palsy.[340, 341] Elderly patients with symptoms of scalp or temporal tenderness or jaw claudication are at risk for 3rd nerve palsy due to giant cell arteritis.

RATIONALE FOR TREATMENT

Diplopia, loss of binocular vision, compensatory head position, and reconstruction of alignment all warrant treatment consideration.

CARE PROCESS

PATIENT OUTCOME CRITERIA

Treatment in adult strabismus is symptom directed, and targeted outcomes may include the following:

- Reconstruction of ocular alignment with improved eye contact and self-image
- Improvement of binocular vision
- Reduction of diplopia
- Reduction of torticollis

DIAGNOSIS

The 3rd nerve follows a course from its origin in the midbrain to the orbit.[342] The 3rd nerve nucleus lies near the midline of the midbrain. It comprises four paired subnuclei and one unpaired subnucleus. The unpaired central caudal nucleus innervates both ipsilateral and contralateral elevator palpebral muscles. If complete 3rd nerve palsy is accompanied by contralateral superior rectus weakness, the lesion is nuclear.

Localization of the lesion by associated findings and symptoms is important in determining further workup, establishing an etiology, and directing treatment. Lesions involving the superior cerebellar peduncle cause ipsilateral cerebellar ataxia,[343] lesions involving the red nucleus cause ipsilateral flapping hand tremor and ataxia,[344] and lesions involving the cerebral peduncle cause ipsilateral hemiplegia or hemiparesis.

Within the subarachnoid space, the 3rd nerve passes close to the tentorial edge and lateral to the posterior communicating artery. Aneurysms in this location cause a pupil-involving 3rd nerve palsy, although the pupil may appear normal at presentation.[287, 345] The nerve passes along the tentorial edge and adjacent to the most medial aspect of the temporal lobe (the uncus). Mass lesions or intracranial bleeding can force the uncus through the tentorial notch, causing compression.[346]

The nerve then enters the cavernous sinus, and pathology there may be accompanied by 6th nerve and 4th nerve paralysis.[347] Within the cavernous sinus, the 3rd nerve separates into superior and inferior divisions. Both enter into the orbit through the superior orbital fissure. The superior division innervates the superior rectus and the levator muscles. The inferior division sends parasympathetic fibers into the ciliary ganglion, the pupillary sphincter, intrinsic muscles controlling accommodation, the inferior oblique, the medial rectus, and inferior rectus. Divisional palsy typically localizes the lesion to the orbit. If the lesion involves the orbital apex or orbit, there may be associated optic neuropathy and proptosis.

History

A detailed medical and ocular history should include specific questions about patient symptoms, speed of onset of the strabismus, and possible associated unilateral or bilateral ptosis or other neurologic symptoms (such as ataxia, tremor, hemiplegia, 6th nerve or 4th nerve palsy, and noted pupillary asymmetry and vision loss).

Examination

A comprehensive eye examination should be performed paying particular attention to the sensorimotor examination, evidence of ptosis and anisocoria, and pupillary responses in bright and dim illumination. It should also include a fundus examination to evaluate for the presence of papilledema or optic atrophy. Evaluation of the 3rd nerve palsy depends on the presumed location of the lesion and is based on other accompanying neurologic findings. Isolated 3rd nerve palsy, however, is what most clinicians encounter. The important characteristics are whether the pupil is involved and the extent of the motility disorder and ptosis. A classic pupil-sparing 3rd nerve palsy has normal pupillary function, complete ptosis, and complete (related) motility dysfunction. In this situation, the etiology is almost always secondary to microvascular

disease with associated diabetes, hypertension, or hyperlipidemia.[340] However, even if the pupil is unaffected, when there is partial extraocular muscle involvement or incomplete ptosis, one cannot be certain of a microvascular etiology; a compressive lesion, for example, might present this way. In this situation, it is recommended to proceed either with neuroimaging including MR imaging with gadolinium and magnetic resonance angiography (MRA) or computed tomography angiography (CTA). In some instances of vasculopathic 3rd nerve palsy, the pupil may be involved, although mildly.

Pupil-involving 3rd nerve palsy is more concerning. A compressive lesion must be ruled out, urgently, especially an aneurysm involving the posterior communicating artery. Active force generation testing in the office may help identify muscles with residual function (which may be responsive to resection) versus completely paretic muscles (where resection will not be effective and the muscle should be left intact to preserve anterior ciliary circulation).[348] Neuroimaging, including MRA or CTA is recommended.[349] If there is a high suspicion for aneurysm despite a normal MRA or CTA, then a catheter angiogram should be considered after brain MR imaging with and without contrast and specific attention to the 3rd nerve is performed. Tumors, including meningioma, schwannoma, and metastatic lesions, are in the differential. Other causes include trauma, subarachnoid hemorrhage, viral illnesses including COVID-19,[350] demyelinating disease, and leptomeningeal disorders.[340] If the neuroimaging is normal, the next step would be serologic testing for infectious diseases (such as syphilis and Lyme), with consideration given to lumbar puncture that would include glucose, protein, cell count, and cytology and culture.

MANAGEMENT

Management of a 3rd nerve palsy is directed toward the cause and then management of the diplopia.

Monitor/Observe

With complete ptosis, many patients are not troubled by diplopia until their lid is elevated.

Nonsurgical

If the patient experiences diplopia, chemodenervation (botulinum toxin) of an antagonist extraocular muscle or the levator or use of occlusion can temporize while waiting for further recovery of function.[351] Prisms, either press-on or ground-in, may be helpful, following partial recovery or following surgical correction. Despite all efforts to alleviate diplopia in the primary position, the incomitant nature of the deficit results in diplopia with minimal shift of gaze from the primary position. Many patients wear an eye patch or occlusive contact lens or MIN lens (Fresnel, Inc.) for times when the diplopia is most bothersome. A deficit of accommodation may cause difficulty reading. Uniocular progressive lenses or bifocals in younger patients can be prescribed to aid accommodation. The bifocal segment should be placed high in the frame when infraduction is compromised.

Surgical

Surgical management is complicated, and success often depends on the number of muscles involved and the degree to which they are involved.[352] A residual exotropia with the ability to adduct past the midline typically responds well to recession of the lateral rectus muscle combined with resection of the medial rectus muscle (with or without adjustment), with or without vertical transposition.[353, 354] Likewise, in partial 3rd nerve palsy, ipsilateral weakening of the superior oblique muscle or its anterior intorting fibers might reduce the hypotropia and intorsion as a result of inferior oblique weakness. Recession with or without posterior fixation of muscles on the contralateral eye can also be used to expand the field of binocular single vision.

For compete paralysis, many other techniques have been tried with variable success.[355, 356] Some form of weakening procedure of the lateral rectus muscle is typically required, whether supramaximal recession, extirpation, or suturing to the periosteum of the lateral orbital rim.[357] Sometimes this is combined with nasal transposition of the superior oblique muscle toward the medial rectus muscle insertion or maximal medial rectus resection for its tethering effect.[358, 359] Traction sutures in combination with supramaximal lateral rectus recession and medial rectus resection may at times overcome the challenge of recurrent exotropia. Botulinum toxin augmented supramaximal lateral rectus recession and supramaximal medial rectus resection may provided similar benefit. Precaruncular and transcaruncular medial fixation has proven

successful at preventing recurrent exotropia in some reported cases.[360-362] Recently, nasal transposition of the split lateral rectus muscle to the medial rectus muscle insertion has been performed with notable success.[363, 364] This procedure can be performed unilaterally or bilaterally,[365] is safest to perform when placing the split ends within 4mm of the medial rectus to significantly reduce the known risk of choroidal effusion,[364] easiest to perform when prior lateral rectus recession has not been performed,[364] and best avoided if aberrant regeneration is present that involves secondary innervation of an extraocular muscle.[366] A comprehensive summary of surgical options to consider for the management of partial and complete 3rd nerve palsy also includes consideration of torsional diplopia and whether the goals of surgical repair are largely reconstructive or to manage diplopia, with a nuanced approach sensitive to the regions of greatest misalignment close to primary position.[356]

Postoperative prism correction may be required to allow for fusion in the primary or reading position. Ptosis surgery should be tempered if the Bell's response is extremely impaired, increasing the risk of exposure keratopathy. Patients treated surgically often have significant diplopia awareness outside of a region of binocular fusion and may benefit from part-time occlusion or a fogging contact lens for high-risk activities like driving a motor vehicle. Patients with concomitant injury to other structures in the brain or brainstem may have central fusion disruption and be unable to fuse despite otherwise satisfactory postoperative alignment. These patients need to be identified and informed before considering any surgical treatment. Botulinum toxin may be used to test for the potential for fusion because some of those patients may regain fusion.[69] Some tolerate chronic postoperative diplopia in exchange for the social benfits of improved eye contact. [356]

PROVIDER AND SETTING

Diagnosis and management of 3rd nerve palsy require the training, clinical judgment, and experience of providers with expertise in neuro-ophthalmology and adult strabismus. Working under the supervision of an ophthalmologist, orthoptists can be an asset in the examination, diagnosis, and nonsurgical management of patients with 3rd nerve palsy.

COUNSELING AND REFERRAL

The ophthalmologist should discuss the findings, explain the disorder, provide diagnosis, and discuss management options with the patient and any caregivers.

SECTION IIL. MYASTHENIA GRAVIS

INTRODUCTION

The term *myasthenia gravis* refers to a group of B-cell mediated autoimmune disorders that profoundly affect activity at the neuromuscular junction causing variable weakness exacerbated by fatigue.[367] Although generalized myasthenia gravis affects large motor groups and sometimes includes ocular features, ocular myasthenia gravis affects only the levator, orbicularis oculi, and the extraocular muscles. It can mimic many types of incomitant strabismus with or without ptosis.

DISEASE DEFINITION

Acetylcholine is released at the neuromuscular junction at the onset of an action potential and migrates across the synapse to reach the associated striated muscle. Acetylcholine receptor antibodies have been demonstrated in nearly all patients with generalized myasthenia and in 40% to 77% of patients with ocular myasthenia. Twitch fibers in extraocular muscles are thought to be particularly susceptible to fatigue, and this characteristic as well as the fewer number of acetylcholine receptor antibodies in these muscles may be responsible for the common ocular manifestations.[368]

PATIENT POPULATION

The patient population includes adults with myasthenia gravis without geographic or racial predilection, although this disorder occurs in children as well in the form of transient neonatal myasthenia (transplacental transmission), congenital myasthenia (not immune mediated), and juvenile autoimmune myasthenia. Patients are at risk for having or developing a thymoma.

CLINICAL OBJECTIVES

- Recognize the disorder to initiate an appropriate workup and referral to other subspecialties, including neurology
- Ensure that proper medical and surgical treatment is provided, and initiate short-term and subsequent long-term management of associated ptosis and strabismus

Thymectomy is indicated, certainly in the presence of thymoma but also for specific age-based and immune-based characteristics for which it may substantially reduce clinical symptoms.[367]

BACKGROUND

PREVALENCE

The incidence ranges from 0.04 to 5/100,000 per year, and prevalence estimates are 0.5 to 12.5/100,000 per year.[369]

RISK FACTORS

There is increased risk for myasthenia gravis in the presence of autoimmune thyroid disease and thymoma.[370]

NATURAL HISTORY

Onset in adults is usually in the third to fourth decade of life but sometimes much later in males. If the disorder is generalized, it may involve bulbar, limb, and respiratory muscles, which can lead to life-threatening respiratory failure. Fifty percent of patients with myasthenia present with ocular symptoms only (typically ptosis and variable strabismus and diplopia), and 50% to 80% of these patients develop generalized systemic myasthenia within a few years.[371, 372]

RATIONALE FOR TREATMENT

Minimizing extraocular motility impairment, diplopia, and compensatory head position that can affect visual function, quality of life, and its socioeconomic consequences warrant treatment.

CARE PROCESS

PATIENT OUTCOME CRITERIA

Treatment is goal directed, and targeted outcomes may include the following:

- Recognition of the disease and prevention of morbidity and mortality from generalized myasthenia gravis
- Reduction of diplopia (if present)
- Restoration of normal ocular alignment, appearance, and improved self-image
- Restoration of binocular function
- Reduction of compensatory head position (if present)

DIAGNOSIS

Variable incomitant strabismus may be accompanied by variable ptosis, both of which worsen with fatigue. Strabismus and associated diplopia may take on an entirely different pattern with fatigue or repetition of examination. Additionally, a period of rest or ice pack test in the physician's office may temporarily reduce or eliminate both the extraocular motility disturbances and ptosis. Ptosis worsens with fatigue (prolonged upgaze) and may have associated Cogan lid-twitch sign. Ptosis of the contralateral eye may worsen upon manual elevation of the more involed eyelid. Ocular saccades are often slow. Patients may also present with lid retraction as a result of associated TED.[373] Pupils are typically not affected but may in rare cases show impaired or slow responses.[374, 375] Pupillary involvement, however, should alert the physician to carefully consider other etiologies such as 3rd nerve palsy.

History

Patients may present with a history of acquired variable strabismus, diplopia, and ptosis. Those with generalized disease may have variable motor weakness, respiratory fatigue, difficulty with chewing, swallowing, holding up the head, and slurred speech.

Examination

Complete sensorimotor examination and external examination is critical, with attention to the presence of strabismus, which changes over the course of prolonged examination, and variable ptosis with possible Cogan lid-twitch sign and slow saccades. Application of an ice pack (ice test) over the closed eyes for 2 minutes in the case of ptosis and for 5 minutes in the case of strabismus may demonstrate a reduction of ptosis of about 2mm and a reduction of misalignment. This phenomenon, thought to relate to diminished anticholinesterase activity, is highly specific to this disorder.[376, 377] A rest test without an ice pack can also be used to aid in diagnosis.[378]

Tensilon (edrophonium) testing may be considered but is best performed by a practitioner experienced with proper intravenous administration, because associated muscarinic activity (excess tearing, salivation, sweating, abdominal cramping, bradycardia, bronchospasm hypotension, and syncope) can occur. The test

should be performed in a monitored setting with atropine available for potential administration. It is 95% sensitive for generalized myasthenia and 86% sensitive in cases of ocular myasthenia.[379]
The presence of the antiacetylcholine receptor antibody (AChR-Ab-binding, blocking, or modulating) can confirm the diagnosis; however, about 20% of patients with generalized myasthenia and about half of those with ocular myasthenia are seronegative. About one-third of these seronegative patients will be seropositive for muscle-specific kinase (anti MuSKAb). Lipoprotein-related protein 4 (LRP4) has been associated with generalized and ocular myasthenia gravis as well.[380]

Repetitive nerve stimulation testing (positive in only one-third of patients with ocular myasthenia) and the far more sensitive single-fiber electromyography (positive in over 90% of patients with ocular myasthenia) may also assist in diagnosis.[381] In many centers, single-fiber electromyography is considered the gold standard for diagnosis.

MANAGEMENT

Pyridostigmine bromide administered orally two to four times a day is the first line of treatment for myasthenia gravis, but about half of patients with strabismus-associated myasthenia show minimal response. In contrast, about 66% to 85% of patients show a positive response to corticosteroids.[382] For some patients, various forms of immunosuppressive therapy with azathioprine, which is known to be effective, and other agents under current investigation such as efgartigimod alfa-fcab may be offered by treating neurologists. Efgartigimod alfa-fcab has recently been FDA approved for patients who test positive for the anti-acetylcholine receptor. Thymectomy is indicated in some cases, always in the presence of thymoma, and may substantially reduce symptoms for certain subpopulations with myasthenia gravis.[367]

Diplopia and strabismus are highly variable and not readily remedied with prisms. Remission or stabilization of the disease is often possible after 2 to 3 years of treatment,[383] and at that point surgical intervention for strabismus may be considered if desired or if prism use is insufficient. Care is indicated in the use of anesthetic agents given any evidence of associated weakness of the respiratory muscles. Surgical management, with and without the use of adjustable sutures, has met with modest success in cases where there is a stabilized primary deviation, sometimes exacerbated by fatigue.[384-389] More than one strabismus surgery may prove necessary.

PROVIDER AND SETTING

Diagnosis and management of myasthenia gravis require the training and clinical judgment of an experienced ophthalmologist typically working in concert with a treating neurologist.

COUNSELING AND REFERRAL

Counseling and referral to a neurologist or neuro-ophthalmologist, and sometimes a general surgeon, is often indicated in the management of myasthenia. The ophthalmologist should discuss the findings, explain the disorder, provide a diagnosis, and discuss management options with the patient and any caregivers and be aware of any comorbidities such as respiratory distress that might present with generalization of the disease.

SECTION IIM. FIXATION SWITCH DIPLOPIA

INTRODUCTION

DISEASE DEFINITION

In patients with childhood strabismus who have a suppression scotoma in their nondominant eye, fixation switch diplopia may occur because of a change in ocular fixation preference.[390] Prior to their change in eye fixation preference, such patients do not perceive diplopia as the result of a suppression scotoma that was formed during childhood in the previously nondominant eye. However, when visual acuity in the previously dominant eye declines, fixation preference may switch to the previously nondominant eye. The previously dominant eye does not have a suppression scotoma, so for the first time, patients with childhood strabismus may experience double vision.

The largest study of fixation switch diplopia included 16 patients with a history of childhood strabismus who later presented with diplopia.[391] The most common underlying etiologies were the use of monovision for the treatment of presbyopia in 38%, the development of myopia in the previously preferred eye in 25%, and incorrect refractive correction in 38% of patients. A trial of monovision with contact lenses is prudent prior to corneal or lenticular refractive surgery to determine whether surgically induced monovision will result in new-onset diplopia. It may occur if cataract development is asymmetric and surgery is done on the nondominant, amblyopic eye first. Other published rare causes of fixation switch diplopia include a corneal ulcer and resultant scar in the dominant eye of a patient with monofixation syndrome and amblyopia,[392] and retinal detachment in the dominant eye of patients with strabismus and amblyopia.[390]

PATIENT POPULATION

The patient population includes adults with fixation switch diplopia.

CLINICAL OBJECTIVES

- Counsel the patient on the diagnosis and treatment options
- Manage diplopia
- Inform the patient's other health care providers of the diagnosis and treatment plan

BACKGROUND

PREVALENCE AND RISK FACTORS

Prevalence and incidence are unknown. Risk factors include any ophthalmic disorder or intervention that switches fixation to the previously nondominant eye in a patient with latent or manifest strabismus.

NATURAL HISTORY

Fixation switch diplopia is a subacute complaint of new-onset diplopia after any ophthalmic disorder or intervention that switches fixation to the previously nondominant eye in a patient with latent or manifest strabismus.

RATIONALE FOR TREATMENT

Diplopia warrants treatment to resolve this new-onset diplopia.

CARE PROCESS

PATIENT OUTCOME CRITERIA

- Reduction or elimination of symptomatic diplopia

DIAGNOSIS

Fixation switch diplopia is the development of new-onset diplopia when fixation preference has shifted to the previously nondominant eye.

History

A detailed medical history includes information on past ocular conditions and ocular fixation preference. Careful documentation of symptoms experienced when fixating with the previously preferred eye, and when fixing with the newly preferred eye, can confirm the diagnosis. A positive family history of strabismus is common.[393] Kushner and Kowal[394] recommend a minimal screening procedure consisting of obtaining a history of childhood eye disease or treatments (such as patching or eye muscle surgery), checking spectacles for prism, cycloplegic refraction, and cover testing for all patients undergoing corneal or lenticular refractive surgery, especially for those planning to adopt monovision.

Common scenarios in which fixation switch diplopia occurs include the following:

- Monovision has been induced by optical means or by refractive surgery
- Myopia with axial elongation has developed in a previously dominant eye
- Following refractive surgery, if the outcome favors fixation with the previously nondominant eye
- An unbalanced refraction has been used that encourages fixation with the nondominant eye
- Following cataract surgery in a previously nondominant eye when the surgery results in better visual acuity of the nondominant eye compared with the dominant eye[391]
- Following asymmetric vision loss from other common diseases such as macular degeneration or diabetic retinopathy when the nondominant eye is left with better acuity

Examination

The comprehensive eye examination of an adult strabismus patient needs to include the following elements:

- Detailed sensorimotor evaluation
- Assessment of refractive status
- Dilated fundus examination

Enabling fixation with the previously dominant eye can be done to confirm a history of monofixation and suppression before the change in ocular fixation preference occurred.

MANAGEMENT

Monitor/Observe

The patient should be monitored/observed if symptoms are mild or occasional or if the patient is opposed to treatment.

Nonsurgical

An attempt can be made to switch fixation back to the dominant eye by pursuing refractive correction. Patients will gradually experience less diplopia if dominance is re-established in the previously dominant

eye. In cases where the fixation cannot be switched back due to permanent and untreatable vision loss, vision in the newly dominant eye should be optimized with refractive correction and the use of prisms. In circumstances when fixation switch diplopia cannot be alleviated, fogging with tape, Bangerter foils, or occlusion may be necessary.

Surgical

In cases where the fixation cannot be switched back because of permanent and untreatable vision loss, strabismus surgery may be an option if there is a significant angle of misalignment and a demonstrated ability to relieve diplopia with prism correction by establishing a different alignment at which the patient can suppress.

PROVIDER AND SETTING

Fixation switch diplopia should be managed by an ophthalmologist with expertise in the diagnosis of long-standing childhood strabismus and abnormalities of binocular function. Working under the supervision of an ophthalmologist, orthoptists can be an asset in the examination, diagnosis, and nonsurgical management of fixation switch diplopia.

COUNSELING AND REFERRAL

Patients should be advised that they have an excellent prognosis if fixation can be switched back to the dominant eye. They should be counseled to avoid any procedures or refractive corrections that result in a switch of fixation to their nondominant eye. The ophthalmologist should discuss the findings, explain the disorder, provide diagnosis, and discuss management options with the patient and any caregivers.

SECTION IIN. FOVEAL MISREGISTRATION (BINOCULAR CENTRAL DIPLOPIA)

INTRODUCTION

DISEASE DEFINITION

Retinal disease that causes distortion or displacement of the fovea in one or both eyes—such as subretinal or epiretinal membranes or after retinal detachment involving the macula—can cause binocular central diplopia. There are two general mechanisms by which binocular foveal misregistration can cause diplopia. In one, distortion manifesting as metamorphopsia, micropsia, or macropsia can render the foveal images in the two eyes too dissimilar to fuse.[395, 396] In the other, dragging of the fovea in one eye, usually by an epiretinal membrane, puts central and peripheral alignment in conflict. This is known as the dragged-fovea diplopia syndrome, described as central-peripheral rivalry.[397, 398] In this situation, the stronger peripheral contribution to motor fusion usually brings the peripheral retinas into alignment and leaves the foveas of the two eyes misaligned, with central diplopia.

PATIENT POPULATION

The patient population includes adults with binocular retinal diplopia.

CLINICAL OBJECTIVES

- Counsel the patient on the diagnosis and treatment options
- Manage diplopia
- Inform the patient's other health care providers of the diagnosis and treatment plan

BACKGROUND

PREVALENCE AND RISK FACTORS

The prevalence of subretinal neovascular membranes and macular epiretinal membranes is 2% for individuals under 60 years of age and increases to as much as 12% for those over 70.[399, 400] Between 16% and 37% of those diagnosed with epiretinal membrane or other maculopathy have binocular central diplopia.[398,401] With aging of the population, it is likely that retinal disease will be an increasingly important cause of diplopia.

NATURAL HISTORY

Within days to weeks of development of maculopathy or foveal abnormality, binocular central diplopia may develop, and this only rarely improves over time.

RATIONALE FOR TREATMENT

Diplopia warrants treatment to improve visual function.

CARE PROCESS

PATIENT OUTCOME CRITERIA

Treatment for binocular central diplopia includes diminishing the diplopia.

DIAGNOSIS

Binocular central diplopia develops within days to weeks of worsening maculopathy or foveal abnormality because the foveal image in the two eyes becomes too dissimilar to fuse.

History

A detailed medical history should include information on ocular conditions and specifically retinal disease involving the macula.

Examination

An examination should include eliciting any history of retinal disease affecting the macula of one or both eyes. A full orthoptic examination is warranted because a proportion of patients who have maculopathy and diplopia have other forms of treatable strabismus.[402] Prism and alternate cover testing demonstrates either no strabismus or a small vertical deviation. Any diplopia relief from prism correction is most often transient, although in rare patients it may prove helpful. Metamorphopsia may be identified on the Amsler grid test and quantified using M-Charts, and aniseikonia (unequal images) can be quantified using the Awaya test. (See Glossary.)

For dragged-fovea diplopia syndrome, the lights on/off test is pathognomonic. In this test, a small white-on-black test letter is shown and, when peripheral fusion cues are eliminated by totally darkening the room, central fusion allows the test letter to be seen singly. When the room lights are turned on, peripheral fusion reasserts itself, the images of the test letter separate and diplopia resumes.[398] This test is not effective unless the entire room is darkened with no cues to peripheral fusion such as door frames or background lighting on a computer monitor. An alternative to the lights on/off test for those who are unable to eliminate all peripheral cues in their examination rooms is the optotype-frame test.[402] (See Glossary.) For the optotype-frame test, the patient is requested to fixate an isolated (uncrowded) Snellen optotype on an illuminated monitor and to describe whether the letter itself is single or double. Assuming it is single, the patient is asked whether the frame of the monitor is single or double. If maintaining a single frame causes diplopia of the letter, peripheral fusion has taken over and foveal diplopia syndrome is present. Stronger peripheral fusion makes it impossible to maintain central single binocular vision when foveal image disparity has become too great.

MANAGEMENT

Monitor/Observe

The patient should be monitored/observed if symptoms are mild or occasional or if the patient is opposed to treatment.

Nonsurgical

Although cover testing in patients with binocular central diplopia often demonstrates small-angle strabismus that is nearly always vertical, prismatic or surgical correction of this deviation is not curative because it does not resolve the mismatch of distorted macular images or the conflict between foveal and peripheral alignment. Even so, intervention can sometimes reduce symptoms. Reduced diplopia awareness has been reported with the use of prism correction or fogging in some patients.[403] Fogging the vision in one eye, which eliminates the foveal conflict by producing a central scotoma,[404] may be successful. Blenderm™

surgical tape applied to the spectacle lens has been used,[3] but Scotch Satin™ tape[398] or Bangerter foils[404] are better tolerated. Occlusive contact lenses may also be successful. A small amount of prism in addition to a Bangerter foil can provide better relief from diplopia in some difficult cases.[405]

Surgical

If superimposition of the foveal images by synoptophore or prism does not satisfactorily resolve or diminish subjective diplopia, strabismus surgery is unlikely to be successful. It may be considered if improved binocular alignment reduces symptoms that are incompletely addressed by fogging or optical correction alone, or if superimposition of the foveal images by synoptophore diminishes subjective diplopia. It is important to remember that some patients with foveal misregistration have treatable causes of diplopia as well.[402] Surgical peeling of the epiretinal membrane may be effective in addressing binocular central diplopia in some patients but may result in new diplopia in others.[403, 406]

PROVIDER AND SETTING

A complaint of diplopia normally prompts referral to a pediatric ophthalmologist, orthoptist, or neuro-ophthalmologist, many of whom are familiar with the diagnosis and management of this perplexing problem.

COUNSELING AND REFERRAL

Patients with binocular central diplopia are generally already under the care of a retina specialist, from whom they are typically referred. While the underlying retinal disease often needs ongoing care, surgical treatment such as membrane peeling improves diplopia in only a proportion of patients. The strabismus specialist may need to discuss the potential benefits of membrane peeling with the retina specialists. The potential value of prism, improved refractive correction, and strabismus surgery to reduce diplopia awareness in some cases should not be overlooked. The patient should be counseled, however, that this condition usually does not improve spontaneously, may worsen, and fogging of one eye may be the most suitable long-term solution. The ophthalmologist should discuss the findings, explain the diagnosis, and discuss management options with the patient and any caregivers.

SECTION III. COMPLICATIONS OF PERFORMING ADULT STRABISMUS SURGERY

INTRODUCTION

Although complications can occur as a result of any surgical procedure, the risk of sight-threatening complications is particularly low with strabismus surgery.[31, 407, 408] The more common complications are minor, often self-limited, or treated with topical medications. More serious complications are fortunately rare.

BACKGROUND

PREVALENCE AND RISK FACTORS

Severe complications from strabismus surgery have been estimated to be 1 in 400 (globe perforation, severe infection, slipped or lost muscle, and scleritis), with 1 in 2,400 resulting in a poor or very poor outcome.[408]

CARE PROCESS

POSTOPERATIVE CONCERNS

The following postoperative concerns are common to adults as well as children during or after strabismus surgery. Intraoperative and postoperative concerns with a higher incidence in the adult population are indicated.

Intraoperative

- Globe perforation (0.08%–5.1%; although serious, most cases have no sequelae but place the patient at higher risk for retinal detachment, vitreous hemorrhage, and endophthalmitis).[408-412] Some cases are observed, others are treated with retinopexy.
- Oculocardiac reflex (67.9%) or asystole (0.11%) during surgery or suture adjustment may be self-limited or require urgent medical attention.[413, 414]
- Pulled-in-two syndrome (1 in 14,000; more likely in adults)[407] or lost muscle
- Operating on the wrong eye or muscle (1 in 2,506)[415]

Early Postoperative[416]

Mild concerns and best treated with observation or a short course of supportive therapy:

- Foreign body sensation
- Corneal abrasion
- Allergic reaction
- Dellen (2.2%–18.9%, higher risk in reoperations and transpositions)[417, 418]
- Subconjunctival hemorrhage
- Chemosis

- Mydriasis
- Reduced accommodation
- Postoperative nausea

More serious concerns requiring active attention and intervention:

- Endophthalmitis (1 in 30,000 to 1 in 185,000)[409, 419]
- Subconjunctival abscess, preseptal/orbital cellulitis (1 in 1,100 to 1 in 1,900)[408, 419, 420]
- Oculocardiac reflex (67.9%) or asystole (0.11%) during suture adjustment may be self-limited or require urgent medical attention.[413, 414] Anterior segment ischemia (1 in 6,000; higher risk with age, vascular risk factors, limbal incisions,[421] and operating on three or more muscles).[422]
- Diplopia, rarely intractable (0.8%; more likely in adults)[13]
- Slipped muscle (1 in 1,500)[408]
- Postoperative orbital hemorrhage (incidence unknown, very rare, potentially greater risk for patients on anticoagulation)[423, 424]

Late Postoperative

Mild concerns:

- Visible muscle insertion
- Visible/dark sclera
- Persistent injection over the surgical site
- Pyogenic granuloma; may be self-limited or treated with excision, steroids, or topical beta-blockers (2.1%)[422]
- Tenon's prolapse
- Advancing plica semilunaris

More serious concerns, requiring more attention and sometimes intervention:

- Epithelial inclusion cyst; may require excision (0.25%)[425]
- Overcorrection or undercorrection (possibly treated with additional strabismus surgery)
- Diplopia, rarely intractable (0.8%; more likely in adults)[13]
- Limitation of eye ductions (possibly treated with additional strabismus surgery)
- Loss of binocular function (may benefit from additional strabismus surgery, orthoptic intervention, or use of a prism)
- Altered eyelid position, common with surgery on the inferior or superior rectus muscles and more notable in patients with thyroid ophthalmopathy (who already may have eyelid retraction). If persistent or of concern, this may be addressed with eyelid surgery.
- Surgically induced necrotizing scleritis (1 in 4,000; more likely in adults)[408]
- Slipped muscle or stretched scar (1 in 1,500)[408]
- Lost muscle (1 in 4,500; more likely in adults)[408]
- Retinal detachment (1 in 10,000 to 1 in 40,000)[409, 426]
- Adhesive syndrome (fat adherence syndrome)[427]

PROVIDER AND SETTING

Diagnosis and management of complications from adult strabismus surgery require the training, clinical judgment, and experience of a pediatric ophthalmologist or strabismologist. Consultation with subspecialists in retina, infectious disease, rheumatology, or neuro-ophthalmology may be indicated.

COUNSELING AND REFERRAL

The ophthalmologist should discuss and explain the findings and discuss management options with the patient. In some cases, treatment may be best managed with the additional expertise of other ophthalmic colleagues with advanced retina, oculoplastics, glaucoma, or immunology expertise, as indicated.

SECTION IV. TECHNICAL CONSIDERATIONS WHEN PERFORMING ADULT STRABISMUS SURGERY

INTRODUCTION

Strabismus surgery in adults is often more challenging than in children for a variety of reasons. A well-thought-out surgical plan with preparation for the unexpected is important. Attention should be given to the following special considerations in surgical planning and management.

CARE PROCESS

SURGICAL PLANNING AND MANAGEMENT

Anticoagulants

Many strabismus surgeons do not routinely stop anticoagulants for strabismus surgery.[428] Temporary discontinuation of anticoagulation medication may reduce intraoperative bleeding, but consultation with the physician prescribing anticoagulation is advised, along with a plan to restart anticoagulation shortly thereafter. Reasons for anticoagulation differ and, in some cases, bridging therapy is indicated.[429] Absorbable gelatin sponges with or without thrombin may also be useful in difficult cases but are rarely required for more routine procedures.

Adjustable Sutures

Adjustable sutures may be used by strabismus surgeons, particularly for adult patients, although many surgeons achieve excellent results without using them. Advocates for adjustable sutures point to several advantages over fixed sutures, including a second chance at obtaining satisfactory alignment and the potential to minimize risk of postoperative diplopia. A variety of techniques (bowtie, noose, semiadjustable) exist, and the timing of the adjustment varies with surgeon preference, ranging from immediately in the operation room, several hours after the surgery, and to up to several days following the procedure. The adjustable suture technique may be most helpful in reoperations and unpredictable cases, such as those with restrictive or paralytic strabismus.[180, 184, 230, 296, 363, 430, 431] Advocates for surgery without adjustable sutures point to reduced cost, a reduction in anxiety, and/or postoperative discomfort for some patients, and the fact that ocular alignment may change considerably after the immediate postoperative period.

Small Deviations

Surgeons will frequently encounter microtropias in adults. Small deviations (≤8 prism diopters horizontally and <3 prism diopters vertically) may prove clinically significant, causing diplopia or asthenopia. Small horizontal or vertical deviations may be successfully treated using a tenotomy procedure (partial, central snip) or a single rectus muscle recession to obviate the need for prism correction.[432] [300]

Chemodenervation

At present, intramuscular injection of botulinum toxin into an extraocular muscle may be used alone or in combination with strabismus surgery to treat new-onset deviations, to enhance the impact of traditional surgery on large deviations, to address a residual deviation after prior strabismus surgery, and to treat

small-angle deviations.[70, 74, 86, 169, 351] Botulinum toxin can also be used to prevent contracture of an ipsilateral antagonist muscle in cases of paralytic strabismus while waiting the requisite period of time for spontaneous resolution before recommending strabismus surgery. A Cochrane systematic review found that it was difficult to assess outcomes given the limited number of randomized controlled trials.[74]

Anesthesia

Retrobulbar or peribulbar anesthesia and monitored sedation or pure topical anesthesia are possibilities in adults having unilateral surgery, though general anesthesia may be preferable in cases of reoperation and complex, bilateral, and longer surgical procedures.

Complex Strabismus

A higher percentage of adults have complex strabismus as a result of scarring from previous strabismus surgery, restriction from orbital trauma, or restriction from other ocular surgeries, including glaucoma seton or scleral buckle surgery, the placement of orbital wall implants after trauma, blepharoplasty, dacryocystorhinostomy, pterygium excision or sinus surgery as well as myotoxicity from local anesthesia.[231] (Many of these concerns are addressed in Section IIG. Strabismus Associated with Other Ophthalmic Surgery.) Scleromalacia may increase the complexity of both surgery and postoperative recovery.

A stretched scar, which results in a weak attachment between muscle and sclera, is a common occurrence in adults who have undergone strabismus surgery in childhood. Suggestive clinical findings include increased deviation in the field of action of the previously operated muscle. It is important to distinguish weak, nonmuscular attachments from more robust muscle tissue at the time of reoperation, because placement of sutures in this nonmuscular tissue will lead to early recurrence of the problematic strabismus pattern. Slipped or tenuously attached muscle (which sometimes appears like a stretched scar), and lost muscles are more common in adults and make surgical outcomes less predictable.[433] A meticulous technique is often required to ensure a successful outcome. An experienced assistant can be very helpful. Sometimes a slipped or lost muscle is readily retrieved by tracing its natural path or by taking advantage of fine attachments to adjacent extraocular muscles. For example, a slipped inferior rectus muscle may still retain its attachments to the adjacent inferior oblique muscle, and a slipped or traumatized medial rectus may be found attached to adjacent plica. If the lost muscle cannot be identified, waiting 2 to 3 months until likely adhesion to the globe may facilitate recovery because the muscle can then be hooked at its new point of attachment. Antagonist contracture may develop as early as 2 weeks in lost muscle. If late intervention is preferred, prevention of antagonist contracture should better be provided by early botulinum toxin injection into the antagonist muscle.[434] High-resolution orbital imaging may facilitate surgical planning. If this proves technically impossible, a transposition procedure of other extraocular muscles may be considered to improve alignment.[407, 408, 435, 436]

Intraoperative Issues

The surgeon should also pay attention to specific intraoperative issues that are far more common in adults. A second strabismus surgeon or skilled assistant may be needed and ample time for surgery allotted. Conjunctiva and Tenon's are fragile in the older population. Thin and delicate conjunctiva may make wound closure difficult or incomplete. Amniotic membrane grafts may sometimes be used in extreme cases. Pulled-in-two syndrome is a complication in which traction on a damaged or abnormal muscle belly results in a horizontal transection or "snapping" of the muscle belly about 8mm to 10mm from its insertion; the transected muscle is both challenging to repair and the complication further compromises alignment.[176] Retrobulbar, intramuscular, and intraocular hemorrhage may occur in adult strabismus surgery as a result of the surgery or periorbital anesthesia.[423, 424, 437] Although rare, they are potentially vision-threatening complications, and the surgeon should be knowledgeable about their management.

Liquefied vitreous is common in adults, whereas children will have formed vitreous. Consequently, adults have higher risk for retinal detachment following inadvertent scleral perforation during strabismus surgery. Various techniques such as short scleral passes may reduce this risk.

PROVIDER AND SETTING

Diagnosis and management of adult strabismus require the training, clinical judgment, and experience of a pediatric ophthalmologist or strabismologist.

COUNSELING AND REFERRAL

The ophthalmologist should discuss the findings, explain the disorder, provide diagnosis, and discuss management options with the patient and any caregivers.

APPENDIX 1. GLOSSARY

Awaya Test: A test of aniseikonia that has the patient compare adjacent calibrated half moons—one red and one green—to determine the degree of difference in image size and appearance. The images can be presented in any meridian enabling quantification of vertical, horizontal, and oblique aniseikonia.

Bagolini Lenses: Striated lenses used to test for suppression and normal or abnormal retinal correspondence.

***Kushner Semi-Adjustable Technique*:** A modification of the adjustable suture technique that limits undesired excess recession over time by allowing only a modest degree of secondary adjustment to an otherwise fixed recession.[180]

Loop Myopexy: A strabismus surgical procedure wherein a suture (typically nonabsorbable) is used to create an adhesion between two adjacent muscles without additional adhesion to sclera. Examples of common use of the loop myopexy technique include loop myopexy between the superior and lateral recti to treat myopic strabismus fixus, and between the superior or inferior rectus muscles and the lateral rectus muscle to improve abduction in the treatment of 6^{th} nerve palsy or Duane syndrome.

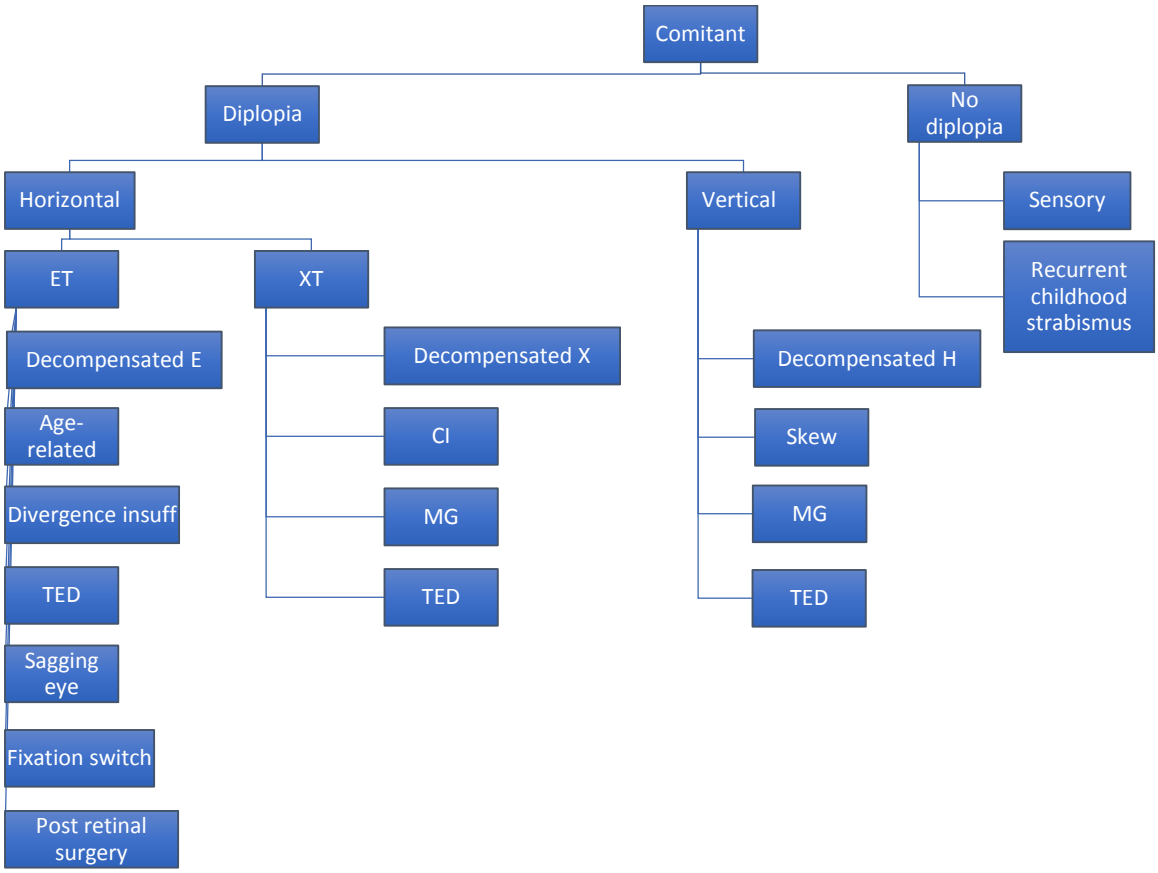
Optotype-Frame Test: This is a test of central versus peripheral fusion. The patient is requested to fixate an isolated (uncrowded) Snellen optotype on an illuminated monitor and to describe whether the letter itself is single or double. Assuming it is single, the patient is asked whether the frame of the monitor is single or double. If maintaining a single frame causes diplopia of the letter, peripheral fusion has taken over and foveal diplopia syndrome is present. This is a disorder wherein stronger peripheral fusion makes it impossible to maintain single binocular vision centrally and occurs when foveal image disparity is sufficient to disrupt central fusion.

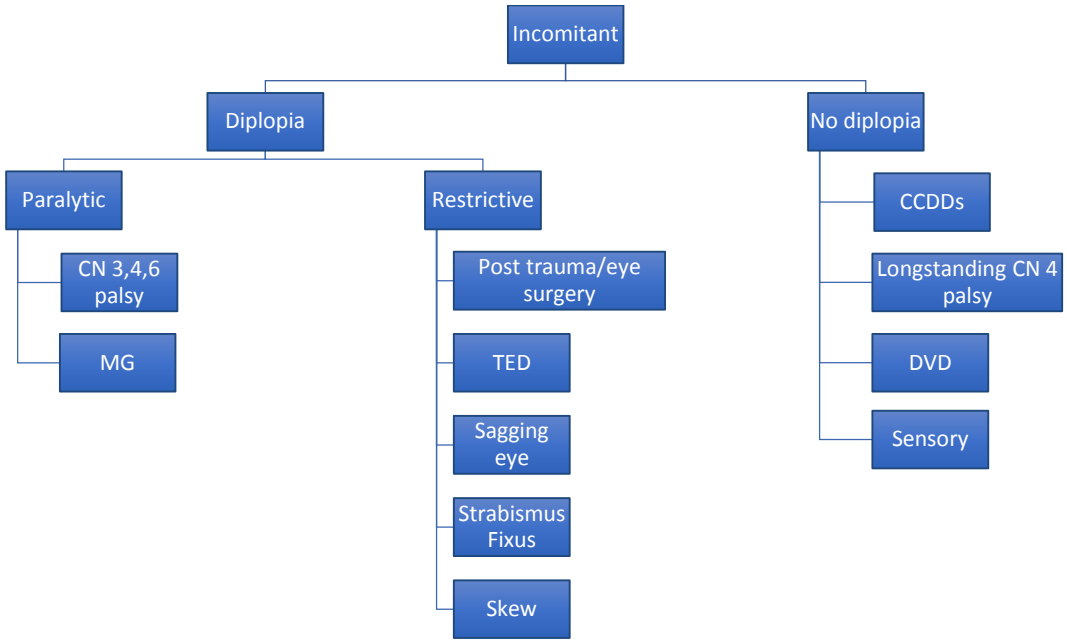
***Sagging Eye Syndrome*:** Some cases of divergence insufficiency may be seen in association with an age-related degeneration of the SR-LR connective tissue band. The strabismus is often accompanied by mild ptosis (or a history of treated ptosis) and deep superior lid sulcus defect associated with aging. Divergence insufficiency is common and sometimes there is associated modest vertical misalignment of the eyes.

Superior Rectus-Lateral Rectus (SR-LR) Band: This band maintains a soft tissue connection between the superior rectus and the lateral rectus muscles as they course posteriorly. Age or staphylomatous growth of the globe can result in a medial shift of the superior rectus and an inferior shift of the lateral rectus as this band of connective tissue fails.

Synoptophore: An instrument that measures the manifest strabismus angle in all planes and allows stimuli to be presented to both eyes at once. The misalignment can be fixed by the device and the ability of the patient to fuse the superimposed images can be tested. This device can also be used for orthoptic training, exercising fusional vergences, and for predicting whether strabismus surgery may result in binocular fusion. The field of view is only 20 to 24 degrees in diameter, however, which can limit peripheral fusion.

APPENDIX 2. ALGORITHM FOR APPROACHING ADULT STRABISMUS BASED ON PRESENTATION OF DEVIATION




Incomitant
Diplopia
No diplopia
Paralytic
Restrictive
CCDDs
CN 3,4,6 palsy
Post trauma/eye surgery
Longstanding CN 4 palsy
MG
TED
DVD
Sagging eye
Sensory
Strabismus Fixus
Skew

APPENDIX 3. LITERATURE SEARCHES FOR THIS PPP

Literature searches of the PubMed and Cochrane databases were conducted in January 2023; the search strategies are listed below. Specific limited update searches were conducted after April 2023.

"divergence insufficiency" OR "divergence insufficiency esotropia" OR "divergence insufficiency pattern" OR "divergence insufficiency pattern esotropia" OR “divergence insufficience”
(convergence[tw] and insufficiency[tw]) OR (("convergence insufficiency" OR "convergence insufficiency and excess" OR "convergence insufficiency and reading study cirs group" OR "convergence insufficiency symptom" OR "convergence insufficiency symptom survey" OR "convergence insufficiency symptom survey ciss" OR "convergence insufficiency symptom survey questionnaire" OR "convergence insufficiency symptom survey score" OR "convergence insufficiency symptoms" OR "convergence insufficiency treatment" OR "convergence insufficiency treatment trial" OR "convergence insufficiency treatment trial citt investigator group" OR "convergence insufficiency treatment trial citt study group" OR "convergence insufficiency treatment trial executive committee" OR "convergence insufficiency treatment trial group" OR "convergence insufficiency treatment trial study group" OR "convergence insufficiency type" OR "convergence insufficiency type intermittent exotropia"))
(superior oblique palsy) OR (("fourth nerve"[tw] OR "trochlear"[tw] OR "fourth cranial nerve"[tw] OR "cranial nerve iv"[tw])) AND palsy[tw]) OR ("superior oblique palsy"[tw] OR "superior oblique paralysis"[tw] OR "fourth nerve palsy"[tw] OR "fourth nerve paralysis"[tw] OR "trochlear palsy"[tw] OR "trochlear paralysis"[tw] OR "cranial nerve iv palsy"[tw]

APPENDIX 4. RELATED ACADEMY MATERIALS

Basic and Clinical Science Course
External Disease and Cornea (Section 8, 2022–2023)

Focal Points 2018
Module: Adult Strabismus

Clinical Statements – Free download available at http://one.aao.org/guidelines-browse?filter=clinicalstatement.
Adult Strabismus Surgery - 2017

Preferred Practice Pattern® Guidelines – Free download available at www.aao.org/ppp.
Amblyopia (2022)
Esotropia and Exotropia (2022)

To order any of these products, except for the free materials, please contact the Academy's Customer Service at 866.561.8558 (U.S. only) or 415.561.8540 or www.aao.org/store.

Orge FH. Strabismus stimulator. 2015; https://www.aao.org/interactive-tool/strabismus-simulator. Accessed August 13, 2019.

Complex Strabismus Simulator
Oct 24, 2018 by Faruk H. Orge, MD; K. David Epley, MD
This simulator expands on the basic **Strabismus** Simulator, allowing the exploration of more complex eye deviations such as the alphabet patterns, cranial nerve...
Interactive / Tool

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