2001—An Ocular Odyssey: Lessons Learned from 25 Years of Surgical Treatment for Graves Eye Disease

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ABSTRACT

Graves eye disease (GED) is a serious autoimmune disorder that often results in orbital congestion, massive extraocular muscle enlargement, mechanical strabismus, and severe diplopia. Surgical treatment of this condition has often yielded unsatisfactory results and unique or unusual complications. At the University of Michigan, I have had the opportunity to participate in an interdisciplinary Graves eye disease center and provide medical and surgical care for strabismus and diplopia in a large number of these patients. The purpose of this study was to retrospectively review my experience with the surgical treatment of these patients to determine what works, what to expect, and how to avoid the pitfalls and complications that have been common in the treatment of these patients.

A retrospective review of the charts of all patients with GED and strabismus or diplopia seen between 1982 and 2001 and who had been followed for at least six months is reported. One hundred eighty-three charts were reviewed, of which 155 met inclusion criteria and 135 had undergone strabismus surgery. These provided the core population for this series.

Charts were reviewed for demographics, clinical, and surgical characteristics with emphasis on the types of surgeries performed, surgical results, and complications. Results are organized in categories according to the lessons they have taught me. Special emphasis was placed on the relationship between orbital decompression and strabismus, between the size of strabismus angle and surgical success, and between the special features of GED as they relate to surgical complications and surgical success. I hope these lessons will assist others in the optimal care of these challenging patients.
INTRODUCTION

It is a great honor for me to present the 32nd Richard G. Scobee Memorial Lecture. In spite of his early death before his 38th birthday, Dr. Scobee became one of the early giants in the field of strabismus because of his remarkable accomplishments during only ten active professional years. While I did not know Dr. Scobee personally, his influence continues to be felt through his many contributions to strabismology: as an educator, for his role in establishing the instruction courses for orthoptists at the annual Academy meeting; as an academician, for his early role in the American Orthoptic Council; as a scientist and author of 62 publications and his classic textbook *The Oculorotatory Muscles*; and as the founder and first editor of the *American Orthoptic Journal*, where he set a high standard for published scholarship and showed his strong support of orthoptics.

Dr. Scobee’s clinical and research interests were broad, with published original observations spanning such topics as the incidence of heterophoria and the reliability of measuring it, as well as several studies concerning the relationship between prism vergences and heterophoria. Another major interest of his was the often overlooked anatomical and mechanical factors in strabismus. It is because of this interest in the anatomic and mechanical side of strabismus that, as a topic for this Scobee lecture, I have chosen to review and examine my experience in the surgical treatment of strabismus and diplopia in Graves eye disease (GED) over the past 25 years: to document the lessons I have learned that contribute to a successful correction of strabismus in this classic mechanical/restrictive muscle disorder.

Graves eye disease (Graves ophthalmopathy, dysthyroid ophthalmopathy, GED) is a serious autoimmune disorder involving the eyelids, extraocular muscles, and orbital contents. While it is associated with other autoimmune conditions such as thyroid dysfunction and myasthenia gravis, its etiology is unclear. It occurs at a prevalence of 16 cases per 100,000 population with a four to one female to male ratio. Onset is commonly in the fourth and fifth decades when it represents the most common orbital disorder, occurring in 50% of patients with Graves disease. Graves eye disease typically runs a one to three-year active course before becoming inactive or “burned out.”

Clinical features include mild to severe proptosis with lid retraction in a typical temporal flare pattern. Secondary myopia of the orbital portion of the extraocular muscles and generalized orbital congestion may result in restrictive strabismus with diplopia or even compressive optic neuropathy. In up to 10% of patients, sight-threatening complications can occur from exposure keratopathy and ulceration or compressive optic neuropathy.

Management strategies are tailored to the type and severity of ocular complications in individual patients. Exposure opthalmopathy may require treatment with lubricants, occlusive shields, eyelid surgery, punctal occlusion, or orbital decompression. Compressive optic neuropathy requires urgent intervention with systemic steroids, orbital radiation, or surgical decompression. The sometime severe cosmetic abnormalities, proptosis and lid retraction, can be greatly improved by orbital decompression to reduce proptosis followed by eyelid surgery to correct lid retraction or ptosis. Finally, and most important to this study, diplopia and strabismus often require prism therapy or custom designed strabismus surgery.

METHODS

A computer search of the patient data base and my surgical records from the
University of Michigan, W. K. Kellogg Eye Center identified all patients with Graves eye disease who were examined by me from 1982 to 2001 and who underwent strabismus surgery by me between 1985 and 2001. All patients whose records were available with at least a six-month follow-up after initial evaluation or last strabismus surgery (range six months to eleven years) were reviewed. All included patient information concerning age, sex, race, presence and type of strabismus and diplopia, presence and type of torsion, history of previous orbital decompression, muscle involvement, medical therapy, surgical therapy, and response to therapy (reoperation, residual diplopia, etc.) was recorded and tabulated for review.

At the Kellogg Eye Center, we are privileged to have an outstanding multidisciplinary clinical model for evaluation and treatment of patients with Graves disease. All patients with suspected Graves disease or thyroid dysfunction from our large Upper Midwestern referral area are initially evaluated in the multidisciplinary Graves disease clinic at the University of Michigan Hospital. There the diagnosis is confirmed and extensive endocrinologic, metabolic, and other laboratory testing, as well as relevant imaging, is performed according to a detailed protocol. Thyroid dysfunction is treated as necessary. After diagnosis confirmation, extensive work-up is completed and thyroid function normalized, all patients with suspected ocular involvement or diplopia are referred for ophthalmological evaluation in the Oculoplastics and Orbital Disease Clinic at the W. K. Kellogg Eye Center. These patients are then evaluated and treated for potential sight-threatening complications including exposure keratopathy or ulceration and compressive optic neuropathy. Baseline detailed ocular motility evaluation is accomplished by our orthoptic staff and diplopia, if present, initially treated with Fresnel or ground in prism therapy when possible. In addition, orbital decompression, if indicated for treatment of exposure, compressive optic neuropathy, or severe cosmetic deformity, is accomplished prior to final strabismological treatment planning. After completion of this initial, sometimes urgent therapy and stabilization, all patients with presumed ocular motility disorders or diplopia are referred to the Skillman Pediatric Ophthalmology and Adult Strabismus Clinic for further strabismological evaluation and definitive treatment with prisms or eye muscle surgery. Finally, after optimal, potential ocular alignment has been restored with prism therapy or eye muscle surgery and diplopia eliminated or minimized, patients are returned to the Oculoplastics clinic for final adjustment of eyelid position for best function and cosmesis.

LESSONS I HAVE LEARNED

Patient Characteristics

The database search revealed 238 patients with GED who were examined by me during this study. Of these, 155 records were available which met all the inclusion criteria. Evaluation of these records constitutes the basis for this lecture. All patients had detailed orthoptic measurements as part of the initial, final and most interval examinations including measurements in diagnostic gaze positions and, frequently, measurement of subjective torsion by double Maddox rod test.

Patient demographics were as follows: 115 patients were female and 40 were male. 146 patients were Caucasian, eight African American, and one Asian. Mean age was 43.5 years with a range of 27 to 58 years. Of the 238 patients seen during this period, 189 (79%) underwent surgical (eye muscle surgery) plus/minus medical (prisms, single vision reading glasses, ra-
Radiation or steroid therapy, etc.) therapy and 49 (21%) required medical therapy alone. The 155 study patients closely mirrored the entire group with 135 (87%) requiring surgical plus/minus medical treatment and 20 (13%) requiring medical treatment alone.

Strabismus type and muscle involvement in these patients are similar to that previously reported in the literature.11 Eighteen patients presented with esotropia alone, 94 with esotropia and hypotropia, and 38 with hypotropia alone. An additional two patients presented with esotropia and hypertropia and three with hypertropia alone. No patients were noted to have exotropia prior to therapy. As indicated by the strabismus type, most patients underwent recession of the medial or inferior rectus muscles. Fifty-five patients underwent bilateral medial rectus recession, while 16 underwent recession of the right medial rectus and 34 of the left medial rectus alone. My strategy for planning vertical rectus muscle surgery evolved somewhat during the course of this study. Twenty-two patients underwent bilateral inferior rectus recession, most with adjustable suture on the more restricted side. Most of these were performed early in the study group. However, because of a high incidence of complications (A-pattern exotropia in down gaze and intorsion) in patients with bilateral inferior rectus surgery, the majority of later patients underwent recession of only one inferior rectus on the more restricted side using an adjustable suture. (This issue will be discussed further later in this paper.) Fifty-seven of these patients underwent right inferior rectus recession alone and 33 left inferior rectus recession. An additional three patients underwent recession of one lateral rectus (two with myasthenia gravis as well as Graves eye disease and one who had undergone previous lateral rectus resection prior to my evaluation). An additional twelve patients had superior rectus recession and eight had superior oblique weakening procedures (six by nasal tenotomy and two using a silicone expander).

Strabismus and Orbital Decompression

Other investigators have examined the relationship between orbital decompression and strabismus in Graves eye disease.12-14 Shorr et al. performed a retrospective review of 50 patients with Graves disease who underwent orbital decompression surgery. Prior to decompression, 16 patients (32%) reported strabismus and diplopia with the following distribution: six with hypotropia alone, four with esotropia and hypotropia, three with esotropia alone, two with exotropia and hypotropia, and one with exotropia. After orbital decompression surgery, the prevalence of strabismus and diplopia increased to 25 patients (50%). The distribution of strabismus types also changed following decompression surgery with 13 patients noted to have esotropia alone, six patients esotropia and hypotropia, two with esotropia and hypotropia, and one with exotropia. After orbital decompression surgery, the prevalence of strabismus and diplopia increased to 25 patients (50%). The distribution of strabismus types also changed following decompression surgery with 13 patients noted to have esotropia and hypotropia, six patients esotropia alone, and six patients hypotropia alone. Ruttem13 retrospectively reviewed his experience with strabismus surgery in Graves eye disease patients who had and had not had orbital decompression. He found that patients who had had orbital decompression had a lower success rate from strabismus surgery, more frequently needed correction for both horizontal and vertical deviation, and had more muscles operated upon than patients who had not had orbital decompression. He hypothesized that the need for orbital decompression in patients was reflective of a worse degree of orbitopathy and that ocular changes from decompression surgery may interfere with a successful result from strabismus surgery.

Among the 135 patients from my series
at the University of Michigan with large enough deviation to require strabismus surgery, 68 (50%) had undergone orbital decompression surgery during follow-up. Of these, 26 (38%) had no strabismus or diplopia prior to decompression surgery. In addition, 46 (68%) had a change in type of strabismus or angle of deviation of greater than or equal to 10° following the decompression.

**LESSON 1:** Orbital decompression causes or changes strabismus. Therefore, complete all orbital decompression surgery prior to final evaluation for strabismus surgery.

**Relationship Between Size of Strabismus Angle and Surgical Success**

Table 1 shows the relationship between size of preoperative ocular deviation and surgical success for patients who had Graves eye disease and esotropia. Eighty-three of 90 patients (92%) with preoperative deviation of less than or equal to 45° were successfully realigned with strabismus surgery alone and six more were comfortably realigned with the addition of small amounts of prism in spectacles. As the angle of deviation increased, the success rate with surgery alone and surgery plus postoperative prism fell such that only three of eight patients (38%) with 55 to 65° esotropia were successfully aligned with surgery alone and only one of five (20%) of those with esotropia of greater than 65 was successfully aligned with surgery alone.

Table 2 shows a similar relationship between the angle of hypotropia and surgical success. Again, 96 of 103 (93%) patients with a hypotropia of less or equal to 20° were successfully realigned with strabismus surgery alone while only two of nine (22%) with deviation between 30-40° and none of four patients (0%) with hypotropia of over 40° could be aligned with surgery alone.

Evaluation of forced duction testing, both with and without restricted muscles attached, as well as coronal CT and MRI scans, suggest orbital mechanical factors may be responsible for this relationship. In many of these patients with large preoperative deviations, passive forced duction testing prior to surgery, as would be expected, is extremely positive, frequently with inability to elevate or abduct the eye more than a few degrees. Also, as expected, restriction is greatest in those with the largest angle of deviation. In addition, in that group of patients with the largest deviation, poor response to surgery can be predicted by repeating the forced duction testing after transsection of the insertion of the restricted medial or inferior rectus muscle from the globe. In those patients with marked improvement
in the passive forced duction to well past the mid-line after tenotomy, successful surgical realignment can be expected. However, in that subset of patients with large preoperative deviations, poor response to surgery can be predicted when little or no improvement in passive forced duction is noted after the involved muscle is detached.

Figures 1 and 2 illustrates the probable etiology of this disparity. The gross orbital specimen (Figure 1) and coronal orbital CT-scan (Figure 2) clearly illustrates how massive extraocular muscle enlargement can mechanically restrict globe movement. In the most severely affected patients with multiple muscle involvement, the mass of the enlarged muscles in the restricted orbital space can restrict the movement of the optic nerve as it exits from the globe because the optic nerve position is fixed between the almost kissing posterior muscle bellies. This restriction to globe movement persists even after removing the muscle insertions, again because it is caused by restriction of the movement of the optic nerve as it exits the globe. Only by transecting the optic nerve at its exit from the sclera would the posterior globe rotate more freely relieving the restriction to allow realignment of the eyes. Obviously, since this is not a reasonable alternative, realignment of the eyes in these patients is not possible unless muscle shrinkage occurs. Careful preoperative review of a coronal CT or MRI scan just posterior to the globe preoperatively can therefore be helpful in predicting surgical failure when the pattern of optic nerve restriction seen in Figure 2 is noted.
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FIGURE 2: Coronal CT scan of a 39-year-old women with severe Graves eye disease and large angle esotropia and hypotropia. This coronal section just posterior to the globe reveals how the enlarged inferior, medial, and superior rectus muscles can prevent abduction and elevation of the globe by restricting movement of the optic nerve posteriorly. This patient had 4+ positive mechanical restriction to abduction and elevation of the globe even with the medial and inferior rectus muscles detached from the sclera.

LESSON 2: You can’t fix them all.
Beware of patients with very large preoperative deviation; esotropia of greater than 45° and hypotropia of greater than 20°. Use coronal CT or MRI scans and forced duction testing after the rectus muscle detached to predict those patients who cannot be completely realigned at the time of surgery.

Complications of Surgery

In addition to inability to surgically realign some patients with large preoperative deviations, several other surgical complications appear to occur more frequently and/or require alternative surgical approaches in Graves eye disease patients compared to other types of strabismus. Near muscle loss occurred in three patients in this series, a prevalence much higher than with other strabismus surgical procedures. A “Pulled in Two Syndrome” (PITS) occurred in one patient with the muscle dehiscence occurring 6-8 mm posterior to the insertion following only moderate tension on a Jameson muscle hook. After extensive exploration, fragments of the posterior muscle belly were recovered and the dehiscence repaired prior to recession of the affected inferior rectus muscle. Although a planned adjustable suture was converted to a fixed absorbable suture, the surgical result was acceptable with very good depression. Because of the difficult exposure caused by marked restriction of affected muscles, suture placement and tenotomy must sometimes be performed without adequate direct visualization. Because of this, suture passes within the muscle tendon were cut on two occasions during transsection of the muscle insertion. Both were identified before complete transsection had occurred and were repaired with re-suturing without sequelae.

Anterior segment ischemia was noted in one patient, a 64-year-old gentleman who had three rectus muscles removed from the affected eye during two surgical procedures eight months apart; the first a recession of the medial rectus/resection of the lateral rectus for what was assumed to be uncomplicated esotropia by the operating surgeon, followed by a re-recession of the medial rectus and recession of the inferior rectus of the same eye eight months later after the diagnosis of Graves eye disease had been made.

Lid retraction, although a common manifestation of Graves eye disease itself, frequently presents or is exacerbated after strabismus surgery in Graves disease patients. In this series, 38 of 112 patients (34%) had an increase in lower lid retraction, primarily following inferior rectus recession. In addition, twelve of 112 patients (11%) experienced increased upper lid retraction, probably associated
with an increase in proptosis following re-
lease of marked restriction during reces-
sion of the medial or inferior rectus mus-
cles. No surgical strategy proved reliable
in preventing this complication. Lysis of
all adhesions to Tenon’s capsule as well as
capsulopalpebral fascia was attempted in
all patients in spite of sometimes difficult
visualization of the inferior rectus be-
cause of marked restriction of abduction,
large deviation, and marked globe depres-
sion. In addition, adjustable lid suture
techniques, such as those described by
Kushner15 and Guyton,16 were also at-
ttempted in 18 patients and did not appear
to be beneficial. Meyer et al.17 reported
good results using a lower eyelid retractor
lysis procedure to prevent eye lid retrac-
tion after inferior rectus muscle recession.
This procedure was not tried in my pa-
tients, but may also be useful. Fortu-
nately, however, this eyelid retraction
was easily corrected by our Oculoplastics
Department as the final step in ocular re-
habilitation as seen Figures 3 and 4.

A-Pattern Exotropia in Down Gaze

A more unusual complication of strabis-
mus surgery, and especially inferior rec-
tus recession, in Graves eye disease pa-
tients has been the development of a
significant A-pattern exotropia in reading
gaze. This problem proved to be common,
with a measurable A-pattern exotropia in
down gaze documented in 26 of 135 pa-
tients and was symptomatic with serious
complaints of difficulty reading, sewing,
etc. in 18. In all of these patients, the A-
pattern was either caused or worsened by
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the extraocular muscle surgery. Significant A-pattern was documented in 22 patients prior to surgery and remained present in 21 of those after surgery, generally becoming more severe and/or symptomatic. In addition, of the 113 patients with no A-pattern preoperatively, 15 developed significant A-pattern exotropia in down gaze following their strabismus surgery.

While this problem has been noted by others\textsuperscript{11}, the exact mechanism is unproven. A likely mechanism for this complication is that a large recession of the inferior rectus, especially bilaterally, weakens the inferior rectus in attempted down gaze and stimulates compensatory overaction of the superior oblique muscle with its secondary abduction and intorsional action. This theory is consistent with the findings of this study, since A-pattern exotropia developed or was made symptomatic in 12 of 22 patients (55\%) with bilateral inferior rectus recession, even if asymmetrical, compared to only eight of 90 (9\%) of those who underwent unilateral inferior rectus recession alone.

In the course of treating these patients, multiple attempts to prevent or treat this condition were evaluated. Since the problem was most common with bilateral inferior rectus recession, the most frequent strategy involved limiting inferior rectus recession to one eye, if possible, or performing a very asymmetrical recession with only 2 or 3 mm recession on the less restricted inferior rectus. Cruz and Davitt\textsuperscript{18} reported on their experience with bilateral asymmetrical inferior rectus recession in eight patients. This procedure was successful in correcting hypotropia without overcorrection during a short follow-up period, but no mention of A-pattern or torsion was included in their paper. Other techniques which underwent trial included nasalizing the inferior rectus at the time of surgery, either with or without the adjustable suture, elevating the medial rectus at the time of surgery, “nasal collapse” of the inferior rectus with nasal transposition of the temporal half of the tendon only and performing a Faden procedure on the contralateral inferior rectus in six patients. Table 3 shows the effect of these procedures on preventing or eliminating the A-pattern exotropia. As can be seen, all reduce the frequency of postoperative A-pattern exotropia when compared to that seen with bilateral inferior rectus recessions. Merely performing unilateral (on the more restricted side) inferior rectus recession greatly reduced the prevalence of this problem. However, the addition of inferior rectus nasal transposition or of combined medial rectus supraplacement and inferior rectus transposition, as well as nasal collapse of the inferior rectus alone proved to be successful strategies for eliminating this problem.

\textbf{LESSON 3: A-pattern exotropia in reading gaze is a common troublesome complication of strabismus surgery and particularly bilateral inferior rectus recession in patients with Graves eye disease. Do not recess the inferior rectus in both eyes if possible. Try transposition of the rectus mus-}

<table>
<thead>
<tr>
<th>Surgical Procedure</th>
<th># Operated</th>
<th># With Symptomatic Post-op A-Pattern XT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recess IR OU</td>
<td>22</td>
<td>12 (55%)</td>
</tr>
<tr>
<td>Recess one IR</td>
<td>90</td>
<td>13 (14%)</td>
</tr>
<tr>
<td>Nasal Transpose IR</td>
<td>18</td>
<td>3 (17%)</td>
</tr>
<tr>
<td>Nasal Transpose IR/H11005</td>
<td>10</td>
<td>1 (10%)</td>
</tr>
<tr>
<td>Supraplace MR</td>
<td>20</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Nasal Collapse IR</td>
<td>20</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Faden Contralateral IR</td>
<td>6</td>
<td>1 (17%)</td>
</tr>
</tbody>
</table>

IR = inferior rectus, MR = medial rectus
cles, nasal collapse of the inferior rectus, or a Faden procedure of the contralateral inferior rectus to prevent or minimize this complication.

**Torsion and Torsional Diplopia**

The presence of torsion and torsional diplopia has been described by previous investigators. Caygill documented measurable extorsion in 43 of 100 patients with GED. He hypothesized the extorsion was caused by inferior rectus and inferior oblique restriction and by superior rectus weakening secondary to stretching. In his series, the torsion was not altered by treatment with systemic steroids, thyroid replacement hormone, or orbital decompression. Nineteen patients in his series had enough torsion to cause torsional symptoms. Sixteen of 19 (84%) of these patients had correction of the extorsion to less than 5 degrees following 3 to 5 mm inferior rectus recession on unilateral or bilateral restricted inferior rectus muscles. Two of the 19 also required inferior oblique myectomy.

Garrity et al. described torsional diplopia in 26 of 428 patients after orbital decompression for Graves eye disease. Twenty-one had intorsion of 5 to 20 degrees (mean 12.8°) and five had extorsion of 5 to 20 degrees (mean = 12°). All patients had also undergone eye muscle surgery with recession of the medial rectus, inferior rectus, or both. These patients underwent treatment with superior oblique tenotomy for intorsion and inferior oblique myectomy for extorsion. He found that superior oblique tenotomy corrected 0 to 12° of intorsion (mean = 7.1°) and inferior oblique myectomy corrected 10° of extorsion. In his series, 15 of 21 patients with intorsion and two of five with extorsion were diplopia free following treatment.

Trobe et al. described extorsion in eight (53%) and intorsion in two (13%) of 15 patients studied with GED. Seven of the patients with extorsion and one with intorsion had 10° or more of cyclodeviation. He presented evidence suggesting the type and size of torsion is helpful in the diagnosis of various types of cyclovertical muscle abnormalities including superior oblique palsy, Graves eye disease, restrictive myopia, myasthenia gravis, and skew deviation.

**Intorsion**

In this study, intorsion with torsional diplopia was documented in 12 of 135 (9%) of patients. The mean cyclodeviation was 16.8° with a range of 9 to 32 degrees. Obviously, none of these patients could fuse with prism alone, and all were severely debilitated and extremely unhappy. Intorsion frequently presented or was exacerbated following bilateral inferior rectus recession (nine of 12 patients) with or without the addition of nasal offset transposition to prevent or treat the A-pattern exotropia in reading gaze previously described.

Several mechanisms may explain the development of intorsion in GED. Increased recruitment of the superior oblique, especially on attempted down gaze, after inferior rectus weakening may result in an increase in its secondary intorsional action. Increased tension on the superior oblique tendon from posterior and inferior shift of the globe following orbital decompression has also been proposed to increase intorsion. In addition, suprplacement of the medial rectus and nasal transposition of the inferior rectus to treat or prevent A-pattern exotropia in down gaze will tend to increase intorsion and, conversely, treatment of intorsion with rectus transposition will aggravate or induce A-pattern exotropia in reading gaze.

Table 4 lists the results of various treat-
TABLE 4
SURGICAL TREATMENT OF INTORSION

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Success</th>
<th>Failure</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO Tenotomy</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>SO Expander</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Tuck IO/Recess SO</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Recess SR</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>IO Advance &amp; Transpose</td>
<td>6</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Transpose IR and/or MR</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

SO = superior oblique, IO = inferior oblique, SR = superior rectus, IO Advance & Transpose = inferior oblique muscle advancement and superior transposition (see text)

Inferior Oblique Muscle Advancement and Superior Transposition was first performed in 1996 for the treatment of intractable intorsional diplopia in GED. During the past six years, six patients have been treated with this procedure and all have had successful elimination of intorsion and torsional diplopia. All patients have been female with an age range of 38 to 56 years. All have had significant A-pattern exotropia and all had undergone bilateral orbital decompression. All also had bilateral medial rectus recessions and bilateral inferior rectus recessions for severe GED with 1/2 tendon width offset transposition for A-pattern. Three had symptomatic intorsion prior to any strabismus surgery and three only after initial horizontal and vertical muscle surgery. All patients had intorsion quantitatively measured preoperatively with double Maddox rod at between 20 to 30 degrees (mean 26°). One patient had undergone previous bilateral superior oblique silicone expander and two patients bilateral superior oblique tenotomy, all with minimal improvement in intorsion or A-pattern.

All of these patients had bilateral Inferior Oblique Muscle Advancement and Superior Transposition with the inferior oblique muscle transposed beneath the lateral rectus and sutured to the sclera at the superior border of the lateral rectus at a point 8 mm posterior to the lateral rectus insertion. This surgery alone resulted in reduced intorsion of 10 to 26 degrees (mean 21°) as well as A-pattern collapse of 10° to 32° (mean 18°) with a follow-up of 6 to 24 months (mean 10 months). All patients treated in this manner were free of torsional diplopia at the last follow-up with intorsion corrected in up- as well as downgaze and minimal if any progression or regression of effect during the follow-up period. This procedure appears to correct approximately 10° of intorsion per oblique muscle transposed, although the effect...
can be increased by resection of up to 6 mm of the inferior oblique prior to transposition and can be performed using an adjustable suture if desired to prevent overcorrection.

**LESSON 4: Intorsion is not always what it seems. Beware of torsional symptoms, especially intorsion with torsional diplopia. Avoid especially large recessions of the inferior rectus in both eyes and be careful of horizontal and vertical transposition of rectus muscles to prevent or treat A-pattern exodeviation in downgaze as these procedures frequently result in or exacerbate intorsion and torsional diplopia. In my experience, Inferior Oblique Muscle Advancement and Superior Transposition is the most effective procedure to treat intorsional diplopia when present.**

**Extorsion**

Extorsion was documented in 21 of 135 patients (16%) with GED in this study. Extorsion with torsional diplopia was documented in nine (7%). Mean extorsion measured 11.6° with a range of 8 to 16 degrees. As expected, none of these patients could fuse with prism alone. Extorsion in these patients appears to be most often caused by severe inferior rectus restriction with unbalanced increase in the secondary extortional action of these muscles. Various treatment strategies were used on these patients generally involving relieving inferior rectus restriction by recessing one or both inferior rectus muscles. Five patients underwent bilateral inferior rectus recession with elimination of extorsion in all five. Five had recession of one inferior rectus alone with elimination of extorsion in only three without additional treatment. However, eight patients underwent recession of one inferior rectus with nasal transposition and all eight had successful correction of extorsion as well as A-pattern exodeviation in downgaze, when present. Superior oblique tuck was also used in one patient to successfully treat extorsion.

**Postoperative Drift Following Strabismus Surgery**

Postoperative drift in alignment from that established six hours postoperatively during suture adjustment to that six to eight weeks postoperatively was investigated. Of patients who had medial rectus recession for esotropia and were adjusted to near orthophoria, 39 of 52 patient remained within 5° of orthophoria after healing while three patients drifted to greater than 5° exodeviation (overcorrection) and nine patients drifted to greater than 5° esotropia (undercorrection). This resulted in a mean postoperative drift of 2.2° in an esodirection back towards the original deviation.

When vertical rectus muscles were operated, however, the result was different. Only 18 of 51 patients who had inferior rectus recession and were adjusted for near orthotropia remained orthophoric following complete healing. Instead, 32 patients developed progressive overcorrection of at least 5° while only one regressed to undercorrection of greater than 5°. The mean postoperative drift following inferior rectus recession was 5.5° toward hyperdeviation (overcorrection). Likewise, although fewer were preformed, superior rectus recessions tended to also progress toward hypodeviation (overcorrection) during healing with a resulting mean of 0.9° hypotropic shift.

The major advantage of adjustable sutures in strabismus surgery is the ability to adjust and control the initial postoperative alignment immediately following surgery. However, this ability is only helpful
when minimal, if any, postoperative drift occurs during healing, or if a typical size and direction of drift can be identified and allowance made for this drift at adjustment time. With this in mind, trends in postoperative alignment drift with each procedure type in GED patients were monitored during the 20+ years of surgical experience reported here.

Table 5 summarizes the final surgical result after postoperative drift in GED patients who underwent inferior rectus resections, as they relate to the postoperative target alignment established after suture adjustment. Based on my experience with a drift towards undercorrection in patients with exotropia, necessitating adjustment to slight overcorrection, I adjusted the initial 14 patients to a final 3 to 8° hypertropia (overcorrection). As the table shows, the majority (78%) of these patients remained overcorrected and even drifted more hypertropic during healing. I then targeted near vertical orthotropia in 35 patients, and again the majority (54%) drifted to 5° or more hypertropia (overcorrection). Based on this experience, I targeted the last 85 patients to a small 3° to 8° hypotropia (undercorrection) with the ability to fuse using 5 to 10 degrees chin-up posture. This strategy, because of progressive small drift towards overcorrection during healing, resulted in a much higher 82% initial success after healing was completed.

**LESSON 5**: Recession effects (weakening) of a tight inferior rectus in Graves eye disease progresses during healing. Therefore, slightly undercorrect the hypertropia when recessing a tight inferior rectus in these patients. A reasonable target alignment is 3° to 6° hypotropia in primary position which allows fusion with 5 to 10 degree chin-up posture.

Postoperative drift following medial rectus recession behaves very differently in patients with GED. Table 6 illustrates the relationship between initial target

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**TABLE 5**

POST-OP DRIFT FOLLOWING INFERIOR RECTUS RECEPTION

<table>
<thead>
<tr>
<th>Target</th>
<th>&gt;5° Undercorrected</th>
<th>Ortho ±5°</th>
<th>&gt;5° Overcorrected</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 to 6° Hypo T; Fusion with 5–10° chin up</td>
<td>6</td>
<td>70(82%)</td>
<td>9</td>
<td>85</td>
</tr>
<tr>
<td>Ortho</td>
<td>2</td>
<td>14</td>
<td>19(54%)</td>
<td>35</td>
</tr>
<tr>
<td>3 to 8°HT</td>
<td>0</td>
<td>3</td>
<td>11(78%)</td>
<td>14</td>
</tr>
</tbody>
</table>

HT = hypertropia, Hypo T = hypertropia, Ortho = orthotropia, Target = target alignment after adjustment

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**TABLE 6**

POST-OP DRIFT FOLLOWING MEDIAL RECTUS RECEPTION

<table>
<thead>
<tr>
<th>Target</th>
<th>&gt;5° Undercorrected</th>
<th>Ortho ±5°</th>
<th>&gt;5° Overcorrected</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 to 6°ET</td>
<td>8(67%)</td>
<td>3</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Ortho</td>
<td>4</td>
<td>70(85%)</td>
<td>8</td>
<td>82</td>
</tr>
<tr>
<td>3 to 6°XT</td>
<td>1</td>
<td>8</td>
<td>11(55%)</td>
<td>20</td>
</tr>
</tbody>
</table>

ET = esotropia, XT = exotropia, Ortho = orthotropia, Target = target alignment after adjustment
alignment immediately following suture alignment and final alignment following complete healing six to eight weeks after surgery. As seen in the table, the surgical result following medial rectus recession tends to remain relatively stable with little consistent drift. Among the twelve patients where a small undercorrection was targeted, 67% remained undercorrected after healing. Of interest, though, three patients drifted toward overcorrection with a final alignment near orthophoria and one patient drifted to a small exotropia (overcorrection). Three of these four patients who drifted in an exodirection had large preoperative esodeviation with very tight medial rectus muscles. Of the 82 patients adjusted to near orthophoria, 85% remained there postoperatively. But again, eight patients drifted in an exodirection with progressively more medial rectus weakening during the healing. Again, six of these eight were patients that had very large preoperative esotropia and very tight medial rectus muscles. Finally, among the 20 patients with a small exotropia (overcorrection) targeted, 55% remained overcorrected after healing.

LESSON 6: Recession of the medial rectus muscle in GED remains relatively stable during healing unless the preoperative esodeviation is very large and the medial rectus very tight. Therefore, adjust the medial rectus to near horizontal orthotropia and adjust very tight medial rectus muscles to a small undercorrection.

The Problem of Late Overcorrection

Significant delayed postoperative drift to late overcorrection, sometimes weeks or even months after surgery, appears to be a more common phenomenon in GED than in many other types of strabismus surgery. In this series, late overcorrection of $10^\circ$ or more, generally resulting in loss of reacquired fusion, with diplopia and need for reoperation, was seen in 13% (15 of 114) of patients following inferior rectus recession, 5% (six of 108) of patients following medial rectus recession and 0% (zero of five) of patients following superior rectus recession.

Especially interesting has been the characteristic increased prevalence of this complication following inferior rectus recession in GED. In my series this complication occurred as early as three weeks and as late as seven months postoperatively. The onset was sudden, (i.e., the patient woke up one morning with new vertical diplopia) in ten patients and more gradually in five. The mean final hyperdeviation measured $11^\circ$ with a range of $4^\circ$ to $22^\circ$. This complication occurred more commonly with larger preoperative deviation (i.e., tighter preoperative inferior rectus muscles). Of those patients with preoperative hypotropia of less than $15^\circ$, five of 48 (10%) developed a late overcorrection compared to 10 of 66 (15%) of patients with preoperative hypotropia of greater than $15^\circ$.

Looking at this another way, Table 7 shows the relationship between late overcorrection and size of initial inferior rectus recession which correlates with size of initial hypotropia and preoperative tightness or restriction of the operated inferior rectus.

<table>
<thead>
<tr>
<th>Size of IR Recession</th>
<th># Overcorrection</th>
<th>No Overcorrection</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–4 mm</td>
<td>10</td>
<td>1(10%)</td>
</tr>
<tr>
<td>4–6 mm</td>
<td>28</td>
<td>3(11%)</td>
</tr>
<tr>
<td>6–8 mm</td>
<td>56</td>
<td>6(11%)</td>
</tr>
<tr>
<td>8–10 mm</td>
<td>35</td>
<td>5(14%)</td>
</tr>
<tr>
<td>10–12 mm</td>
<td>5</td>
<td>1(20%)</td>
</tr>
</tbody>
</table>

IR = inferior rectus
rectus muscle. As shown in the table, the frequency of overcorrection remains stable in the 10 to 11% range for recessions up to 8 mm with an increase to 14% for recessions of 8 to 10 mm and to 20% of 5 patients requiring recessions of 10 to 12 mm.

Several mechanisms for the increased frequency of late overcorrection following inferior rectus recession in GED have been proposed. Wright has proposed that anomalous adhesions around Lockwood’s ligament in GED could pull the inferior rectus muscle anteriorly, thus slackening the anterior aspect with weakening of its depression function as the scar adhesion contracts. Ludwig recently proposed an increased prevalence of “Stretched Scar Syndrome” in these patients because of the increased chronic tension on the collagen forming at the new insertion caused by tight restriction. This traction causes collagen stretching during a vulnerable period resulting in a stretched scar and late overcorrection. She has also presented evidence to suggest that the timing of occurrence of overcorrection is consistent with animal models and her experimental studies concerning this phenomenon.

Wright (personal communication) has recently presented several cases that he feels also support the stretched scar mechanism. Hudson and Feldon found that proptosis and superior rectus muscle volume were significantly greater in patients with overcorrection and they suggested combined superior and inferior rectus muscle recessions using adjustable sutures in these patients to prevent late overaction of the superior rectus.

Findings at reoperation in this study failed to provide broad support for these mechanisms. At reoperation, the inferior rectus muscle was found where expected based on operative reports and adjustment notes in 14 of 15 patients. Only two of 15 patients presented any suggestion of “stretched scar” with the remainder demonstrating strong muscular tissue present at the scleral attachment site. In addition, results of reoperation surgery in these patients do not support the necessity to use either fixed (rather than adjustable) sutures or non-absorbable suture material. Thirteen of 15 patients had successful correction of their late hypertropia following a single adjustable inferior rectus advancement using absorbable Vicryl® suture. The remaining two patients were successfully corrected with one adjustable followed by one fixed inferior rectus advancement, again using absorbable sutures. No patients required non-absorbable sutures to obtain satisfactory postoperative vertical alignment. These results and my observations concerning clinical characteristics and anatomic findings in patients with late overcorrection if inferior rectus recession in GED lead me to believe that a basic change in muscle contractility or restriction secondary to the trauma of surgery itself, possibly with associated inflammation, is responsible for late overcorrection. In addition, myasthenia gravis was strongly suspected or confirmed in five of 15 patients who experienced this complication. In these patients, neuromuscular transmission abnormalities may explain the decreased muscle contractually observed.

LESSON 7: Beware of late overcorrection following inferior rectus recession in GED. While the mechanism of this complication remains unclear or inconsistent, the secondary hypertropia responds nicely to advancement of the involved inferior rectus muscle with or without a hangback adjustable suture. Non-absorbable suture was not required in any of these patients and only two re-
quired fixed rather than hangback sutures during a second reoperation. I still feel the advantages of adjustable sutures in these complex patients are worth the slight increased risk of this complication that absorbable hangback sutures might bring.

SURGICAL RESULTS

Other investigators have reported the short and long-term surgical results in treating strabismus in Graves eye disease.28-32 Many different surgical strategies have been proposed with varying results. Although eye muscle surgery on patients with severe restrictive GED has been among the most technically challenging surgeries I have performed, by following the lessons discussed previously, excellent surgical results can be obtained in the majority of patients.

While surgical success can be defined in many ways, elimination of diplopia in important gaze positions, especially primary position and slight down gaze for reading, as well as limiting the need for reoperation are important indicators. In general, surgery was planned to eliminate horizontal, vertical, and torsional diplopia as well as to provide the largest possible centered single binocular visual field using a single surgical procedure. In this series, by modifying the surgical plan over time as these lessons were learned, the initial reoperation rate, defined as reoperation planned for surgical failure within eight weeks of surgery was 7% (nine of 135 patients). Over time, some patients who were initially successfully treated, decompensated, or required or requested additional surgery to eliminate the need for prisms, head posture, etc. This resulted in a final reoperation rate after all follow-up of 23% (31 of 135 patients).

Fusion with elimination of diplopia in important gaze positions at last follow-up visit was also a common result of strabismus surgery in this series. One hundred eight of 135 patients (80%) were able to fuse without diplopia in primary position without anomalous head posture or prism. In addition, 118 of 135 patients (87%) were able to fuse with or without head posture and 131 of 135 (97%) were able to comfortably fuse after surgery either with or without the addition of optical prism therapy.

CONCLUSION

In summary, over the past 25 years I have been fortunate to see and treat, along with my support staff, a large number of complex patients with Graves eye disease. The interdisciplinary program for the treatment of Graves disease at the University of Michigan has become a model program for optimal treatment of this condition and its many complications. This vast experience has allowed me to learn about the natural history of this disease, and to intervene surgically when necessary. I have learned many lessons from this experience. The most important of these have been presented here. It is my sincere hope that these lessons will help others better understand and treat their patients with strabismus and diplopia from Graves eye disease to help them to return to more normal work, family, and personal life.

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REFERENCES

24. Ludwig IH: Scar remodeling after strabismus
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