Dual-Augmented Transposition of Vertical Recti in Chronic Abducens Palsy

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• PURPOSE: To report the results of dual augmentation of vertical rectus muscle transposition (VRT) in the treatment of chronic sixth nerve palsy.
• DESIGN: Retrospective case series.
• METHODS: This is a retrospective review of medical records of patients with chronic sixth nerve palsy who underwent dual augmented VRT with or without medial rectus (MR) recession from 2013 to 2016. Data collection included sex, age, laterality, and duration of postoperative follow-up. Pre- and postoperative limitation of abduction and adduction were recorded using a 6-point scale. Improvement of esotropia in prism diopter (PD), head turn in degrees, and limitation of abduction and adduction were reported and analyzed.
• RESULTS: Fourteen cases were identified. Mean patients' age at the time of surgery was 22.5 years. Postoperatively, esotropia and head turn were corrected by a mean of 31.3 PD and 18.2 degrees, respectively. Limited abduction was improved from -4.3 to -1.6, while in cases that underwent MR recession, adduction declined from 0.4 to -0.3. Postoperative induced small-amplitude hypertropia was reported in 3 cases.
• CONCLUSION: Dual augmented VRT was effective in controlling esotropia, head turn, and limited abduction associated with chronic sixth nerve palsy with low rate of induced vertical deviation. Combined MR recession carries a risk of induced limitation of adduction. (Am J Ophthalmol 2019;197:59–64. © 2018 Elsevier Inc. All rights reserved.)

LATERAL TRANSPOSITION OF VERTICAL RECTI (VRT) to the edges of the paralyzed lateral rectus (LR) muscle has been described as the method of choice to overcome diplopia, primary position esotropia, and limitation of abduction secondary to chronic sixth nerve palsy.[1] In many circumstances, the transposition is combined with weakening, either pharmacologic (botulinum toxin injection) or surgical (recession), of the ipsilateral medial rectus (MR) muscle, especially in case of significant MR contracture.[2] The transposition procedure itself could be either total muscle transposition or partial tendon transposition. The latter technique was adopted to decrease the incidence of anterior segment ischemia, especially when simultaneous ipsilateral MR recession would be planned.[3]

Various surgical modifications were described to augment the effect of the transposition procedures; they include posterior scleral fixation suture (Foster's modification) of the transposed muscle near the edge of the LR muscle,[4] suture union of the transposed VR muscle to the LR muscle (Wright's modification),[5] and resection of a segment of the transposed VR muscle.[6]

In the current patient series, we combine 2 modifications (Foster and Wright) to augment partial VRT in management of chronic sixth nerve palsy, with documentation of the effect of this dual-type augmentation on associated esotropia and limited abduction. To our knowledge, this dual augmentation has not described in strabismus literature so far.

PATIENTS AND METHODS

AFTER APPROVAL FROM THE ETHICAL COMMITTEE OF Benha University Hospital affiliated to Benha University, medical records of all patients with chronic nonresolving sixth nerve palsy of more than 6 months duration who underwent dual-type augmented partial VRT between 2013 and 2016 were retrospectively reviewed. Patients who underwent simultaneous ipsilateral MR recession at the time of dual augmented VRT were also included. Patients were excluded if there was a history of previous strabismus surgery with less than 6 months postoperative follow-up, together with those associated with other cranial nerve palsies. Fourteen patients who were operated during that period were identified and were included in the final data analysis. All included patients had complete abducens palsy, as evident by very minimal to no abduction force on forced generation test and floating saccades.

Patients' characteristics were obtained, including age at the time of surgery, sex, laterality of the condition, etiology of palsy, duration of condition, previous treatments, concurrent associated surgery on ipsilateral MR muscle, and duration of follow-up. All patients were subjected to complete ophthalmic and orthoptic examinations both preoperatively and postoperatively. Angle of esotropia in the forced primary position was measured using alternate prism

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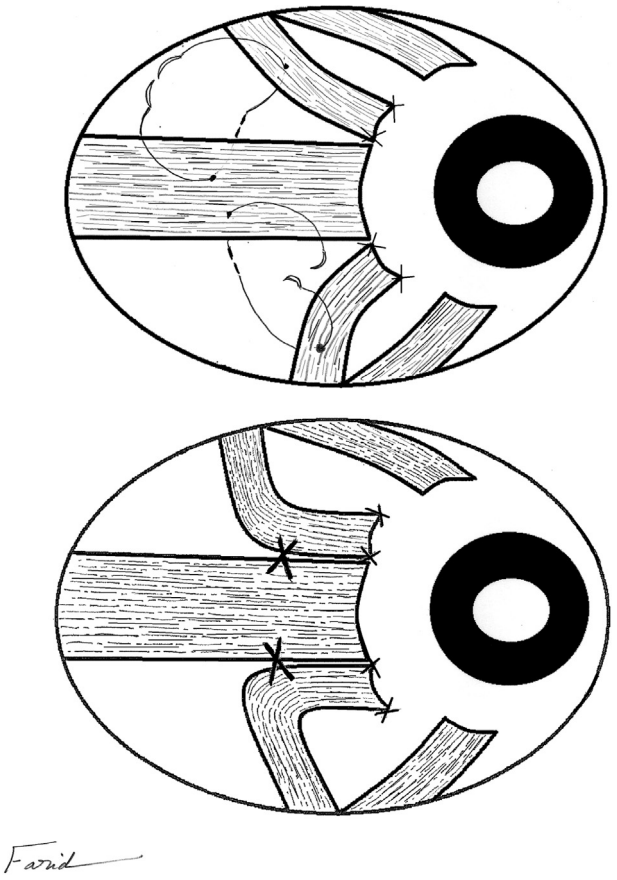

FIGURE 1. Graphical drawing of dual-augmented vertical rectus muscle transposition. (Top) After the split halves of vertical recti were sutured to the sclera adjacent to lateral rectus muscle insertion, a double-armed 5-0 polyester suture was used to join each transposed half of the vertical rectus muscle with the lateral rectus muscle, including a scleral path 10 mm posterior to the insertion and adjacent to the edge of the lateral rectus muscle. (Bottom) After the suture was tied, the 2 muscles were aligned and approximated to a point that extended posterior to the site of suture placement.

cover test. Degree of limitation of abduction was assessed on a scale from -1 to -6, where -6 refers to inability of the eye to move from the adducted position, -5 refers to an eye that moves from adducted position but is unable to reach the midline, -4 refers to an eye that reaches the midline but is unable to proceed further, and the rest of the scale is the same as the traditional one.[7] Compensatory abnormal head posture in the form of head turn was measured and documented using an orthoptic goniometer with 5-degree scale while the patient was fixating a distant accommodative target. Records of intraoperative and postoperative complications were also obtained.

All patients underwent the surgical procedure of dual augmented partial lateral transposition of both vertical recti, which was combined with ipsilateral weakening of the ipsilateral antagonist MR muscle if intraoperative forced duction test revealed significant MR contracture. All procedures were performed under general anesthesia using a limbal approach and no adjustable sutures were used in all patients. Forced duction test was performed as the first step in all cases and if MR contracture was encountered, the MR was traditionally recessed through the limbal conjunctival incision in an amount great enough to free the restriction. Through limbal conjunctival periotomy, the superior and inferior recti were reached, hooked, and freed from the surrounding Tenon capsule and fascia. Each muscle was then vertically split using a pointed hook approximately 14 mm posteriorly; care was taken to include 1 anterior ciliary vessel in each half. A double-armed 6/0 polyglactin suture was passed through the temporal half of each VR muscle close to its scleral insertion before it had been disinserted from the sclera. The temporal half of each VR muscle was then laterally transposed and fixed to the sclera along the spiral of Tillaux above and below the paralyzed LR muscle (Figure 1, Top).

Dual augmentation of the transposition was then performed. The needle of a double-armed nonabsorbable 5/0 polyester suture was passed through the temporal half of the transposed vertical muscle segment 10 mm posterior to its new insertion, then through the sclera close to the edge of the LR muscle, and finally through the corresponding peripheral one third of the paretic LR muscle (Figure 1, Top). In addition to posterior fixation of the transposed muscle, the suture—when tied—approximated and aligned the transposed VR muscle segment to the LR (Figure 1, Bottom). Care was taken to ensure that there was no remaining gap between the LR muscle and the transposed VR muscle segment. Finally, the conjunctiva was closed by interrupted 8/0 polyglactin sutures.

At each follow-up visit, angle of deviation in the forced primary position was measured. In addition, degree of head turn and limitation of abduction were also assessed and documented. Careful slit-lamp examination of the anterior segment was performed at each visit to detect any signs of anterior segment ischemia. Statistical analysis was performed using statistical software (StatLab, SPSS for Windows V.17.0. Chicago: SPSS Inc.). The paired *t* test was used to compare pre- and postoperative values; a *P* value less than .05 was considered significant.

RESULTS

PATIENTS' CHARACTERISTICS TOGETHER WITH PRE- AND postoperative findings are summarized in Table 1. Out of the trial's 14 patients, 9 patients were male and all cases were unilateral, with involvement of the right eye in 8 patients. Mean age of patients at time of surgical interference was 22.5 (range 4-63) years. Trauma was the leading cause of sixth nerve palsy (9 cases, 64.2%). The remaining causes were vascular and congenital (2 cases each, 14.2%) and

TABLE 1. Patients' Characteristics With Preoperative and Postoperative Data

					Preoperative					Postoperative						
Patient No.	Age (y)	Sex	Side	Etiology	Deviation	Head Turn (Degrees)	Abd.	Add.	Diplopia	Deviation	Head Turn	Abd.	Add.	Diplopia	MRR	FU
1	13	M	OD	Traumatic	25ΔET	20	-3	0	Y	2ΔET	0	-1	0	N	4	9
2	11	M	OD	Traumatic	40ΔET	30	-6	1	Y	10ΔET	10°	-2	-1	N	5.5	6
3	9	M	OD	Traumatic	50ΔET	45	-6	1	Y	12ΔET	5°	-3	0	N	5.5	7
4	12	F	OS	Traumatic	30ΔET 2ΔHT	30	-5	1	N	-2ΔXT 4ΔHT	0	-1	-2	N	5	6
5	48	M	OD	CCF	60ΔET 4HT	0	-6	0	N	15ΔET 4HT	0	-2	-1	N	6	11
6	33	F	OS	Inflammatory	30ΔET	15	-4	0	Y	-4ΔXT	5°	-1	0	N	4	10
7	21	M	OS	Traumatic	40ΔET	20	-3	0	Y	5ΔET	0	-2	0	N	4.5	8
8	8	F	OD	Congenital	20ΔET	20	-4	0	N	-5ΔXT	5°	-2	0	N	0	6
9	14	M	OS	Traumatic	45ΔET	30	-5	1	Y	10ΔET	5°	-3	-1	N	5.5	6
10	63	M	OD	CVS	30ΔET	15	-3	0	Y	8ΔET	5°	-1	0	N	4	7
11	4	F	OS	Congenital	35ΔET	20	-4	0	N/A	-4ΔXT 2HT	0	-1	0	N/A	4	6
12	42	M	OD	Traumatic	40ΔET	25	-5	1	Y	6ΔET 2HT	5°	-2	0	N	4.5	6
13	12	M	OD	Traumatic	30ΔET	15	-4	0	Y	4ΔET	0	-1	0	N	0	6
14	26	F	OS	Traumatic	25ΔET	15	-3	0	Y	5ΔET	5°	-1	0	N	3	7

Abd. = abduction; Add. = adduction; CCF = carotid-cavernous fistula; CVA = cerebrovascular accident; ET = esotropia; FT = face turn; FU = follow-up (in months); HT = hypertropia; MRR = medial rectus recession in mm; N = no; N/A = not available; XT, exotropia; Y = yes.

TABLE 2. Mean and Ranges of Preoperative and Postoperative Values for Esotropia, Head Turn, and Ocular Duction

Item	Preoperative (Range)	Postoperative (Range)	Mean Change (Range)	*P* Value
ET (PD)	35.7 (20–60)	4.4 (5 XT to 15 ET)	31.3 (20–45)	<.0001
Head turn (degrees)	21.4 (0–45)	3.2 (0–10)	18.2 (0–40)	<.0001
Abduction	-4.3 (-3 to -6)	-1.6 (-1 to -3)	2.7 (1–4)	<.0001
Adduction	+0.4 (0 to +1)	-0.3 (0 to -2)	-0.7 (-3 to 0)	.0025

ET = esotropia; FT = face turn; PD = prism diopter; XT = exotropia.
Values are expressed as mean values.

inflammatory (1 case, 7%). Intraoperative forced duction test was found positive in 12 cases and those cases only underwent ipsilateral MR recession (mean 3.9 mm, range 3-6 mm). Preoperative diplopia was reported in 10 patients (71.4%) and all those patients showed elimination of their diplopia after surgery.

Esotropia in the forced primary position was improved postsurgically from 35.7 prism diopter (PD) (range 20-60 PD) to 4.4 PD (range 5 PD XT to 15 PD ET) ($P < .0001$). Head turn to the same side was corrected from 21.4 degrees (range 0-45 degrees) to 3.2 degrees (range 0-10 degrees) ($P < .0001$), while limited abduction was improved from -4.3 (range -3 to -6) to -1.6 (range -1 to -3) ($P < .0001$). Postoperatively, mean adduction had declined from +0.4 (range 0-1) to -0.3 (range 0 to -2) ($P = .0025$) (Table 2). Limited postoperative adduction was reported only in 4 cases (28.5%) and those were among patients who underwent simultaneous ipsilateral medial rectus recession (Figure 2, Bottom). Average postoperative follow-up was 7.2 months (range 6-11 months).

No intraoperative complications such as scleral perforation were reported in any patient. Postoperatively, 4 cases of defective adduction of ≤ -2 were developed and in those cases, the limitation was minimal (mean -1.2, range 0 to -2), which warranted no further actions. No cases of anterior segment ischemia were reported in any patient. Postoperative induced vertical deviation (hypertropia) was reported in 3 cases. The deviation was of small amplitude (mean 2.6 PD, range 2-4 PD) and therefore no further action was required.

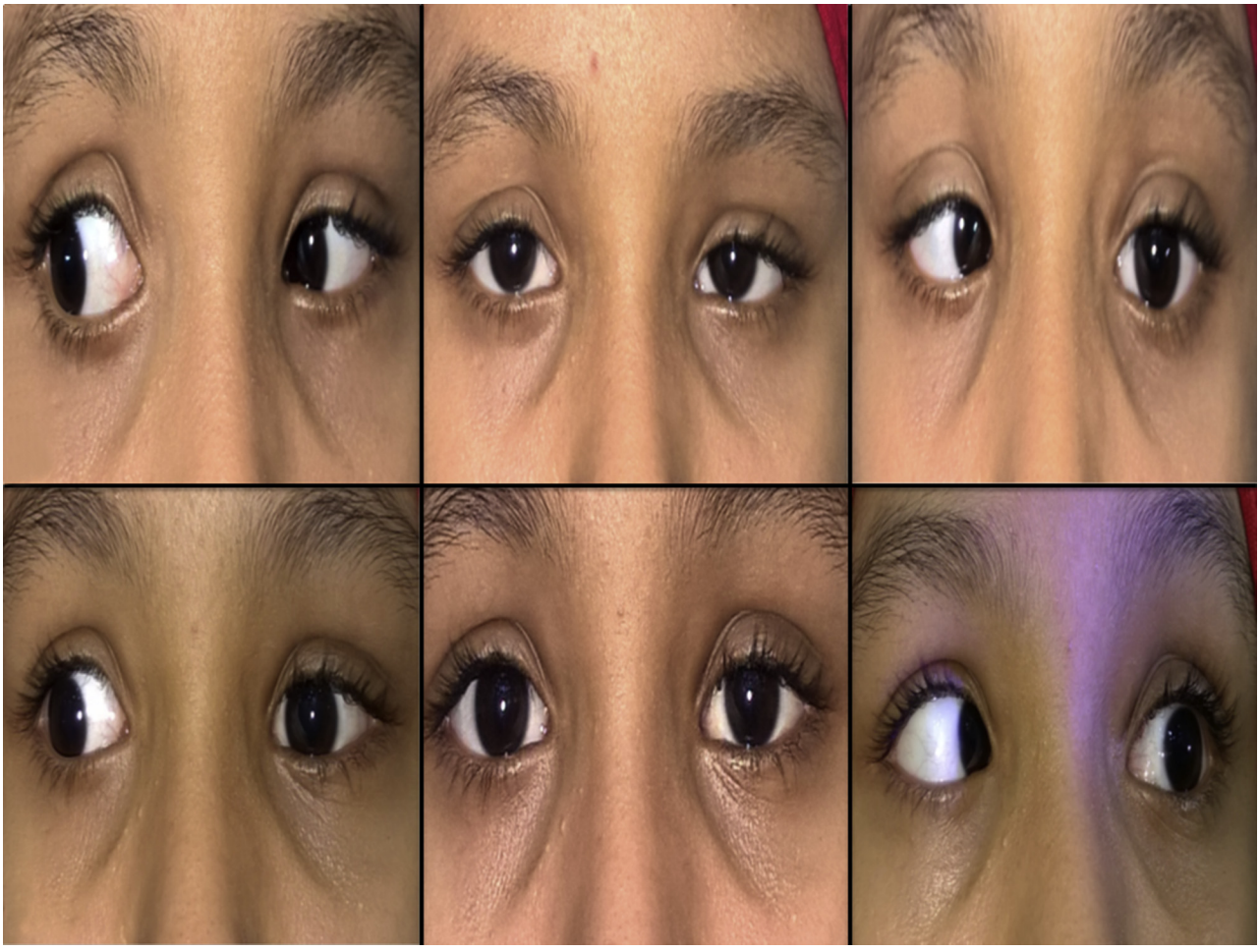

FIGURE 2. Color photographs of horizontal gazes in patient experiencing chronic abducens palsy. (Top) Preoperative photographs with 30 prism diopter esotropia and -5 limited abduction in the left eye. (Bottom) Postoperative photographs showing orthotropia and improvement of abduction to -1 with induced limitation of adduction of -2 in the left eye.

DISCUSSION

VERTICAL RECTUS MUSCLE TRANSPOSITION, EITHER TOTAL or partial, is a well-established form of surgical intervention for treatment of esotropia and limited abduction associated with chronic sixth nerve palsy.[2] In order to enhance the effect of the transposition procedure, various forms of augmentation were proposed. In 1997, Foster introduced augmentation of vertical muscle transposition by posterior fixation of the transposed muscle to the sclera close to the border of lateral rectus muscle.[4] In 2000, Brooks and associates performed augmentation of VRT by resecting a 4-mm segment of the vertical recti before scleral attachment.[6] Wright in 2007 introduced another modality of augmentation of VRT by uniting the transposed vertical rectus muscle to the LR without scleral attachment.[5] In our patient cohort, we review the result of a dual augmentation by combining Foster's idea of posterior scleral fixation with Wright's posterior muscle union in treatment of esotropia and limited abduction secondary to chronic sixth nerve palsy. We have found the new dual-type augmentation very useful in correction of esotropia, abnormal head position, and abduction limitation associated with chronic abducens palsy.

In the Foster trial,[4] ET was improved by a mean value of 37 PD while average limitation of abduction improved from -4.4 to -2.7 following full vertical recti transposition augmented with posterior fixation suture. Britt and associates[2] showed the results of partial vertical rectus transposition augmented with posterior (Foster) fixation suture in 5 patients with sixth nerve palsy. Mean deviation in the primary position was improved from 45.2 PD ET to 5 PD XT with correction of abduction from -3.1 to -0.5. In Brooks and associates' trial,[6] the ET was improved by an average of 42.6 PD after combined 4-mm resection and partial transposition of vertical recti. The same strategy was applied by Couser and associates[8] and revealed an average 37 PD improvement of ET and correction of limited

abduction from -4 to -3. In 2015, Gonzales and Kraft compared 3 transposition procedures in management of sixth nerve palsy, namely, full tendon vertical rectus transposition, full tendon transposition augmented with 4-mm tendon resection, and full vertical rectus transposition augmented with posterior fixation suture. The average correction of ET was 36, 46.4, and 41.3 PD while mean improvement of abduction was 0.94, 1.64 and 1.41, respectively.[9] In the current trial, the mean correction of ET is 31.3 PD and average improvement of abduction is 2.7.

It has been postulated that lateral transposition of vertical recti to the paralyzed LR muscle would increase the net abducting force actively via an increase in the tonic abduction force and passively through an increase in the muscle path course.[10] However, Foster claimed that the gap between the transposed muscle and the LR would hamper the transposition effect and closing the gap with an equatorial suture would accentuate the abducting force vectors.[4] It was shown by magnetic resonance imaging studies that orbital connective tissue sheets have resulted in minimal displacement of the transposed muscles, especially in the posterior orbit, which was overcome by posterior augmentation suture.[11,12] These studies showed that placement of the posterior fixation suture shifted large parts of the transposed muscle, which became parallel with the paretic LR muscle. However, it was assumed by Foster that the effect of posterior fixation suture in aligning the transposed vertical muscle with the LR muscle extends posterior to the site of placement of the suture.[4] We do agree with Foster's assumption that muscle alignment induced by posterior fixation suture, especially when coupled with muscle-to-muscle union, could extend posterior to the site of suture placement (Figure 1, Bottom).

There are few articles in strabismus literature that studied the effect of Wright augmented vertical recti transposition. In this method, the VRT is augmented by approximation of the transposed VR and LR muscles by posterior nonabsorbable sutures without a scleral attachment. By such method of augmentation, the paretic muscle tension would increase, which leads to more lateralization of force vector.[5] Mehendale and associates in 2012 reviewed their results with superior rectus transposition augmented with Wright's muscle union suture in management of a composite group of patients with sixth nerve palsy and esotropic duane retraction syndrome. In 3 out of 17 patients, the muscle belly union augmentation was coupled with an adjacent scleral pass, though the authors did not specify the exact location of the scleral pass relative to the border of the lateral rectus muscle.[13] In 2016, Singh and associates reviewed the result of Wright's augmentation combined with 4-mm VR muscle resection in treatment of 15 patients with chronic sixth nerve palsy.[14] In their trial, the combined augmentation procedure has resulted in improvement of esotropia from 58 to 7.2 PD, with 8 cases of postoperative residual esotropia (3 cases were more than 10 PD ET) and 6 cases of postoperative consecutive exotropia. Interestingly, they had 4 cases with preoperative significant vertical deviation (mean 6.25 PD) and in 2 of them they modified their approach by performing the resection on only 1 vertical rectus muscle for fear of more accentuation of their preoperative vertical deviation. Finally, they had an induced vertical deviation of less than 4 PD in 2 patients.

The dual-augmentation approach has some advantages. First, the isolated posterior fixation suture approximates only the VR muscle fibers anterior to its placement and aligns them with the LR muscle. When a muscle union suture (Wright's) was added, it brought more amounts of muscle fibers, even posterior to the suture placement, to be aligned with the LR muscle and therefore increased the abducting tonic force generated by the procedure of transposition. Second, muscle union allows muscle approximation even if the lateral fixation suture was inadvertently placed more anteriorly owing to difficult access. Third, the scleral fixation of muscle union allows for better alignment of the transposed muscle. If muscle union is not to be coupled with scleral fixation, approximation of LR to the transposed VR muscle may occur in the opposite direction; that is, the LR approximates the VR muscle instead of the reverse. Therefore, scleral fixation forces the transposed VR muscle to approximate the LR and hence the net force generated would be in the direction of action of LR.

Following augmented VRT, limitation of adduction has been reported in the current series as well as in previous reports.[2,15,16] For this reason, it was recommended by some authors that MR weakening should not be performed at the time of VR transposition. However, we believe that isolated VRT is likely to fail in the presence of significant MR contracture unless concurrent MR weakening is to be undertaken. To avoid the possibility of compromising adduction postoperatively, MR recession could be performed using adjustable suture technique. Postoperative limitation of adduction reported in the current series was of small magnitude that did not mandate an additional procedure.

In conclusion, the dual augmentation of VRT well controls esotropia, face turn, and limited abduction associated with chronic abducens palsy, with low incidence of postoperative induced new vertical deviations. Concurrent ipsilateral MR muscle weakening is advocated, especially in cases with longstanding MR contracture, as evident by positive FDT but with an incidence of induced limitation of adduction.

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REFERENCES

1. Rosenbaum AL, Kushner BJ, Kirschen D. Vertical rectus muscle transposition and botulinum toxin (Oculinum) to medial rectus for abducens palsy. *Arch Ophthalmol* 1989;107(6):820–823.
2. Britt MT, Velez FG, Thacker N, Alcorn D, Foster RS, Rosenbaum AL. Partial rectus muscle-augmented transpositions in abduction deficiency. *J AAPOS* 2003;7(5):325–332.
3. Saunders RA, Sandall GS. Anterior segment ischemia syndrome following rectus muscle transposition. *Am J Ophthalmol* 1982;93(1):34–38.
4. Foster RS. Vertical muscle transposition augmented with lateral fixation. *J AAPOS* 1997;1(1):20–30.
5. Wright KW. Color Atlas of Strabismus Surgery: Strategies and Techniques. 2nd ed. New York: Springer; 2007.
6. Brooks SE, Olitsky SE, de B Ribeiro G. Augmented Hummelsheim procedure for paralytic strabismus. *J Pediatr Ophthalmol Strabismus* 2000;37(4):189–195.
7. Farid MF, Elbarky AM, Saeed AM. Superior rectus and lateral rectus muscle union surgery in the treatment of myopic strabismus fixus: three sutures versus a single suture. *J AAPOS* 2016;20(2):100–105.
8. Couser NL, Lenhart PD, Hutchinson AK. Augmented Hummelsheim procedure to treat complete abducens nerve palsy. *J AAPOS* 2012;16(4):331–335.
9. del Pilar González M, Kraft SP. Outcomes of three different vertical rectus muscle transposition procedures for complete abducens nerve palsy. *J AAPOS* 2015;19(2):150–156.
10. Scott AB. Action force tests in lateral rectus palsy. *Arch Ophthalmol* 1971;85:397–404.
11. Miller JM, Demer JL, Rosenbaum AR. Effect of transposition surgery on rectus muscle paths by magnetic resonance imaging. *Ophthalmology* 1993;100(4):475–487.
12. Clark RA, Rosenbaum AL, Demer JL. Magnetic resonance imaging after surgical transposition defines the anteroposterior location of the rectus muscle pulleys. *J AAPOS* 1999;3(1):9–14.
13. Mehendale RA, Dagi LR, Wu C, Ledoux D, Johnston S, Hunter DG. Superior rectus transposition and medial rectus recession for Duane syndrome and sixth nerve palsy. *Arch Ophthalmol* 2012;130(2):195–201.
14. Singh P, Vijayalakshmi P, Shetty S, Vora P, Kalwaniya S. Double augmented vertical rectus transposition for large-angle esotropia due to sixth nerve palsy. *J Pediatr Ophthalmol Strabismus* 2016;53(6):369–374.
15. Coats DK, Brady-McCreery KM, Paysse EA. Split rectus muscle modified Foster augmented partial transposition procedure for paralytic strabismus: a report of 5 cases. *Binocul Vis Strabismus Q* 2001;16(4):281–284.
16. Paysse EA, Brady McCreery KM, Ross A, Coats DK. Use of augmented rectus muscle transposition surgery for complex strabismus. *Ophthalmology* 2002;109(7):1309–1314.