Adjustable Nasal Transposition of Split Lateral Rectus Muscle for Third Nerve Palsy

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IMPORTANCE Third nerve palsy causes disfiguring, incomitant strabismus with limited options for correction.

OBJECTIVE To evaluate the oculomotor outcomes, anatomical changes, and complications associated with adjustable nasal transposition of the split lateral rectus (LR) muscle, a novel technique for managing strabismus associated with third nerve palsy.

DESIGN, SETTING, AND PARTICIPANTS Retrospective medical record review appraising outcomes of 6 consecutive patients with third nerve palsy who underwent adjustable nasal transposition of the split LR muscle between 2010 and 2012 with follow-up of 5 to 25 months at a tertiary referral center.

INTERVENTION Adjustable nasal transposition of the split LR muscle.

MAIN OUTCOMES AND MEASURES The primary outcome was postoperative horizontal and vertical alignment. Secondary outcomes were (1) appraising the utility of adjustable positioning, (2) demonstrating the resultant anatomical changes using magnetic resonance imaging, and (3) identifying associated complications.

RESULTS Four of 6 patients successfully underwent the procedure. Of these, 3 patients achieved orthotropia. Median preoperative horizontal deviation was 68 prism diopters of exotropia and median postoperative horizontal deviation was 0 prism diopters ($P = .04$). Two patients had preoperative vertical misalignment that resolved with surgery. All 4 patients underwent intraoperative adjustment of LR positioning. Imaging demonstrated nasal redirection of each half of the LR muscle around the posterior globe, avoiding contact with the optic nerve; the apex of the split sat posterior to the globe. One patient had transient choroidal effusion and undercorrection. Imaging revealed, in this case, the apex of the split in contact with the globe at an anterolateral location, suggesting an inadequate posterior extent of the split. In 2 patients, the surgical procedure was not completed because of an inability to nasally transpose a previously operated-on LR muscle.

CONCLUSIONS AND RELEVANCE Adjustable nasal transposition of the split LR muscle can achieve excellent oculomotor alignment in some cases of third nerve palsy. The adjustable modification allows optimization of horizontal and vertical alignment. Imaging confirms that the split LR muscle tethers the globe, rotating it toward primary position. Case selection is critical because severe LR contracture, extensive scarring from prior strabismus surgery, or inadequate splitting of the LR muscle may reduce the likelihood of success and increase the risk of sight-threatening complications. Considering this uncertainty, more experience is necessary before widespread adoption of this technique should be considered.

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Third nerve palsy causes disfiguring, incomitant strabismus with limited options for correction. Orbital fixation, \(^1\) superior oblique transposition, \(^6\) and lateral rectus (LR) muscle transposition to the superior nasal \(^10\) and inferior nasal globe \(^12\) have been described. In 1991, Kaufmann \(^13\) suggested splitting the LR and transposing the superior and inferior halves to a retroequatorial location near the vortex veins. Subsequently, Gokyigit et al. \(^14\) modified this technique by transposing the superior and inferior halves of the split LR muscle anterior to the vortex veins and 2 mm posterior to the superior and inferior borders of the medial rectus (MR) muscle.

In this study, we describe a modification of the Gokyigit et al. \(^14\) technique using adjustable sutures to allow for intraoperative and postoperative refinement of ocular alignment. We present our outcomes using this approach, showing the utility of the adjustable technique to optimize postoperative alignment and demonstrating the associated anatomical changes with high-resolution magnetic resonance imaging of the orbits before and after surgery. We describe limitations of this procedure as well and offer recommendations regarding case selection to avoid postoperative undercorrection and vision-threatening complications.

Methods

A retrospective review of the medical records of patients treated for third nerve palsy with adjustable nasal transposition of the split LR muscle between July 2010 and August 2012 was performed with institutional review board approval at Boston Children's Hospital. Informed consent was waived by the board. There were no exclusion criteria. The initial and final ocular alignment, perioperative adjustment of the LR halves, postoperative motility, and complications were abstracted. Surgical success was defined as postoperative alignment within 10 prism diopters (Δ) of orthotropia in primary position by Krimsky or Hirschberg assessment. The pre- and postoperative alignment were analyzed with nonparametric tests using SPSS (IBM) and MATLAB (The MathWorks, Inc). One patient had bilateral third nerve palsy; this patient’s horizontal misalignment was divided in 2 and counted as 2 measurements for computational purposes. Where available, pre- and postoperative high-resolution magnetic resonance imaging were reviewed to assess anatomical changes produced by this procedure.

At the beginning of the operation, both eyes were prepped and draped to allow for comparison of the resting position of the 2 eyes before and after the procedure. Radial conjunctival incisions were placed in all 4 quadrants of the operative eye. The LR muscle was isolated and separated from attachments to the surrounding Tenon capsule, pulleys, and inferior oblique muscle. The upper and lower halves of the LR muscle were secured at the insertion with 2 separate double-armed, 6-0 polyglactin 910 sutures (Vicryl; Ethicon). The muscle was then detached and split in half longitudinally 18 to 24 mm posteriorly (Figure 1A, left panel). The length of split varied depending on the size of the globe, but the goal was to split 2 to 3 mm posterior to the globe. A Gass muscle hook was placed within the superior-nasal conjunctival incision and passed laterally under the superior oblique and superior rectus muscles. The upper LR sutures were passed through the opening in the Gass hook and the hook was retracted to transpose the sutures to a position adjacent to the superior pole of the MR muscle (Figure 1B, left panel). The inferior oblique muscle was exposed through the inferotemporal conjunctival incision with a small muscle hook. The Gass muscle hook was first passed around this muscle, then the lower LR sutures were passed through the opening in the hook, and the hook was retracted to transpose the sutures posterior to the insertion of the inferior oblique muscle. The Gass hook was then passed through the inferior nasal incision beneath the inferior rectus muscle and used to nasally transpose the lower-half LR sutures (Figure 1B, right panel). The upper LR sutures were reattached to the sclera adjacent or anterior to the upper pole of the MR muscle and secured to each other with an overhand knot followed by placement of a sliding-noose suture. \(^3\) The lower-half LR sutures were attached similarly but to the lower pole of the MR muscle. The pole sutures of the 2 halves of the split LR were advanced through the sliding noose, enabling transposition of the insertion of each half of the split LR to the region adjacent to the MR insertion; the degree of advancement was chosen to leave the eye as much as 20Δ esotropic to orthotropic in the horizontal plane and with no vertical misalignment. The sutures were then trimmed in the short-tag noose configuration \(^16\) (Figure 1A, right panel). If required, conjunctival incisions were partially closed, leaving a sufficient opening to allow for postoperative adjustment. Video 1 provides a narrated guide to the procedure. In 1 case, the superior and inferior oblique muscles were disinserted to simplify the passage of the superior and inferior halves of the LR over regions of prior strabismus surgery with attendant scarring.

Results

The record review identified 6 patients (3 male, 3 female) with third nerve palsy in whom adjustable split nasal transposition of the LR muscle was attempted (Table). Details of each case are provided in the eAppendix in Supplement.

The procedure could not be completed in 2 cases (cases 3 and 5, see the Table for details). Both of these patients had prior LR muscle surgery with extensive fibrosis and loss of elasticity of the muscle, which prevented splitting and transposition beyond the temporal aspects of the vertical rectus muscles. Although the surgery for case 6 was completed, an unusual amount of traction was required to transpose the split halves of the LR. In the remaining 3 cases (cases 1, 2, and 4), surgery was completed without difficulty. There was no indication in the record that forced ductions were performed after the procedure, in part because of some trepidation about stressing the scleral passes holding the lateral rectus muscle on the medial side of the globe.

Of the 4 patients (5 eyes) in whom the procedure was completed (cases 1, 2, 4, and 6), the median follow-up was 12.5 months and the mean was 13.8 months (range, 5-25 months). A successful outcome was achieved in 3 patients (cases 1, 2,
In the fourth patient (case 6), the exotropia recurred during the first postoperative month, and we only achieved a reduction of 56% from 90Δ preoperatively to 40Δ at final follow-up (eFigure 4 in Supplement). Overall, the median exotropia changed from 68Δ preoperatively to 0Δ postoperatively (Wilcoxon signed rank test, \( P = .04 \); Figure 3).

Two patients (cases 1 and 4) had preoperative vertical misalignments that resolved with surgery. Case 1 required a superior rectus recession and disinsertion of the previously transposed and flaccid superior oblique muscle in addition to adjustment differentially of the split nasal transposition of the (previously recessed) LR muscle. Case 4 required adjustment of the 2 halves of the split LR muscle to eliminate 8Δ of vertical misalignment. Three of the 4 patients underwent intraoperative adjustment of LR muscle positioning with variation in the position of the LR muscle halves between 2.5 mm anterior to 6.0 mm posterior to the insertion of the medial rectus muscle.

After the procedure, eye movements were severely limited in all patients except for case 6, who was undercorrected. Two complications were observed, both in case 6. This patient developed transient choroidal effusions 1 day postoperatively (eFigure 5 in Supplement), which largely resolved over the course of 3 days. There was no permanent decrement in vision. She also developed notable globe retraction on attempted abduction 5 months postoperatively (Video 2). This was addressed with a reoperation to detach the lateral rectus muscle from the posterior aspect of the globe and secure it to the lateral orbital rim.

High-resolution magnetic resonance orbital imaging was available for review in 2 of the 3 patients who had successful

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**Figure 1. Schematic Interpretation of Nasal Transposition of the Split Lateral Rectus (LR) Muscle**

A. Anterior view, left eye. Left panel shows passage of Gass muscle hook after LR muscle has been detached and split; right panel shows position of upper and lower muscle halves adjacent to medial rectus (MR) insertion. B. Superior and inferior views of the left eye after transposition is complete. The superior view demonstrates the course of the LR muscle under the superior oblique tendon; the inferior view shows the course behind the inferior oblique muscle. The presumed orbital pulley directs the LR muscle forward before it courses behind the globe. IO indicates inferior oblique muscle; IR, inferior rectus muscle; SO, superior oblique muscle; and SR, superior rectus muscle.
residual deviation. Later, Morad and Nemet\(^1\) combined these procedures and nasalization of the inferior rectus muscle reduced the second procedure involving resection of the MR and recession to 30–40 Δ and hypotropia by 5 to 10 Δ (from 25–30 Δ to 20 Δ). A procedure reduced his patient’s exotropia by 40 to 50 Δ (from 80 Δ to 30–40 Δ) and hypotropia by 5 to 10 Δ (from 25–30 Δ to 20 Δ). A second procedure involving resection of the MR and recession to 30–40 Δ and hypotropia by 5 to 10 Δ (from 25–30 Δ to 20 Δ). A procedure reduced his patient’s exotropia by 40 to 50 Δ (from 80 Δ to 30–40 Δ) and hypotropia by 5 to 10 Δ (from 25–30 Δ to 20 Δ).

Kaufmann\(^1\) addressed potential problems with induced palsies and achieved orthophoria with 12 months’ follow-up. 2 procedures in 1 surgery for a child with third and fourth nerve palsies and achieved orthophoria with 12 months’ follow-up. Kaufmann\(^2\) addressed potential problems with induced torsion and vertical deviation by splitting the LR muscle and transposing the superior and inferior halves to a region 20 mm posterior to the limbus and posterior to the superior and inferior nasal vortex veins. The procedure was performed on 2 patients with reduction of the exotropia by 54 Δ (from 78 Δ to 24 Δ) in 1 patient and 37 Δ (61 Δ to 24 Δ) in the second. The hypotropia was overcorrected in the first patient and eliminated in the second. Despite the improvement in the horizontal deviation by the techniques described by Taylor\(^8\) and Kaufmann,\(^1\) a horizontal deviation remained. In an effort to obtain further reduction of the horizontal deviation, Gokyigit and colleagues\(^14\) modified this technique bringing the superior and inferior halves of the LR muscle anterior to the vortex veins and approximately 2 mm from the superior and inferior edges of the MR muscle, respectively. Their series of 10 patients, the preoperative deviation varied between 45 Δ and 90 Δ. Of these, 5 had a postoperative alignment within 10 Δ of orthotropia. Their innovation of placing the muscle halves equatorially greatly improved the effectiveness of this concept. Moreover, in 3 patients, they combined this technique with a subsequent MR strengthening procedure, suggesting that this is more likely to give long-term benefit because there is no longer any opposing force from the LR. Gokyigit and colleagues\(^14\) report an overall 3.7 Δ improvement in vertical alignment.

Our technique enhances the previously reported split LR transposition by enabling a patient-specific fine-tuning of both horizontal and vertical alignment during surgery, in the recovery room, and up to 1 week later, if required.\(^1\) Horizontal centration is facilitated by adjustable recession from the spiral of Tillaux as in cases 1 and 6, anterior transposition in case 2, and placement at the spiral of Tillaux in case 4. Vertical cen-
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Figure 2. Successful Treatment of a 7-Month-Old Boy (Case 2) With Bilateral Third Nerve Palsies

A, Preoperative clinical image (following ptosis repair). B, Postoperative clinical image 13 months after bilateral nasal transposition of the split lateral rectus (LR) muscle, which is maintained at 20 months postoperatively. C and D, Preoperative axial T2 turbo spin echo images show the normal position of the LR muscle (C) and the postoperative, bilateral split of the LR muscle (arrowheads) posterior to the globe (D). E, Preoperative coronal T1 image at 3 months of age shows the attenuation of the superior, medial, and inferior rectus muscles (arrowheads in right orbit, similar appearance in left orbit) and the normal LR muscle. F, Postoperative coronal T1 image 15 months after surgery shows splitting of the LR muscle posterior to the globe (arrowheads).

Integration is achieved by asymmetric placement of the inferior and superior halves of the LR as in cases 1 and 4. In case 1, the preoperative vertical misalignment (12Δ of hypertropia) was attributed to prior transposition of the superior oblique muscle; thus, vertical rectus muscle surgery was performed as well as a fine-tuning of the residual vertical deviation by adjusting the tension of the 2 halves of the split LR (Table). In case 4, the preoperative hypotropia of 8Δ was successfully eliminated by adjusting the tension of the 2 halves of the transposed LR. In our cases, all adjustments were done intraoperatively. A late postoperative adjustment was considered in case 6 to reduce the tension of the muscle against the globe to treat the choroidal effusions; however, the effusions improved spontaneously. We found that the postoperative alignment observed under general anesthesia correlated well with the position of the eyes on awakening. Thus, the intraoperative adjustment may have enhanced success in our patients.

In the magnetic resonance images, the split halves of the LR muscle traveled anteriorly and then made an almost 90° turn toward the nasal part of the eye. This is likely the result of constraints on muscle pathways created by connective tissue and, in particular, the connective tissue pulleys within the orbit. This may have further enhanced the creation of adducting vector forces sufficient to center the globe as previously theorized and demonstrated by Taylor.8,10 Given sustained innervation of the LR muscle, the new alignment should remain stable indefinitely (unless the LR muscle stretches or slips, or a new restriction develops due to fibrosis) in contrast with procedures such as nasal orbital fixation, which tend to lose their effect over time.1,3-5 Our first 2 patients have had stable postoperative alignments at 25 and 20 months of follow-up, respectively. As anticipated in a patient with complete third and fourth nerve palsies who then has a procedure to limit function of the lateral rectus muscle, the eye is left with severely limited motility, not unlike orbital wall fixation1-5 and superior oblique transposition procedures.6,7

Imaging of the undercorrected patient (case 6) demonstrated that the apex of the LR muscle split was not posterior to the globe; instead, it was far enough anterior that it approximated the globe on its temporal surface (Figure 4). Although review of the surgical video indicates that the split of the LR went well behind the equator of the globe, it is possible that
this was still insufficient to allow for the split LR muscle to be pulled nasally across the posterior surface of the globe. Alternatively, there may have been more extensive connective tissue attachments or more anteriorly placed pulleys that limited the ability to transpose the muscle. Consistent with this hypothesis, greater than normal tension was required to nasalize the split LR during the procedure and choroidal effusions developed after surgery. Our patient developed gradual recrudescence of the exotropia and retraction of the globe with attempted abduction over the first month after surgery. Healing of the apex of the split LR muscle across the posterior temporal globe as shown in the imaging (Figure 4A, lower panel) likely resulted in the undercorrection and the Duane syndrome–like phenomenon.

Planned split LR muscle transposition was abandoned in cases 3 and 5 because severe contracture resulted in an inelastic, foreshortened LR muscle. Both patients had prior surgical procedures recessing the LR muscle and we suspect sarcomere shortening resulted in muscular contraction and insufficient muscle length to allow transposition. Alternatively, scarring around the surrounding connective tissue (including the pulleys) in these cases may have also prevented the nasal movement of the muscle. Previous lateral rectus recession, however, should not be considered a contraindication when considering this technique. Case 1 had a successful outcome despite having previously undergone a 9-mm LR muscle recession. In her case, a normal-appearing LR muscle was noted intraoperatively with minimal contracture. The exact impact of previous LR muscle recession, length of time before reoperation, patient age, and other orbital factors in predicting success or failure remains to be determined.

Conclusions

The adjustable approach to nasal transposition of the split LR muscle for treatment of strabismus associated with third nerve palsy offers the flexibility of intraoperative and short-term postoperative fine-tuning of residual horizontal and vertical misalignment. This can achieve excellent horizontal alignment in primary position in some patients who have few other options for surgical correction. It can also be used to reduce vertical deviation associated with prior attempts at surgical repair, hypotropia associated with complete third nerve palsy, and inadvertent asymmetry in vertical tone caused by unequal splitting of the LR muscle during surgery. While dramatic improvement may be achieved in some cases, attention to case selection is essential and patient expectations must be managed appropriately.

We advise caution when considering this procedure for patients with extreme LR muscle contracture. Moreover, if severe tension is felt when nasalizing the split halves of the LR...
muscle, the length of the split must be reexamined for adequacy. If the muscle still does not come across to the nasal globe when moderate pressure is applied, it may be best to abandon this approach and select another procedure. Although many patients will enjoy excellent and stable postoperative alignment in primary position, all patients should be advised of the possibility of reduced vision from choroidal effusions or optic nerve compromise and should be prepared for the risk of undercorrection or a Duane syndrome–like cocontraction. Dilated fundus examination is recommended intra- and postoperatively to monitor for optic nerve compromise or choroidal effusions. More experience is necessary before widespread adoption of this technique should be considered.

**ARTICLE INFORMATION**

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