Superior or inferior rectus transposition in esotropic Duane syndrome: a longitudinal analysis

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PURPOSE To evaluate the results of superior rectus transposition (SRT) or inferior rectus transposition (IRT) in esotropic Duane syndrome.

METHODS The medical records of patients with esotropic Duane syndrome who underwent ciliary vessel–sparing SRT or IRT by a single surgeon in private practice were included. Pre- and postoperative head posture, primary position deviation, fundus torsion, collapse in pattern, and improvement in ductions were analyzed between groups.

RESULTS A total of 21 patients were included: 7 had a V-pattern esotropia and/or larger abduction deficiency in downgaze compared to upgaze and underwent IRT; 14 underwent SRT of which 6 had A pattern and/or larger abduction deficiency in upgaze compared to downgaze. Orthotropia within 10^{Δ} of esotropia was achieved in 10 patients (71.4%) with SRT and 4 patients (57.1%) with IRT. Pattern was reduced and abduction improved in all patients. The improvement in abduction was slightly better in elevation after SRT compared with IRT (1.7 ± 1 vs 1.4 ± 0.7; $P = 0.4$) and in depression after IRT compared to SRT (2 ± 1.2 vs 1.1 ± 0.7; $P = 0.05$).

CONCLUSIONS Both SRT and IRT procedures effectively correct the head posture and primary position deviation in esotropic Duane patients. SRT can be advantageous in patients with an A pattern or more limitation of abduction in elevation; IRT, in patients with a V pattern or more limitation of abduction in depression. (J AAPOS 2019;23:21.e1–7)

Esotropic Duane syndrome is a congenital cranial dysinnervation disorder characterized by the absence of abducens nerve and anomalous innervation of the ipsilateral lateral rectus muscle. The limitation of abduction, globe retraction, and lid fissure changes associated with adduction constitute the major diagnostic features of type 1 Duane syndrome.

Unilateral or bilateral medial rectus recessions have been widely used to correct ocular alignment and head turn in Duane syndrome; however, improvement in abduction is very limited, and adduction deficit may be created in cases with aberrant innervation of the lateral rectus muscle.[1-5] Attempts to find a surgical procedure that could improve the abduction and expand the field of binocular single vision have led to the development of a variety of vertical rectus transposition (VRT) procedures.[6-13] In 2006 Johnston and Crouch (Johnston SC, Crouch ER Jr, Crouch ER IOVS 2006;47:ARVO E-Abstract 2475) proposed superior rectus transposition (SRT) as a means to reduce the risk of anterior segment ischemia, and it was soon adapted by several surgeons for the treatment of Duane syndrome and abducens nerve palsy. In recent years the first author (ECS) has also used inferior rectus transposition (IRT) in select patients with Möbius syndrome,[14] esotropic Duane syndrome, and abducens nerve paralysis with V-pattern esotropia. The aim was to correct the pattern strabismus and to facilitate the reduced abduction capacity of downgaze compared to upgaze. Pattern strabismus is a common and relatively unheeded finding in Duane syndrome that can be caused by aberrant partial innervation of the lateral rectus muscle during up- or downgaze.[15] The purpose of this study was to evaluate the results of superior or inferior rectus transposition in esotropic Duane syndrome and to address the role of duction pattern in surgical planning.

Subjects and Methods

The medical records of consecutive patients with esotropic Duane syndrome who had undergone a single VRT procedure (SRT or IRT) with or without medial rectus recession between January 2013 and December 2017 were reviewed retrospectively. Preoperative measurements and surgeries were performed by a single surgeon (ECS). Patients with a minimum follow-up of 3 months were included in the analysis. The study was carried out with approval from the Institutional Review Board of Ankara Numune Education and Research Hospital and adhered to the

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Table 1. Patient characteristics in superior rectus transposition and inferior rectus transposition groups

	Group	
	SRT	IRT
Age, years, mean ± SD (range)	6.2 ± 5.6 (1.5-23)	10.6 ± 9 (2-28)
Male/female	10/4	5/2
Right/left/bilateral	1/12/1	4/3
Follow-up, mos	20 ± 16.8 (3-51)	16.6 ± 16.8 (3-49)
Previous surgery		
Ipsilateral MR recession[a]	—	2/7
BTX injection to ipsilateral MR	2/14	—
Simultaneous surgery		
Ipsilateral MR recession	8/14	6/7
BTX injection to ipsilateral MR	—	1/7
Ipsilateral LR recession	1/14	—

BTX, botulinum toxin-A; *IRT*, inferior rectus transposition; *MR*, medial rectus muscle; *SD*, standard deviation; *SRT*, superior rectus transposition.
[a]Surgery performed elsewhere.

European Good Clinical Practice Guidelines and to the Declaration of Helsinki.

The diagnosis of esotropic Duane syndrome involved the presence of congenital abducens nerve paresis together with any sign of aberrant innervation of globe retraction with lid fissure narrowing or up- or downshoot at adduction. Patients with hyperopia of >1.50 D (spherical equivalent) or significant astigmatism (>2.50 D) received full cycloplegic correction. The following data were collected from the patient records: laterality, age at the time of surgery, primary and secondary deviation at the primary position, A- or V-pattern measurement when possible, grade of ductions, degree of anomalous head posture, degree of globe retraction, fundus torsion, reoperations, and complications. Primary and secondary deviation were measured in the primary position by alternate prism cover test with appropriate correction in place at near and at distance. Krimsky testing was used for uncooperative subjects. The degree of head turn was determined using a goniometer in cooperative patients as an estimate of angle between the line of vision and the direction of the nose while the patient was viewing a 20/32 target at distance. Ocular ductions were recorded in nine positions of gaze on a scale of 0 to −5, with 0 indicating full motion and −5 indicating unable to reach the midline. Ocular alignment measurements taken at the last follow-up examination were used for reporting postoperative outcomes.

Ocular motility pattern determined surgical strategy. If the abduction capacity in elevation was equal to or worse than primary position or depression, SRT was performed. If abduction capacity at depression was worse than primary position or elevation, IRT. The difference of the abduction capacity in vertical gaze usually presented itself as pattern strabismus. Medial rectus recession was added for large deviations or significantly restricted medial rectus muscles.

The ciliary vessel–sparing SRT and IRT were performed via fornix approach under surgical microscope. The superior rectus muscle was carefully isolated and dissected from surrounding intermuscular septum and fascial attachments from the superior oblique. Special care was taken to dissect the lower lid retractors from the inferior rectus and not to expose fat tissue. Any sign of fat prolapse was used as an indication to embed the fat back into the Tenon's tissue with interrupted or mattress 8.0 polyglactin 910 sutures. The anterior ciliary vessels were dissected from the orbital surface of the vertical muscle from the insertion until they penetrated into the muscle about 6–10 mm back. The muscle was secured 2–4 mm from the insertion using a double-armed 6-0 polyglactin suture, and the muscle was resected. The amount of resection depended on the magnitude of the deviation as measured in the primary position and ranged between 2.0 and 4.0 mm. Resections ≥3.5 mm resulted in consecutive exotropia in some of our earliest cases. Thus, we mostly preferred 2 mm resection in deviations of $\leq 15^{\Delta}$, 3 mm or resection in deviations of 20^{Δ}-30^{Δ}, and 3.5–4.0 mm resection in deviations of $\geq 35^{\Delta}$. The resection amount was decreased in case of an accompanying medial rectus recession surgery. The stump of the muscle was removed following the transposition with Westcott scissors, with special care to preserve the vessels. The temporal edge of the vertical muscle was then reattached adjacent to the border of the lateral rectus muscle and the nasal edge of the vertical muscle to the temporal edge of its original insertion following the spiral of Tillaux. In an attempt to gain more abduction vector without increasing the amount of resection, the temporal edge of superior rectus muscle was further advanced 1–2 mm beneath the upper border of lateral rectus muscle in 2 patients (cases 2 and 6).

IRT entailed the same surgical steps as SRT. After transposition, the insertion of the inferior rectus muscle was placed along the spiral of Tillaux, between the lower edge of the lateral rectus muscle and the temporal edge of inferior rectus muscle insertions. In some cases the distance between the lateral rectus and the superior or inferior vertical rectus muscles was shorter than the width of the transposed muscle. Then, a third suture was used to align the sagging central portion of the transposed muscle along the spiral of Tillaux.

Forced duction testing was performed intraoperatively during various stages of the surgery in all patients. Depending on the amount of deviation in primary position and the tightness of the medial rectus muscle, an ipsilateral medial rectus recession was also performed in some cases (deviation $>15^{\Delta}$ in primary position). The surgeon (ECS) prefers a modified loose loop recession with nonabsorbable suture for the medial rectus muscle, especially in cases with aberrant lateral rectus innervation, to decrease the chances of overcorrection.

The ocular alignment measurements at final follow-up or at the last visit before a reoperation were used as postoperative outcome measures. Surgical success was defined as postoperative primary position deviation within 10^{Δ} of esotropia.

Statistical analysis were performed using SPSS Statistics 17.0 (SPSS Inc, Chicago, IL). Wilcoxon signed-rank test was used to analyze the pre- and postoperative findings on head turn, esotropia, and limitation of abduction. A P value of <0.05 was considered statistically significant.

Results

A total of 21 patients treated for esotropic Duane syndrome met inclusion criteria: 14 patients who underwent SRT and 7 who underwent IRT. The mean age at the time of surgery was 6.2 ± 5.6 years (range, 1.5-23 years) in the SRT group and 10.6 ± 9 years (range, 2-28 years) in the IRT group. The average postoperative follow-up was 20 ± 16.8 months (range, 3-51) for the SRT group and 16.6 ± 16.8 months (range, 3-49) for the IRT group. Patient characteristics are summarized in Table 1.

Of the 14 patients in the SRT group, 2 (cases 6 and 14) had undergone a botulinum toxin injection to the medial rectus muscle prior to surgery, and none had a history of previous muscle surgery. Eight patients in the SRT group underwent simultaneous medial rectus recession and 1 patient (case 7) underwent simultaneous recession of the lateral rectus muscle to correct the globe retraction. Of the 7 patients in the IRT group, 2 had a previous history of ipsilateral medial rectus recession: one (case 18) was treated with IRT alone; in the other (case 16), a medial rectus re-recession was added to the IRT surgery. Four patients had simultaneous medial rectus recession with IRT and 1 (case 20) had simultaneous botulinum toxin injection to the medial rectus muscle. Pre- and postoperative findings of all patients are provided in eSupplement 1 (available at jaapos.org).

In the SRT group, mean deviation in primary position improved from preoperative esotropia of 28.6$^{\Delta}$ ± 12.1$^{\Delta}$ (range, 15$^{\Delta}$-55$^{\Delta}$), to 5.8$^{\Delta}$ ± 10.1$^{\Delta}$ (range, 0$^{\Delta}$-35$^{\Delta}$) postoperatively ($P = 0.001$); 1 patient had postoperative exotropia of 12$^{\Delta}$. There was also a marked improvement after surgery in head turn (25.4° ± 7.7° vs 2.1° ± 6.4°; $P < 0.001$) and abduction (−4 ± 0.4 vs −2.6 ± 0.8; $P < 0.001$). Eight patients became orthotropic, 2 patients had esotropia of ≤10$^{\Delta}$ after surgery.

Three patients (cases 7, 8, 13) had residual esotropia of >10$^{\Delta}$ in the early postoperative period. Case 8 had undergone an SRT without a medial rectus recession that resulted in residual esotropia of 15$^{\Delta}$, and case 13 had undergone an SRT and 2 mm medial rectus recession that resulted in esotropia of 35$^{\Delta}$. Medial rectus recession surgery was planned for the treatment of residual esotropia in these patients. Case 7 had undergone a simultaneous lateral rectus recession surgery at the time of SRT to decrease the amount of retraction. This patient presented with an esotropia of 10$^{\Delta}$ and hypertropia of 6$^{\Delta}$ at postoperative week 1. At 2 months' follow-up hypertropia has resolved, leaving the patient with a residual esotropia of 15$^{\Delta}$. Residual deviation in this patient was subsequently treated with a single injection of botulinum toxin to the ipsilateral medial rectus muscle, resulting in orthotropia, which was maintained over 2 years' follow-up.

One patient in the SRT group (case 6) presented with an overcorrection of 12$^{\Delta}$ and hypertopia of 10$^{\Delta}$ after SRT and medial rectus recession surgery. This patient has recently underwent a second surgery. Spring back and forced duction tests during revision surgery revealed that SRT caused restriction toward adduction. She was treated with medial rectus advancement and 3 mm recession of the transposed superior rectus muscle parallel to the spiral of Tillaux, resulting in orthotropia at the first postoperative visit. Table 2 summarizes the changes in the motility pattern, esotropic deviation, and head turn following the SRT surgery.

In the IRT group esodeviation in primary position improved from a preoperative esotropia of 28.3$^{\Delta}$ ± 6.1$^{\Delta}$ (range, 18$^{\Delta}$-35$^{\Delta}$) to 8.7$^{\Delta}$ ± 7.7$^{\Delta}$ (range, 0$^{\Delta}$-20$^{\Delta}$) postoperatively ($P = 0.03$). One patient developed a postoperative exotropia of 25$^{\Delta}$. Mean preoperative head turn of 22.1° ± 3.9° (range, 15°-25°) reduced to 5.7° ± 6.1° (range, 0°-15°) postoperatively ($P = 0.03$). Abduction deficiency improved from −3.4 ± 0.4 to −2.1 ± 0.7 ($P = 0.02$). Two patients became orthotropic and 2 had 10$^{\Delta}$ of esotropia.

There were 3 cases (cases 15, 16, 18) with unsatisfactory outcome after IRT surgery. Case 15 had a preoperative esotropia of 30$^{\Delta}$ and was treated with IRT and slanted medial rectus recession that resulted in residual esotropia of 12$^{\Delta}$. Case 18 had a right esotropia of 35$^{\Delta}$ and a right hypotropia in primary position of 8$^{\Delta}$ following right medial rectus recession. Right hypotropia increased to 40$^{\Delta}$ on right gaze because of an abnormal innervation of the inferior rectus muscle. In an attempt to correct the right downshoot at right gaze the IRT procedure was slightly modified for this patient. The inferior rectus muscle was isolated and secured, as described previously, then disinserted with a 2.5 mm wedge-shaped resection on the temporal half. The temporal pole of the inferior rectus was reattached at the lower pole of lateral rectus muscle and the nasal pole of inferior rectus was reattached 3 mm behind the original temporal pole of the inferior rectus insertion. One 5.0 nonabsorbable polyester suture was placed through the sclera 6 mm posterior to the lateral rectus insertion to fix the temporal half of the inferior rectus muscle fibers temporally in order to augment the transposition effect. Postoperatively the hypotropia in right gaze due to aberrant innervation was significantly resolved but she still had a residual esotropia of 30$^{\Delta}$. We believe that the undercorrection occurred for two reasons. First, wedge resection of the inferior rectus was partial instead of complete. Second, the recession of the nasal pole of the inferior rectus muscle was performed with reference to the spiral of Tillaux. These two factors might have lessened the effect of IRT surgery. She was treated with botulinum toxin injection, which resulted in an esotropia of 20$^{\Delta}$ and a right hypertropia of 5$^{\Delta}$ at 8 months' follow-up. Case 16 had an esotropia of 35$^{\Delta}$ despite a previous medial rectus recession, and to augment the effect of the transposition surgery, IRT with 4 mm of resection and an ipsilateral medial rectus re-recession was performed. After surgery she developed a consecutive exotropia of 25$^{\Delta}$ and 10$^{\Delta}$ of right hypertropia. Medial rectus advancement was planned for this case; however,

Table 2. Comparison of clinical characteristics before and after SRT and IRT

	SRT			IRT		
Clinical characteristic[a]	Pre-op	Post-op	*P* value	Pre-op	Post-op	*P* value
A pattern ≥10 PD	6/14	1/14	—	—	—	—
V pattern ≥15 PD	—	—	—	7/7	3/7	—
Amount pattern	13.2 ± 18.2 (0-60)	3 ± 5.4 (0-15)	0.03	32.2 ± 15.6 (15-50)	12.3 ± 13.7 (0-35)	0.03
Eso in primary[b]	28.6 ± 12.1 (15-55)	5.8 ± 10.1 (−12[c] to 35)	0.001	28.3 ± 6.1 (18-35)	8.7 ± 7.7 (−25[c] to 20)	0.03
Head turn, deg	25.4 ± 7.7 (10-40)	2.1 ± 6.4 (−10 to 15)	0.001	22.1 ± 3.9 (15-25)	5.7 ± 6.1 (0-15)	0.03
Abduction deficiency	−4 ± 0.4	−2.6 ± 0.8	0.001	−3.4 ± 0.4	−2.1 ± 0.7	0.02
In elevation	−4 ± 0.7	−2.2 ± 1.1	0.001	−1.6 ± 0.7	−0.2 ± 0.4	0.02
In depression	−2.7 ± 1.1	−1.7 ± 0.9	0.001	−4.1 ± 0.5	−2.1 ± 1.3	0.02

ESO, esodeviation; *IRT*, inferior rectus transposition; *PD*, prism diopter; *SRT*, superior rectus transposition.
[a]Results reported as ratios indicate patient numbers; otherwise, results are mean values with standard deviation and range (in parentheses).
[b]The given means represent mean deviation after surgery in patients with postoperative orthotropia or esotropia.
[c]Deviation in patients with postoperative exotropia.

the patient's parents were satisfied with the current result aesthetically because of the coexisting negative angle kappa and declined further surgery. The overcorrection in this case led us to limit the medial rectus recession and lower our resection amount in VRT surgery. The first author's experience with intraoperative forced duction testing and postoperative outcomes led him to conclude that vertical rectus transposition with resection carries a highly restrictive component in its function that depends on the amount of resection.

Two patients in the IRT group (cases 16, 18) and 2 patients in the SRT group (cases 2, 6) developed hypertropia after the surgery. Hypertropia in case 2 resolved spontaneously in primary position but continued in downgaze. In case 6 it was treated with recession of the transposed superior rectus muscle parallel to the spiral of Tillaux.

Because the indication of IRT and SRT was based on the abduction capacity in elevation and depression, preoperatively limitation of abduction in elevation ($P = 0.001$) and depression ($P = 0.03$) differed significantly between groups (Table 2). Abduction was clinically improved as a reference to the vertical midline following with each of the transposition procedures in all cases. Motility improvement in lateral upgaze was slightly better in the SRT group than the IRT group (1.7 ± 1 vs 1.4 ± 0.7), and the motility improvement in lateral downgaze was slightly better in the IRT group than the SRT group (2 ± 1.2 vs 1.1 ± 0.7). However, these differences did not reach to a statistical significance. Figure 1 and Figure 2 show the motility pattern in cases 12 and 17 pre- and postoperatively.

Two cases had fibrotic band underneath the medial rectus insertion. These were 2–4 mm wide, strong fibrotic transparent structures with distinct separate insertion in close vicinity of the rectus insertion that could have been easily overlooked. Following the disinsertion of the neighboring rectus muscle, they caused obvious indentation over the sclera during the traction test. Their insertion on the sclera could be followed toward its origin in the posterior Tenon's tissue. Upon extirpation of this tissue, the significant restriction was released.

None of the patients in either group complained of postoperative torsional diplopia. The data for pre- and postoperative fundus torsion was available in 7 patients. Four patients in the SRT group showed an asymptomatic increase in fundus intorsion, whereas 1 patient in the IRT group had resolution of fundus extorsion after surgery.

Discussion

The main goals of surgery in esotropic Duane syndrome are to improve the anomalous head turn, correct alignment in primary position, and increase abduction. Because improvement in abduction is quite limited with medial rectus recession surgery, a variety of VRT procedures have been used to increase the abduction vector in the affected eye.[6] Several modifications have been described in order to reduce the risk of anterior segment ischemia and the induced vertical deviation due to the transposition surgery.[6-13] Recently, IRT has appeared as a second alternative to VRT in select patients with abduction deficiency.[14,16]

The management of Duane syndrome requires recognition of various clinical patterns caused by differences in aberrant innervation of the lateral rectus muscle.[15] A- and V-pattern strabismus along with variations in the amount of abduction deficiency in elevation and depression are relatively common in Duane syndrome.[17] These patterns may indeed be due to the nature of the lateral rectus innervation.[15] That is, if the aberrant lateral rectus innervation is more prominent in upgaze, then the eye will abduct more efficiently in elevation and this will result in a V pattern. On the contrary, if the aberrant innervation is more prominent in downgaze, abduction in depression will be greater, resulting in an A pattern. To our knowledge, the specific role of pattern strabismus in esotropic Duane syndrome has not been investigated previously.

Since SRT was first described in 2006, few studies have investigated its effectiveness in Duane syndrome.[18-22] Mehendale and colleagues[18] and Yang and colleauges[19] reported good results after SRT augmented with loop-

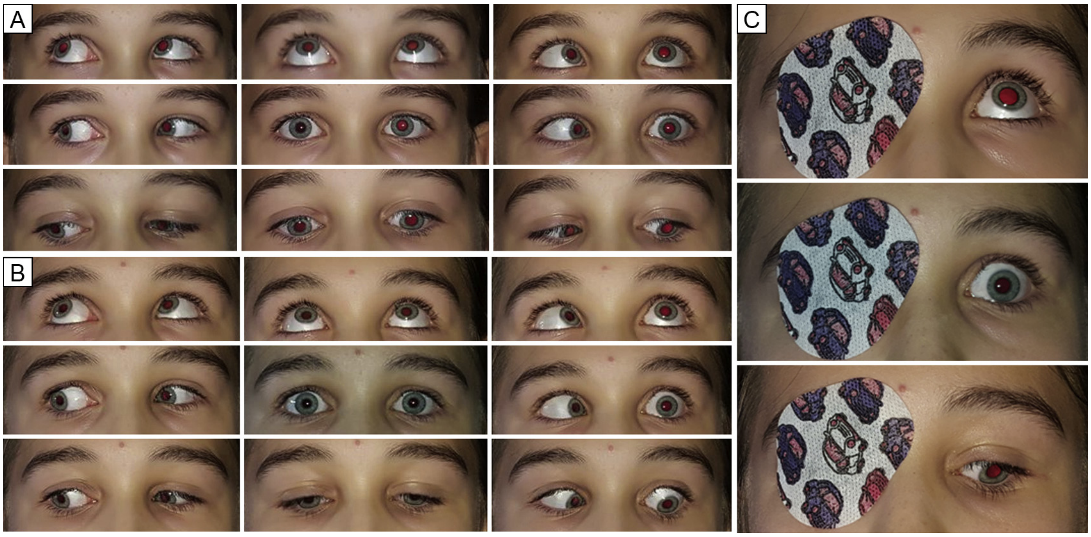

FIG 1. Patient with esotropic Duane syndrome and A pattern (case 12). A, Preoperative motility pattern. B, Postoperative motility pattern after superior rectus transposition. C, Postoperative duction pattern in case 12 after superior rectus transposition.

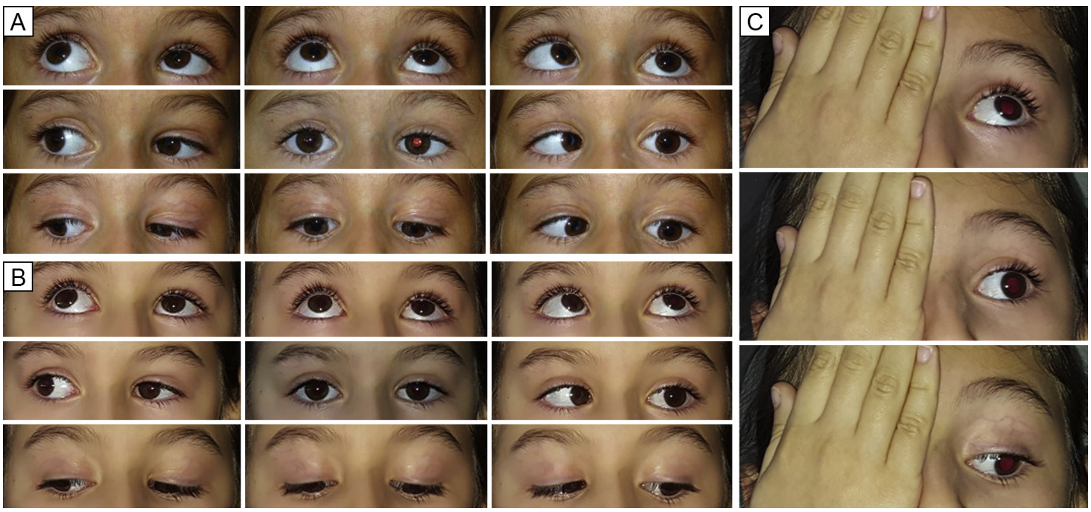

FIG 2. Patient with esotropic Duane syndrome and V pattern (case 17). A, Preoperative motility pattern. B, Postoperative motility pattern after inferior rectus transposition and medial rectus recession. C, Postoperative duction pattern after inferior rectus transposition.

myopexy (without a scleral pass) in patients with Duane syndrome and abducens nerve palsy. Tibrewal and colleagues[20] documented a success rate of 87% and a significant improvement of abduction after augmented SRT (with a scleral pass). In the present study, Brooks' modification was used and SRT was augmented with resection of the transposed muscle.[23] We prefer this technique to use of augmentation sutures for several reasons. First, it is easier to adjust in the event of iatrogenic vertical misalignment. Second, we can reduce the number of sclera passes and, third, titrate the amount of improved abduction based on the amount of esotropia. Despite the differences in the surgical techniques applied, the results of SRT in the present study in which 10 (71.4%) patients achieved orthotropia within 10^{Δ} and showed a significant improvement in abduction (≥1 unit) are comparable to those of previous studies.[18-22] In the IRT group, 1 patient achieved 12^{Δ} of esotropia, and 4 patients (57.1%) achieved orthotropia within 10^{Δ}. The mean amount of esotropic correction was $18.5^{\Delta} \pm 7.9^{\Delta}$ and the mean amount of improvement in abduction was 1.4 ± 0.6 units with IRT. Recently Velez and colleagues[16] reported 5 patients with abducens nerve palsy who underwent IRT with medial rectus recession and found a mean esotropic correction of 27.8^{Δ} and an abduction improvement of 1.9 units. The results of IRT appear to be comparable to the results of SRT and VRT.[6,7,18-22]

New vertical deviations have been reported with SRT.[18,22,24,25] In our series, one patient developed persistent and another transient hypertropia (resolving within 2 months of surgery). In patients with induced vertical misalignment we further advanced the temporal edge of the superior rectus muscle by suturing it below the superior border of the lateral rectus muscle. The recession of the transposed muscle along the spiral of Tillaux successfully resolved the induced hypertropia. We speculate that this kind of advancement with the intention of receiving more abducting power also increased the vertical vector force of the superior rectus muscle, resulting in hypertropia. Two IRT group patients developed hypertropia. In case 18 it was probably induced by the 3 mm recession of the nasal pole of the inferior rectus muscle; in case 16 it could have occurred from premature loosening of the absorbable suture of the inferior rectus muscle. Neither patient required revision surgery, and thus we cannot confirm this speculation.

Transposition of a single vertical rectus muscle carries a risk of torsional strabismus. Subjective torsion was not measured in the present study. Despite the fundus intorsional shift, which was noted in 4 patients following SRT and 1 patient following IRT, none of our patients complained of torsional diplopia during the course of long-term follow-up. Therefore, our finding in this aspect is consistent with previous studies that claim that the risk of torsional diplopia is very low after SRT.[18-20,22,24]

We observed overcorrection and significant limitation in adduction in 1 patient after SRT and medical rectus recession in 1 patient after IRT and medical rectus re-recession. Intraoperative medical rectus advancement was performed in 3 patients depending on the traction and spring back test findings, resulting in long-term orthotropia in 2 cases. These cases would have been overcorrected had there been no intraoperative adjustment. This finding led us to reduce the amount of resection of the superior rectus or inferior rectus muscles and also the amount of recession of the medical rectus in patients undergoing VRT. We choose to start the surgery with vertical rectus transposition, even if the medial rectus muscle is found to be very tight on traction testing. Then, the amount of the medial rectus recession is intraoperatively titrated according to the intraoperative alignment, forced duction, and spring-back tests. We tend to decrease the amount of medial rectus recession with regard to the lateral rectus aberrant innervation to prevent the postoperative adduction deficiency. In our experience, the amount of correction achievable by SRT alone is variable, ranging between 5^{Δ} and 22^{Δ}. Recently Agarwal and colleagues[21] and Akbari and colleagues[22] have investigated the surgical outcome of SRT in patients with Duane syndrome and abducens nerve palsy and found that the dose–response of SRT was lower in Duane syndrome. As stated by Tibrewal and colleagues,[20] the tightness and contracture of the medial rectus muscle and the amount of lateral rectus aberrant innervation are important factors responsible in this dose–response relationship to transposition surgery and should be considered before performing ipsilateral medial rectus recession in combination with SRT or IRT.

Three patients in the SRT group and 2 in the IRT group had residual esotropia of $>10^{\Delta}$. Our experience in patients 7 and 18 suggest that botulinum toxin can be a useful adjunct for cases with undercorrection after single VRT surgery.

The improvement in abduction in elevation was better in the SRT group, as previously documented by Yang and colleagues,[19] and the improvement in abduction in depression was better in the IRT group after transposition surgery in the present study. The trend toward more improvement in abduction on the side of the transposed vertical rectus muscle is an expected finding and can be used to achieve a more balanced abduction capacity in elevation and depression with the transposition of a single vertical rectus muscle. In this study, ocular motility pattern was the main determinant in surgical planning. Patients with better abduction in elevation and/or V pattern were treated with IRT; those with better abduction in depression and/or A pattern, with SRT. Patients with equal abduction deficiency in elevation, depression, and vertical midline were also treated with SRT, because this procedure is now widely accepted as the standard treatment of care in esotropic Duane syndrome. After surgery, we found that the amount of pattern was significantly reduced in both groups. Hence, selective transposition of the vertical rectus muscle on the side of more abduction deficiency may be a useful approach to address both esotropia and pattern strabismus in Duane syndrome.

Our study is limited by its small retrospective design, limited follow-up time in 33% of patients (3 months), and the lack of binocular single visual field measurements. Despite these limitations, our results suggest that SRT and IRT can effectively treat esotropic Duane syndrome. The pattern strabismus can be reduced and a relatively uniform abduction can be achieved in elevation and depression by selective transposition of the vertical rectus muscle on the side of greater abduction deficiency.

Literature Search

The authors searched PubMed on March 30, 2018, for English-language results using the following terms: *alphabetical pattern*, *Duane syndrome*, *duction pattern*, *inferior rectus transposition*, and *superior rectus transposition*.

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