Anterior and Nasal Transposition of the Inferior Oblique Muscles

David R. Stager, Jr, MD,[a] George R. Beauchamp, MD,[a] Weldon W. Wright, MD,[a] and Joost Felius, PhD[a,b]

Background: When performing anterior transposition of the inferior oblique (IO) muscle, placement of the posterior suture close to the lateral border of insertion of the inferior rectus (IR) muscle decreases the incidence of antielevation syndrome (AES). We hypothesized that placement of the suture nasal to the IR muscle insertion will convert the IO muscle into an intorter and depressor. Here we present the first series of results obtained with a new procedure for the treatment of elevation in adduction with extorsion and abnormal head postures. ***Methods:*** Twenty patients with IO muscle overaction, superior oblique (SO) muscle palsy, absent SO muscles, AES, or Duane syndrome were studied. Before surgery, each patient showed at least one, but often more, of the following signs: elevation in adduction, exotropia (XT) in up gaze, abnormal head posture, and extorsion. Each underwent anterior and nasal transposition (ANT) of the IO muscle, with the new insertion typically 2 mm nasal and 2 mm posterior to the nasal border of the IR muscle insertion. ***Results:*** Large improvements in ocular alignment, extorsion, and head posture were found in most patients. However, a poor result was noted in a patient with Y-pattern XT, who developed a mild amount of comitant XT after an extreme degree of ANT (4 mm nasal and 3 mm anterior to the nasal border of the IR muscle insertion). In Duane syndrome, ANT corrects upshoot, but downshoot may get worse. Mersilene permanent sutures, rather than dissolving suture materials, are recommended to avoid postoperative retraction of muscle fibers. ***Conclusions:*** ANT converts the IO muscle into an intorter and tonic depressor and can significantly improve elevation in adduction. This procedure seems particularly useful in patients with severe or recurrent congenital and acquired SO palsies, particularly as a secondary procedure. Extreme ANT may induce exotropia in the primary position. (J AAPOS 2003;7:167–173)

Anterior transposition[1,2] of the inferior oblique (IO) muscle has been widely used for the treatment of increased adduction (traditionally termed "IO overaction") associated with dissociated vertical deviation (DVD).[3-8] A recognized risk of IO muscle anteriorization is that it may cause a limitation in increased abduction, resulting in an apparent IO muscle overaction in the contralateral eye, often accompanied by Y-pattern exodeviation. This "anti-elevation syndrome" (AES), named and described by Kushner,[9] has been studied by several investigators.[9-11] Stager[12,13] postulated that the functional origin of the posterior fibers of the temporal portion of the IO muscle (the posterior temporal fibers) after the anterior transposition procedure is formed by the myoneural junction of the neurofibrovascular bundle (NFVB). This, along with Kushner's[14] observation of excessive extorsion in up gaze in these patients, has helped us to understand AES from a mechanical point of view: The insertion is temporal to the y-axis of Fick (torsional movement), anterior to the x-axis (vertical movement), and temporal to the z-axis (horizontal movement) (Figure 1A). This notion also explains why AES occurs less frequently if the new insertion of the IO muscle is placed close to the temporal border of the insertion of the inferior rectus (IR) muscle[9-11] and thus close to the y- and z-axes (Figure 1B). Stager[13] suggested that placing the new IO muscle insertion even further nasally, just anterior to the mid-portion or the nasal half of the IR muscle insertion, decreases the risk of AES even more because the functional origin and the posterior and temporal fibers of the IO muscle would then be superimposed with the y- and z-axes (Figure 1C), thus eliminating extorsion and abduction.

Recently, we proposed a new technique in which the IO muscle is transposed not only anteriorly but also nasal to the nasal border of the insertion of the IR muscle[15] (Figure 2). This anterior and nasal transposition (ANT) procedure places the insertion of the IO muscle to the y-axis and anterior to the x-axis, thereby converting the IO muscle from an extorter and elevator in adduction to an intorter and tonic depressor in adduction (Figure 3).

After the initial case report, we now present a pilot study of 20 patients who underwent ANT of the IO

From The Department of Ophthalmology, University of Texas Southwestern Medical Center,[a] and the Retina Foundation of the Southwest, Dallas, Texas[b].
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Reprint requests: David Stager, Jr., MD, Pediatric Ophthalmology and Center for Adult Strabismus, 8201 Preston Rd, Suite 140-A, Dallas, TX 75225.

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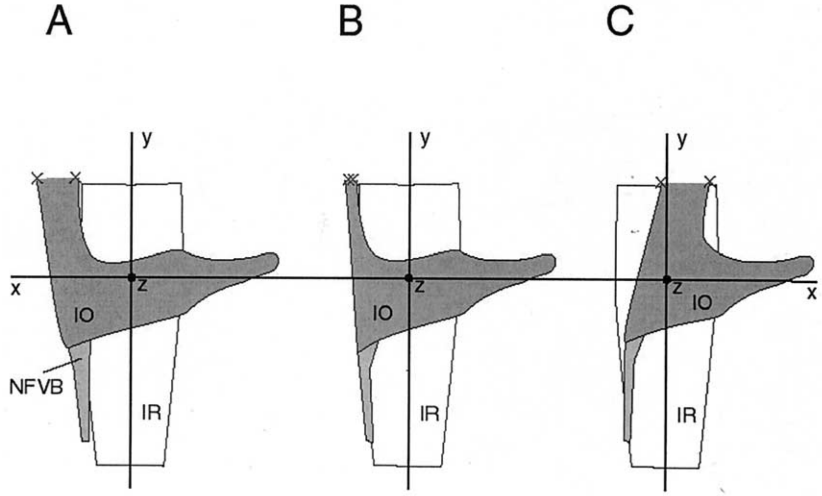

FIG 1. A, Schematic representation (inferior view) of the traditional anterior transposition of the IO muscle. B, Placing the new IO muscle insertion close to the temporal border of the IR muscle decreases the risk of AES.[9] C, Placing the new insertion even further nasally should decrease the risk of AES even more.[13] The axes x, y, and z are the axes of Fick and correspond to the directions of rotation of the globe. IO, inferior oblique; IR, inferior rectus; AES, antielevation syndrome.

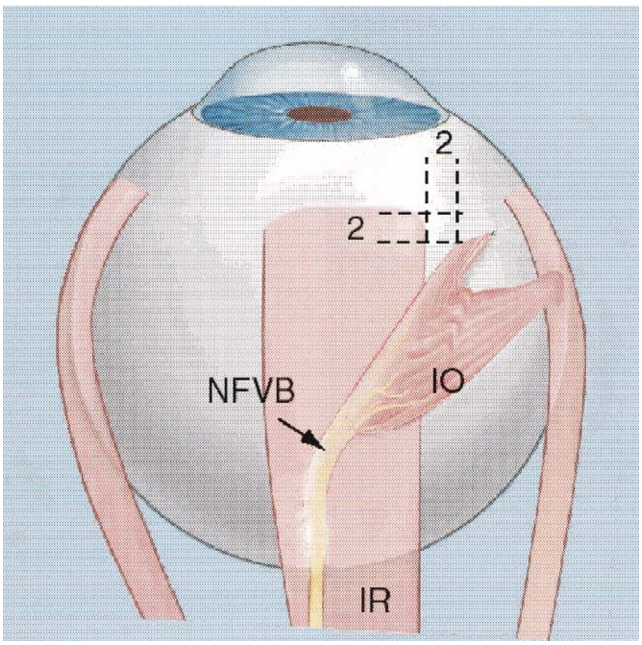

FIG 2. Representation of the eye (viewed from below) with the IO muscle in its new position after ANT, 2 mm nasal and 2 mm posterior to the insertion of the IR muscle. The neurofibrovascular bundle (NFVB) acts as functional origin of the anteriorized IO muscle. IO, inferior oblique; ANT, anterior and nasal transposition.

muscles between August 2000 and February 2002. Initially, the ANT procedure was performed in patients in whom previous treatment for IO muscle overaction and/or superior oblique (SO) palsy had failed. After more insight was gained regarding the effects of the increased adduction, torsion, and tonic depression produced by ANT, the procedure was also applied as primary surgery in other cases, eg, in patients with absent SO muscles; severely increased adduction; Duane syndrome with severe upshoot, (which usually responds poorly to recession of the IO muscle); and in Y-pattern exotropia (XT), for which it was postulated that the effects of intorsion and adduction in up gaze may be used as a means to control up-gaze XT.

MATERIALS AND METHODS

Patients

Twenty patients ranging in age from 2.3 to 79 years (median, 10.0) underwent ANT of the IO muscle. These patients had a variety of conditions, most of which included signs consistent with severe IO muscle overaction with or without SO muscle palsy. A brief description of each patient, including diagnosis and preoperative measurements, is given in Table 1. Oblique muscle action was graded on the standard scale from −4 to +4.

Ten patients underwent unilateral ANT, and 10 patients underwent bilateral ANT. Nine patients underwent ANT as a secondary procedure to the IO muscle; 2 patients had had previous surgery to other extraocular muscles; and 9 patients underwent ANT as a primary procedure.

Surgical Technique

Similar to the procedure for IO anterior transposition, the lateral rectus (LR) muscle was isolated with a muscle hook and the eye rotated nasally and superiorly. After isolating the IO muscle with a muscle hook, the IO muscle was disinserted and reattached to the sclera with the posterior-temporal fibers attached typically 2 mm nasal and 2 mm posterior to the nasal extent of the insertion of the IR muscle. In some patients, a smaller or larger degree of ANT was performed by placing the new insertion closer to or further from the nasal border of the insertion of the IR muscle. Use of the new Beauchamp IO muscle clamp

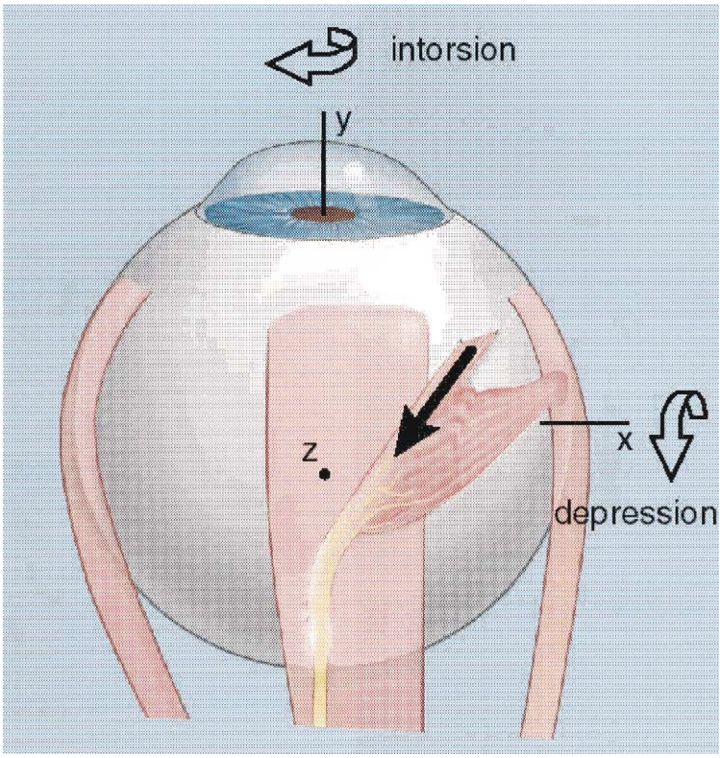

FIG 3. The IO muscle after ANT, Contraction of the IO muscle creates a torque vector (black arrow) that causes the globe to depress and intort (open arrows) around the x- and y-axes, respectively. IO, inferior muscle; ANT, anterior and nasal transposition.

(Model SP7-60458; Storz Ophthalmics, St. Louis, MO), which is straight and features a set of stops that create a 0.6-mm gap between closed blades, prevented the muscle tissue from being crushed. This hopefully permitted a strong scleral adhesion. A second suture attached the anterior-temporal fibers of the IO muscle insertion 3 mm nasal to the first suture (Figure 2).

Initially, dissolving Vicryl sutures were used, until it was found that the stretched posterior temporal fibers of the IO muscle occasionally slipped (ie, retracted) over time. Similar to traditional anterior transposition of the IO, the posterior temporal fibers are stretched from their normal 10-mm length to approximately 16 mm from the ancillary origin at the NFVB to the new insertion. Chronic tension on these fibers may cause the temporal aspect of the new insertion to retract posteriorly when the suture dissolves. This may also occur if the attached fibers have been devitalized with a crushing hemostat during detachment from the original insertion. This phenomenon has been reported in tight IR muscles associated with surgery for thyroid myopathy, and we have also observed it frequently on close examination of patients who underwent surgery a second time after traditional IO anterior transposition. Further problems of posterior retraction of the fibers were avoided by using a 6-0 Mersilene (Ethicon, Somerville, NJ) permanent woven suture and by taking care to preserve the viability of the insertional end of the IO muscle through use of the Beauchamp IO muscle clamp.

RESULTS

The degree of ANT performed in each eye—indicated by the placement of the new insertion in millimeters (in both nasal-temporal and anterior-posterior directions) from the nasal border of the IR as well as alignment in primary position at follow-up—is given in Table 1. Follow-up ranged from 3 weeks to 24 months (median, 8 months). Changes in the signs of abnormalities are shown in Table 2. Note that torsion was assessed through funduscopy in some patients and through sensory testing (double Maddox rod) in others. The ANT procedure was generally successful with some significant exceptions. A description of the results according to main diagnosis is provided below.

Superior Oblique Weakness

Ten patients presented with typical findings of SO muscle palsy. In 4 of the 5 patients in whom the SO muscle weakness was caused by a congenital 4th-nerve palsy (patient nos. 1 through 4), ANT was the first muscle correction surgery and resulted in improvements in head tilt, torsion, increased adduction, exotropia in up gaze, and esotropia in down gaze. In the last patient with congenital SO muscle palsy, ANT resulted in further improvement of residual IO muscle overaction after previous IO muscle recession. Two of the patients with congenital SO muscle palsy showed a limitation of elevation at follow-up. No

TABLE 1. Patient characteristics, treatment, preoperative and postoperative motility, and alignment

Patient No.	Age (y)	Diagnosis and Previous Muscle Surgery	Oblique Muscle Action IO	Oblique Muscle Action SO	Alignment in 1° Gaze (△)	Other Significant Preoperative Findings	ANT: New Insertion (mm)	Follow-up (mo)	Alignment in 1° Gaze (△)
SO Weakness									
1	2	Congenital SOP	+4 OD	−3 OD	18 RHT		2N, 2P (OD)	4.7	Ortho
2	6	Congenital SOP	+4 OU	−4 OU	8 ET	V-pattern	2N, 2P (OU)	6.1	2 ET
3	69	Congenital SOP	+4 OS	−4 OS +4 OD	6 XT 36 LHT		3N, 3P (OS)	19.0	20 LH(T)
4	3	Masked congenital SOP	+3 OS	−3 OS +2 OD	16 LHT		2N, 2P (OU)	10.8	4 ET
5	11	Congenital SOP; IO overaction after recession IO	+3 OU	−2.5 OU	15 XT 18 RHT	In left gaze: 30 RHT	0N, 3P (OD)	1.5	8 RH(T)
6	3	Left SO absent; IO overaction after recession IO	+3 OS	−3 OS	Ortho		2N, 2P (OS)	8.0	Ortho
7	3	Apert syndrome; right IR & both SO absent, recession right IO	+3 OU	Not graded	Ortho		3 mm inf to MR (OU)	20.9	Ortho
8	79	Residual SOP after retinal detachment surgery, Harada-Ito	None	Not graded	Ortho		3N, 3P (OS)	7.5	Ortho
9	50	Residual SOP after removal hemangioblastoma, bilateral Harada-Ito, bilateral MR recession	+2 OD +1 OS	−2 OS −3 OD	5 RHT		3N, 3P (OD) 3N, 0P (OS)	12.6	2 ET
10	15	SOP after removal arteriovenous brain malformation; recession IO	+2 OS	−2 OS	18 XT 4 LHT		0N, 6P (OS)	8.2	Ortho
Primary IO Overaction									
11	2	Primary IO overaction	+4 OU	−2 OD −1 OS	6 RHT	DVD	2N, 2P (OU)	6.5	4 ET
12	4	Residual IO overaction after bilateral AT IO	+2.5 OD +2 OS	−2.5 OD −2 OS	12 ET	DVD	2N, 3P (OU)	1.5	12 XT
13	8	Ocular albinism; IO overaction after multiple oblique surgeries	+2 OS	None	20 XT 10 LHT	Nystagmus	0N, 0P (OS)	13.7	Ortho
14	15	Recurrent IO overaction after bilateral IO myotomy	+3 OD +4 OS	−3 OU	6 E	V-pattern	2N, 3P (OU)	0.8	6 ET
AES									
15	4	AES after bilateral AT IO, nasal myectomy right IO	+2 OD	−2 OD	4 ET	DVD	2N, 2P (OD) 2N, 3P (OS)	1.0	Ortho
16	15	AES after bilateral AT IO	None	None	8 X(T)	V-pattern; DVD	2N, 2P (OU)	10.6	1 RHT
Duane Syndrome									
17	41	Duane syndrome with upshoot in adduction	+2 OD +4 OS	−1.5 OU	30 XT 25 LHT	In right gaze: 25 XT, 42 LHT	2N, 2P (OS)	6.8	4 X
18	16	Duane syndrome with up- & downshoot in adduction	+4 OS	+3 OS	6 X		2N, 0P (OS)	9.2	Ortho
Y-pattern XT									
19	8	Y-pattern XT	+4 OU	+3 OD +2 OS	Ortho	In up gaze: 30 XT	4N, 3A (OU)	23.8	Ortho
Post Retinal Detachment									
20	46	Torsional diplopia, RHT after retinal detachment surgery	+1 OD	+1 OS	15 RHT		2N, 2A (OD)	2.7	8 XT 3 HT

Abbreviations: IO, inferior oblique; SO, superior oblique; SOP, superior oblique palsy, OD, right eye; RHT, right hypertropia; N, nasal; P, posterior; ortho, orthophoria; OU, ooo; ET, esotropia; IOS, left eye; LHT, left hypertropia; XT, exotropia; MR, medial rectus; DVD, dissociated vertical deviation; E, esophoria; AES, antielevation syndrome; AT, anterior transposition; IR, inferior rectus; X, exophoria; A, anterior.

surgery was performed on the SO muscles in these patients.

In patient number 6, it was established during previous surgery that the left SO muscle was absent. ANT resulted in further improvement of the residual IO muscle overaction after the IO muscle had previously been recessed (see also the earlier case report[15]). This patient developed a mild amount of hyperphoria ($6^{\triangle}$ LH). In patient number 7, who had Apert syndrome, previous surgery had shown that the right IR muscle and both SO muscles were absent. A rather extreme degree of ANT in this patient placed the insertion of the IO muscle 3 mm inferior to the insertion of the medial rectus muscle and was followed by late undercorrection on the right side. Subsequent surgery identified posterior retraction of the posterior temporal fibers of the right IO muscle. Repeat ANT surgery using

TABLE 2. Preoperative and postoperative signs

Patient No.	Elevation in Adduction		Up gaze XT		Abnormal Head Posture		Torsion	
	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative*	Postoperative
SO Weakness								
1	X	Eliminated			X	Eliminated		
2	X	Improved					X (Fundus)	Eliminated
3	X	Eliminated	X	Eliminated	X	Occasional	X (DMR)	Improved
4	X	Eliminated			X	Eliminated		
5	X	Improved			X	Eliminated		
6	X	Eliminated			X	Eliminated		
7	X	Eliminated						
8					X	Eliminated	X (DMR)	Eliminated
9	X	Eliminated					X (DMR)	Improved
10	X	Eliminated			X	Eliminated	X (DMR)	Eliminated
Primary IO Overaction								
11	X	Eliminated	X	Eliminated			X (Fundus)	Eliminated
12	X	Improved						
13	X	Improved			X	Persisting		
14	X	Improved						
AES								
15	X	Improved	X	Improved				
16			X	Improved			X (Fundus)	Eliminated
Duane Syndrome								
17	X	Eliminated	X	Eliminated	X	Only at near		10° intorsion (DMR & fundus)
18	X	Eliminated						
Y-pattern XT								
19			X	Improved				
Postretinal Detachment								
20	X	Improved					X (DMR)	Improved

Abbreviations: XT, exotropia; SO, superior oblique; X, exophoria; DMR, double Maddox rod; IO, inferior oblique; AES, antielevation syndrome.
*The technique that was used to assess signs of torsion is indicated in parentheses.

Mersilene permanent sutures eliminated the increased adduction.

ANT successfully corrected SO muscles palsies that developed after retinal detachment surgery, brain tumor removal, and resection of an arteriovenous malformation in the brain after previous, unsuccessful Harado-Ito procedures (patient numbers 8 and 9) and IO recession (patient number 10). Increased adduction and abnormal head posture were eliminated in these patients, and significant improvements in extorsion were achieved.

Primary Inferior Oblique Overaction

In all 4 cases of primary IO muscle overaction, ANT successfully improved increased adduction (patient numbers 11 through 14) and eliminated extorsion and exotropia in up gaze in patient number 11. Patient number 12 appeared successfully treated but after 6 weeks of follow-up developed a mild exotropia in the primary position as well as up and down gaze. The head posture in patient number 13 persisted after a rather small degree of ANT. As in all types of anterior transposition procedures, these patients showed limitation of elevation to approximately 35° in all horizontal gaze positions. Three of these patients had previously undergone other IO-weakening procedures.

Antielevation Syndrome

Two patients presented with AES secondary to previous anterior transposition of the IO muscles (patient numbers 15 and 16). In patient number 15, it was concluded during surgery that the apparent AES on the left (ie, pseudo-overaction of the right IO muscle) was being caused by posterior slippage of the right IO muscle. The anterior transposition in the right eye was then converted to an ANT, which corrected the problem. In patient number 16, ANT did not help decrease DVD, but it greatly decreased XT in up gaze and improved fundus torsion.

Duane Syndrome

Two patients, both with increased adduction, presented with type II Duane syndrome (patient numbers 17 and 18). ANT successfully eliminated increased adduction (decreasing overaction of IO muscles by approximately 60% in patient number 17 and by 100% in patient number 18), but it induced some intorsion in up gaze in patient number 17. Before surgery, patient number 18 showed both upshoot and downshoot in adduction, and a 7-mm SO spacer was added to the ANT procedure. Unfortunately, after surgery the downshoot was worse. After dynamic high-resolution magnetic resonance imaging (MRI) showed abnormalities in the LR muscle pulley in adduction, posterior fixation sutures were placed, incorporating the upper and lower quarter of the LR muscle. This eliminated the downshoot in adduction.

Y-Pattern Exotropia

Patient number 19 presented with a Y-pattern exotropia with 30△ XT in up gaze, marked apparent overaction of both IO muscles, and mild overaction of the SO muscles. A denervation and extirpation procedure was considered, but because of the irreversible nature of that procedure and the mild amount of SO muscle overaction, we elected to do an enhanced ANT procedure instead (new insertion 4 mm nasal and 3 mm anterior to the IR muscle insertion). Unfortunately, the Y-pattern persisted after surgery, and 16△ XT in primary position developed. It was thought that abnormal innervation or an abnormality in the muscle pulley system could be the cause of the lack of response to the ANT procedure. A subsequent MRI study showed an angle deformity in both IR muscles posteriorly (Figure 4), which could be responsible for the exodeviation in primary gaze. Both LR muscles were then recessed, and the patient has been orthophoric in the primary position since then (presently 10 weeks of follow-up).

Posttreatment of Retinal Detachment

Apart from the 2 cases of SO muscle palsy secondary to retina and brain surgery described above, ANT was performed in an additional patient (number 20) with hypertropia, increased adduction, and excyclotropia after retinal detachment surgery. All symptoms significantly improved after the ANT procedure.

DISCUSSION

The action of the IO muscle in the primary position is extorsion and elevation. Overaction of the IO muscle is characterized by increased adduction. Stager[12,13] proposed that the functional origin of the posterior-temporal fibers of the IO muscle after anteriorization is located where the NFVB attaches to the muscle (Figure 2). As a result, the altered torque vector causes the globe to depress, abduct, and extort on contraction. The technique described in this article places the insertion of the IO muscle on the nasal side of the IR muscle (and thereby nasal to the y-axis and anterior to the x-axis of Fick), thus placing the posterior temporal fibers of the IO muscle (from the NFVB to the insertion) in a direction that is anterior and nasal from the ancillary origin. This results in a torque vector that causes the globe to intort and adduct (instead of extort and abduct) on contraction and converts the IO muscle into a tonic depressor and antielevator (Figure 3).

The typical degree of ANT that was applied in these patients was 2 mm nasal to the IR muscle nasal border and 2 mm posterior to the IR muscle insertion. However, the group of patients was rather heterogeneous, and different effects were intended in different patients. Therefore, several patients received different dose degrees of ANT (Table 2). After a median of 8 months follow-up, we found that ANT resulted in (1) decrease in elevation in adduction; (2) decreased extorsion, especially in up gaze but also in primary gaze and down gaze; (3) tonic depression and antielevation similar to that seen after traditional anterior transposition procedures; (4) improvement in abnormal head posture in patients with severe SO muscle palsy or recurrent SO muscle palsy after other procedures; and (5) improvement in V-pattern deviations in up gaze. We have found ANT to be helpful for patients with SO muscle palsy, severe elevation in adduction, Duane syndrome with innervational upshoot, and AES.

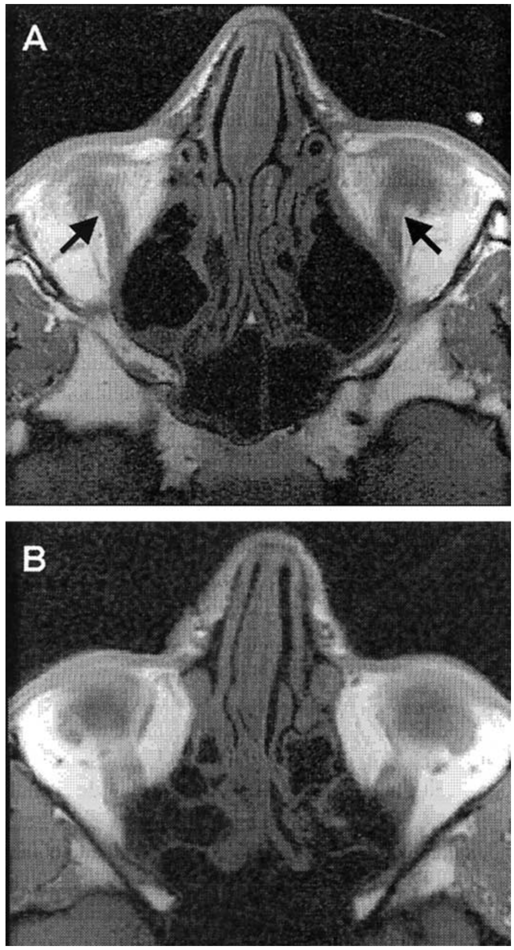

FIG 4. A, High-resolution magnetic resonance imaging scan showing angle deformities in the IR muscles (black arrows) in patient 19 after enhanced ANT procedure. The IO muscle was inserted 4 mm nasal to the IR muscle insertion. B, A comparable image from a normal subject. IR, inferior rectus; ANT, anterior and nasal transposition; IO, inferior oblique.

This series also revealed a number of risks: First, although effective for the treatment of SO muscle palsy, ANT limits elevation. The effects of ANT on alignment are more pronounced in up gaze than in down gaze, thereby causing the risk of inducing intorsion and esotropia in up gaze. Second, although effective in eliminating innervational upshoot in patients with Duane syndrome, ANT may make the downshoot worse if there is a mechanical cause (pulley abnormality) to the upshoot and downshoot. Third, intorsion in up gaze occurred in 1 patient, although we generally do not find this to be a problem in patients whose occupation does not require binocular vision in up gaze. Fourth, ANT appears not to be helpful in patients with Y-pattern XT. Complications include exotropia when the muscle is placed far (4 to 5 mm) nasal to the IR muscle nasal border, causing a distortion of the IR muscle belly by the nasal shift of ancillary origin of the IO muscle. The lack of success in Y-pattern XT may be an indication that the Y-pattern is not related to abnormal functioning of the IO muscle but perhaps to abnormal innervation comparable with Duane syndrome. Finally, ANT may not be successful after multiple strabismus surgeries.

The ANT procedure was performed with success both unilaterally or bilaterally. In the patients who underwent unilateral ANT, no specific problems in up gaze were found except in patient no. 6, who developed mild hyperphoria in up gaze. Limitations of elevation were noted in several unilateral and bilateral cases.

In an attempt to explain unsuccessful ANT in 2 patients in this series, high-resolution MRI images of the extraocular muscles were obtained. In one case, after a markedly enhanced procedure, postoperative XT in the primary position was attributed to an angle deformity in the IR muscles; in the other case, MRI showed an abnormality in the LR muscle pulley. Because MRI results were not available for the other patients in this series, the incidence and significance of angle deformities in the IR muscle belly remains unclear. We do not know whether in fact this occurs only with the enhanced ANT technique or if it may also occur with the "standard" ANT technique, which so far has not caused an XT shift in the primary position. We advise against reattaching the inferior temporal fibers of the IO muscle further nasally than the proposed 2 mm that we have determined to be safe.

CONCLUSION

ANT of the IO muscles may be an effective procedure to weaken and reverse the action of the IO muscle when other IO muscle weakening procedures fail, and it also may be used for severe or recurrent IO muscle overaction. It is an effective procedure for increased adduction, torsion, and head tilt. It may be indicated when other techniques have failed or are deemed destined to fail, eg, the SO for patients in whom muscle is absent. We stress that this is a new procedure and that it should not replace current proven surgical techniques. In particular, we believe that in most cases of SO muscle palsy and IO muscle overaction, the first-choice treatment should consist of established procedures for weakening the IO muscle and strengthening the SO muscle. Further evaluation will be needed until we find an appropriate niche for ANT in our surgical armamentarium.

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