Outcomes after superior rectus transposition and medial rectus recession versus vertical recti transposition for sixth nerve palsy

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Abstract

Purpose: To compare the effectiveness of superior rectus transposition and medial rectus recession (SRT/MRc) versus inferior and superior rectus transposition (VRT) for acquired sixth nerve palsy.

Design: Consecutive, interventional case series

Methods: The medical records of a consecutive series of patients with acquired sixth nerve palsy who underwent VRT or SRT/MRc by a single surgeon were reviewed. The pre- and postoperative findings were compared between the two groups.

Results: Eight patients (mean age, 46.8 years) underwent SRT/MRc and 8 patients underwent VRT (mean age, 51.1 years). Lateral fixation was performed on all but 4 patients in VRT group. Preoperative esotropia in primary position and abduction deficit were similar in both groups (SRT/MRc, 41.9 PD, -4.6; VRT, 55.6 PD, -4.5; p=0.195, 1.0). The SRT/MRc group underwent a mean MR recession of 6 mm (range, 5-7). Four patients in the VRT later underwent MR recession (mean 5.3 mm, range 5-6). In addition, 5 patients in the VRT group had one or more botulinum toxin injections in the medial rectus muscle. No additional procedures were performed in the SRT/MR group. Fewer additional procedures were performed with SRT/MR (SRT/MR, 0; VRT, 1.8±1.2; p<0.010). At last follow-up, residual esotropia (SRT/MRc, 7.1 PD; VRT, 10.3 PD; p=0.442) was similar in both groups, but abduction was better in the SRT/MRc group (SRT/MR, -3.0±0.7; VRT, -3.8±0.4; p=0.038). There were no new persistent vertical deviations or torsional diplopia.

Conclusions: Final outcomes were similar with SRT/MRc vs. VRT. However, fewer additional surgical procedures were needed with SRT/MR.
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Short title: Outcomes after superior rectus transposition

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Sixth nerve palsy induces debilitating diplopia and often requires a large head turn to minimize or eliminate diplopia. If there is residual function of the lateral rectus muscle, surgical options include ipsilateral or bilateral recession of the medial rectus muscles, botulinum toxin injections in the ipsilateral medial rectus muscle, and resection or plication of the ipsilateral lateral rectus muscle. If there is no lateral rectus function and there is no rotation beyond the midline, complete or partial transposition of the superior and inferior rectus muscles laterally with or without lateral fixation is commonly performed. However vertical rectus muscle transposition must be combined with ipsilateral medial rectus muscle recession if there is contracture of the medial rectus muscle. Since anterior ciliary arteries course through the vertical rectus muscles, transposition increases the risk of anterior segment ischemia particularly when combined with ipsilateral medial rectus muscle recession. Other complications of vertical recti muscle transposition include new vertical deviations and induced torsion.

Recently, full tendon transposition of only the superior rectus muscle to the lateral rectus muscle has been reported to reduce the number of vertical rectus muscles requiring surgery for treatment of sixth nerve palsy. Mehendale and colleagues reported good postoperative alignment and improved abduction in a small series of patients with sixth nerve palsy and Duane retraction syndrome who underwent this procedure. Other small series have also reported favorable outcomes using this procedure in patients with sixth nerve palsy and Duane syndrome. Velez and colleagues reported no clinically significant torsional diplopia in a small case series of patients with Duane syndrome and sixth nerve palsy after this procedure. However, no studies have compared outcomes with vertical recti transposition (VRT) vs. superior rectus transposition with medial rectus recession (SRT/MRc) when treating sixth nerve palsy.

The purpose of the present study is to compare outcomes of SRT/MRc with full tendon VRT for acquired sixth nerve palsy performed by a single surgeon.

**Methods**

The medical records of a consecutive series of patients with acquired sixth nerve palsy who had at least a -4 limitation of abduction who underwent VRT (1988-2005) or SRT/MRc (2013-2016) by a single surgeon (SRL) were reviewed. SRT/MRc was first adopted by the surgeon (SRL) in 2013. Prior to this, VRT was exclusively performed when treating patients with complete sixth nerve palsy. This study was approved by the institutional review board of Emory University and adhered to the tenets of the Declaration of Helsinki.

Superior rectus transposition plus medial rectus recession was performed as described elsewhere. The superior rectus muscle was isolated taking care to clear the muscle of attachments to the overlying levator palpebral superioris muscle and the underlying superior oblique tendon. The muscle was secured, detached, and then reattached to the eye along the spiral of Tillaux. After 1997 a posterior fixation suture was then placed between the lateral and superior rectus muscles 8 to 10 mm
posterior to the insertion of the lateral rectus muscle, incorporating approximately one-third of the muscle width coupled with a scleral pass using 5-0 polyester suture.

Conventional superior and inferior rectus muscle transposition was performed by detaching the muscles from their insertions and then reattaching them to the sclera along the spiral of Tillaux. Four patients in the VRT group had the transposed muscle fixated to the lateral rectus muscle 8-10 mm posterior to the insertion of the lateral rectus muscle using 5-0 polyester suture incorporating approximately one-third of the muscle width and fixating it to the sclera.

Botulinum toxin (Botox®; Allergan, Parsippany New Jersey) was injected into the ipsilateral medial rectus muscle using topical anesthesia and electromyographic guidance in selected cases pre- or intraoperatively if there was contracture of the medial rectus muscle. It was also offered to patients postoperatively with persistent diplopia that could not be managed with a prismatic correction or a small head turn. A standard dose of 2.5 units of botulinum toxin was injected in all cases. Lastly, patients who had persistent diplopia that did not improve after treatment with botulinum toxin were given the option of having additional strabismus surgery.

Adduction was graded on a scale from 0 (indicating full adduction) through −4 (indicating an eye that was able to move past the midline) and −5 (indicating an eye that approached but was unable to reach the midline) to a maximum of −8 indicating a rare case where the eye was fixed in an extreme adducted position. We always used the ocular alignment measurements taken at the last follow-up examination when reporting postoperative outcomes.

Statistical calculations were performed using IBM SPSS statistics 22.0 (IBM, Armonk, New York). Mann-Whitney U test was used to analyze preoperative and final ocular alignment in primary position and the limitation of abduction. Pearson’s chi square test was used to analyze gender and laterality. $P < 0.05$ was considered statistically significant.

Results

The medical record review identified 8 patients who underwent SRT/MRc and 8 patients who underwent VRT. Mean age at the time of surgery was 46.8 years (range, 12.4 to 83.3 years) in the SRT/MRc group and 51.1 years (range, 32.1 to 70.3 years) in the VRT group. The time from symptom onset to surgery was 44.6±53.0 months (range, 7.6. to 170.8) in the SRT/MRc group and 51.1±60.4 months (range, 8.9 to 167.3) in the VRT group (Supplemental Tables 1 and 2). The two groups were comparable in terms of age, sex, laterality and time from symptom onset to surgery. The median follow-up was 6.2 months (range, 1.0 to 27.0 months) in the SRT/MRc group and 17.3 months (range, 3.6 to 100.1 months) in the VRT group($p$=0.083). The preoperative esotropia in primary position was 41.9 prism diopter (PD) (range, 25 to 70 PD) in the SRT/MRc group and 55.6 PD (range, 40 to 95 PD) in the VRT group. The limitation of abduction was -4.6 (range, -4 to -6) in the SRT/MRc group and -4.5 (range, -4 to -5) in the VRT group. There was no significant difference in preoperative angle in primary position and abduction deficit between the two groups ($p$=0.195 and 1.0 respectively). The patients in the SRT/MRc group underwent a
mean medial rectus recession of 6 mm (range, 5 to 7 mm). No additional procedures were performed on the patients in the SRT/MRc group. Additional procedures were performed on 6 patients (75%) in the VRT group. Four of the patients in the VRT underwent a medial rectus recession (mean 5.3 mm, range 5-6 mm) 6 to 24 months later. One of these patients subsequently underwent a medial rectus recession and lateral rectus resection performed on the contralateral eye. Five patients in the VRT group had a total of nine botulinum toxin injections in the medial rectus muscle. Four patients had botulinum toxin injected twice and one patient had a single injection. The difference in the number of additional procedures performed between the two groups was highly significant (SRT/MRc, 0; VRT, 1.8±1.3; p<0.010). At last follow up, the esotropia in primary position was 7.1 PD (range, 0 to 16 PD) in the SRT/MR group and 10.3 PD (range, 0 to 20 PD) in the VRT group. A total of 36.4 PD (range 15 to 44) of esotropia was corrected in the SRT/MRc group and 45.4 (30 to 75) in the VRT group (p=0.442, 0.234, respectively). The final limitation of abduction was -3.0±0.7 (range, -2 to -4) in the SRT/MRc group and -3.8±0.4 (range, -3 to -4) in the VRT group (Figure 1). The correction of duction was 1.6 (range, 1 to 2) in the SRT/MRc group and 0.7 (range, 0 to 2) in the VRT group. The difference was statistically significant (p=0.038, 0.021, respectively)(Table 1 and Figure 2). There was an induced deficit in adduction of -0.5 to -1.0 in two patients in each group. There was no esotropia in primary gaze. One patient had a small angle esotropia in adduction.

Two patients in the SRT/MRc group had a small hypertropia preoperatively, but the hypertropias resolved after surgery. Two patients in the VRT group had a hypertropia preoperatively (16 and 10 PD), but the hypertropias resolved in one patient and decreased in the other patient to 4 PD postoperatively. None of the patients reported torsional diplopia postoperatively. No serious intra or postoperative complications occurred.

Discussion

A variety of vertical rectus muscle transposition procedures have been reported to improve alignment in patients with sixth nerve palsy.\(^2, 3, 12-15\) Potential complications of these procedures include new vertical deviations, induced torsion and anterior segment ischemia.\(^5, 16, 17\) Many patients with residual esotropia following vertical rectus muscle transposition later undergo ipsilateral medial rectus recession. Tenotomy of three or more rectus muscles increases the risk of anterior segment ischemia.\(^18\) A variety of partial tendon transposition have been developed to reduce the risk of anterior segment ischemia\(^12, 19-22\) but even using these procedures anterior segment ischemia may develop.\(^23, 24\) Other options include full-tendon transposition with botulinum toxin injected in the medial rectus muscle. However esotropia may recur 4 to 6 months after this procedure when medial rectus function recovers.

Johnston et al\(^6\) introduced a modification of VRT in which only the superior rectus muscle is transposed. We adopted this technique and combined it with lateral fixation and medial rectus recession using an adjustable suture when treating patients with complete sixth nerve palsy.
The present study showed that SRT/MRc had comparable efficacy to VRT to correct the esodeviation. However, SRT/MRc improved adduction more than VRT even though patients undergoing VRT had on average 1.8 more procedures than patients undergoing SRT/MRc. However, the follow-up was longer for the VRT group so with a longer follow-up more patients in the SRT/MRc group may have had additional procedures. These additional procedures included ipsilateral medial recession, contralateral medial rectus recession and lateral rectus resection and injection of botulinum toxin into the ipsilateral medial rectus muscle. These procedures were associated with additional direct and indirect (time off from work, discomfort and inconvenience) costs. Ipsilateral medial rectus recession also put these patients at increased risk of developing anterior segment ischemia.

SRT/MRc with fixation suture in this study corrected a mean of 36.4 PD of esotropia. Previous studies of SRT/MRc coupled with lateral fixation in patients with sixth nerve palsy have reported correcting a similar amount of esotropia. Previous studies have reported VRT coupled with medial rectus recession or botulinum toxin injection correcting 30 to 50 PD of esotropia and VRT with posterior fixation suture correcting 40 to 55 PD of esotropia in patients with sixth nerve palsy. In our series, VRT corrected a similar amount of esotropia albeit these patients also underwent a mean of 1.8 additional procedures (MRC and or botulinum toxin injection, recession and resection of horizontal rectus muscle in contralateral eye).

SRT/MRc showed better efficacy than VRT for improving abduction; abduction improved from -4.6 to -3.0 with SRT/MRc. This value is comparable to a previous study that reported abduction improving from -4.8 to -3.0. Abduction improved from -4.5 to -3.8 in our VRT group. Others have reported greater improvement in abduction following VRT.

New vertical deviation has been reported to occur in 0 to 12% of patients undergoing VRT. VRT combined with lateral fixation may increase the incidence of new vertical deviations. New vertical deviations have also been reported with SRT. Mehendale and colleagues reported new vertical deviations in 2 out of 7 patients following SRT. Velez and colleagues reported 1 out of 7 patient with a significant new hypertropia following SRT. None of the patients in our series developed persistent new vertical deviations, although several patients had a transient vertical deviation immediately following SRT that resolved in several days. A few patients had a vertical deviation preoperatively. In all but one case, they resolved postoperatively. It is somewhat surprising that persistent vertical deviations do not occur more often after this procedure. It is likely that supraduction is not significantly altered by SRT since the pulleys, not the insertion of the superior rectus muscles, serve as the functional origin. Miller and colleagues reported that the posterior portion of the transposed muscle is not as deviated toward the palsied muscle as would be expected from transposition because of resistance from the pulleys.

Torsional change is another potential complication of SRT. None of the patients in the present series experienced torsional diplopia after SRT/MRc. Velez and colleagues and Mehendale and colleagues reported that this technique did not induce clinically significant torsional diplopia.
There are a number of limitations to our study. First, it is a relatively small retrospective study. Second, there were some differences in the baseline characteristics between the two groups (e.g. the preoperative esotropia was larger in the VRT group) and the length of follow-up was longer for the VRT group. However, the mean postoperative esodeviation drift was <1 PD in the SRT/MRc group after a mean follow-up of nearly 7 months suggesting very little drift postoperatively. In addition the difference in length of follow-up was not statistically significant. Third, forced ductions were not quantified so these could not be compared between the two groups. Fourth, the grading of abduction was not masked. Finally, objective torsion and binocular fields were not evaluated for all patients pre- and postoperatively.

Strengths of the study include the same surgeon performing all of the procedures and all of the pre- and postoperative examinations.

Despite many limitations, this study suggests that SRT/MRc is not inferior to VRT for correcting esotropia and limitation of abduction with sixth nerve palsy and SRT/MRc has the advantage of requiring fewer additional procedures.
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b. Financial Disclosures: No financial disclosures.

c. Other Acknowledgments: None
References:


Figure Captions

Figure 1 Patient 8 with right traumatic sixth nerve palsy. (Top) Preoperative photos of a 47 year old woman 10 months following a closed head injury. There is a 30 prism diopter esotropia and 2 prism diopter right hypertropia in primary position and -4 limitation of abduction. She had constant diplopia and wore a patch over her right eye. She underwent a right superior rectus transposition with lateral fixation and a 6 mm medial rectus recession using an adjustable suture. (Bottom) Postoperatively she was orthotropic in primary position and only had diplopia in right gaze. Her abduction in the right eye also improved.

Figure 2 Bar graphs comparing superior rectus transposition/medial rectus recession (SRT/MRc) and vertical transposition groups (VRT) pre and postoperatively. (Top) Angle of deviation in prism diopters (PD) in primary position is similar in two treatment group. (Bottom) Limitation of abduction in similar preoperatively, but significantly less in the SRT/MRc group postoperatively (small “a” denotes a non-significant difference and “b” denotes a significant difference between treatment groups).
Table 1 Comparison of Patients’ Characteristics and Outcomes in Superior Rectus Transposition/Medial Rectus Recession versus Vertical Transposition Groups

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Group</th>
<th>SRT/MRc</th>
<th>VRT</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (range), years</td>
<td></td>
<td>46.8±26.3 (12 to 83)</td>
<td>51.1±15.0 (32 to 70)</td>
<td>0.693^</td>
</tr>
<tr>
<td>Sex, male</td>
<td></td>
<td>3/8</td>
<td>5/8</td>
<td>0.317*</td>
</tr>
<tr>
<td>Right eye</td>
<td></td>
<td>4/8</td>
<td>3/8</td>
<td>0.614*</td>
</tr>
<tr>
<td>Time from onset to surgery (range), months</td>
<td></td>
<td>44.6±53.0 (7.6 to 170.8)</td>
<td>51.1±60.4 (8.9 to 167.3)</td>
<td>0.959^</td>
</tr>
<tr>
<td>Follow-up, median(range), months</td>
<td></td>
<td>6.2 (1.0 to 27.0)</td>
<td>17.3 (3.6 to 100.1)</td>
<td>0.083^</td>
</tr>
<tr>
<td>Preoperative esodeviation (range) PD</td>
<td></td>
<td>41.9±14.6 (25 to 70)</td>
<td>55.6±21.8 (20 to 95)</td>
<td>0.195^</td>
</tr>
<tr>
<td>Correction of esodeviation (range) PD</td>
<td></td>
<td>36.4±11.5 (15 to 54)</td>
<td>45.4±15.0 (30 to 75)</td>
<td>0.234^</td>
</tr>
<tr>
<td>Final esodeviation (range) PD</td>
<td></td>
<td>7.1±7.0 (0 to 16)</td>
<td>10.3±9.1 (0 to 20)</td>
<td>0.442^</td>
</tr>
<tr>
<td>Preoperative abduction (range)</td>
<td></td>
<td>-4.6±0.9 (-4 to -6)</td>
<td>-4.5±0.5 (-4 to -5)</td>
<td>1.000^</td>
</tr>
<tr>
<td>Correction of duction (range)</td>
<td></td>
<td>1.6±0.5 (1 to 2)</td>
<td>0.7±0.7 (0 to 2)</td>
<td>0.021^</td>
</tr>
<tr>
<td>Final abduction (range)</td>
<td></td>
<td>-3.0±0.8 (-4 to -2)</td>
<td>-3.8±0.4 (-2 to -4)</td>
<td>0.038^</td>
</tr>
<tr>
<td>Number of additional procedures, (range)</td>
<td></td>
<td>0±0 (0)</td>
<td>1.8±1.3 (0 to 3)</td>
<td>0.010^</td>
</tr>
</tbody>
</table>

*Pearson’s X² test  
^Mann-Whitney U test

Unless otherwise indicated, data are expressed as mean values.