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ORIGINAL ARTICLE

Treatment of convergence insufficiency exotropia in adults using a selective muscle fiber surgery algorithm

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Abstract

Introduction: Treatment of adults with convergence insufficiency-type (CI-XT) exotropia is challenging as surgery frequently results in distance and lateral gaze esotropia. Recent evidence demonstrates differential compartmental function of extraocular muscle fiber groups. Selective surgery of muscle fiber groups may diminish near-distance disparities (NDD) while maintaining alignment at distance.

Methods: Seven adults with a NDD ≥8 prism diopter (PD) were included in this study. Patients with a NDD <15 PD and a distance deviation of <10 PD were treated with lateral rectus (LR) inferior marginal tenotomy, those with NDD >15 PD and distance deviation of >10 PD were treated with LR slanted recessions, and those with limitation in adduction with negative forced duction testing were treated with medial rectus (MR) inferior fiber plication. Success was defined as <8 PD of XT at distance and near without overcorrection and a NDD ≤8 PD.

Results: Postoperatively, the mean distance deviation was reduced from 7.71 ± 6.87 PD to an overcorrection of 1.43 ± 3.78 PD, and the near deviation from 20.29 ± 9.57 PD to 0.86 ± 1.57 PD. The NDD was reduced from 12.57 ± 3.15 to 2.29 ± 3.73 PD. Six of the 7 (85.7%) patients met criteria for success. One subject was overcorrected at distance and two were slightly undercorrected at near but without diplopia.

Discussion: CI exotropia remains a surgical challenge. Treatment may be optimized when using an individualized approach favoring selective LR and MR procedures when possible.

Conclusions: Preliminary data reveal that selective techniques may eliminate diplopia while collapsing NDD in patients with CI-XT. A focused algorithm will help surgeons select the procedure most likely to benefit each individual patient.

Introduction

Convergence insufficiency (CI)-type exotropia is characterized by a greater exodeviation at near fixation than distance fixation by 10 prism diopter (PD) or more.[1] If uncorrected, patients experience significant asthenopia and diplopia at near. Mild CI-type exotropia is often treated non-surgically with interventions such as prisms or vision therapy; therefore, this condition infrequently requires surgical intervention, comprising only 18% of all forms of intermittent exotropia requiring surgery in one series.[2,3] For those patients who fail non-surgical options, existing surgical techniques are often unreliable as no single operation is proven to reliably collapse near-distance disparity while also achieving satisfactory alignment at both distance and near. Various surgical treatments for CI-type exotropia (CI-XT) have been evaluated, including bilateral lateral rectus (LR) recession with and without slanting,[4-7] bilateral medial rectus (MR) resection with and without slanting,[8-10] unilateral MR resection,[11] unilateral LR recession with MR resection (R&R),[12,13] and variations of the above with adjustable sutures. In a direct comparison of reports of bilateral R&R with or without slanting, unilateral MR resection with or without slanting and unilateral R&R, it was found that unilateral R&R

with MR resection based on the near deviation, and LR recession based on the distance deviation achieved the best alignment.[14] However, the success rates of the above procedures vary widely, ranging from 18% to 92%.

Selective surgery of independent muscle groups for the treatment of CI-XT shows promise, as prior studies have demonstrated successful collapse of near-distance disparities (NDD) while maintaining alignment at both distance and near.[4,5] This empiric success may be explained physiologically by underlying compartmentalization of extraocular muscle (EOM) functions. Demer recently demonstrated evidence that certain EOMs are split functionally by segregated bifurcations of motor nerves.[15] These independent muscle fiber groups exert varied contractility on the inferior versus superior or medial versus lateral scleral insertions of EOMs, supporting the basis for EOM surgeries involving portions of rectus muscles.[15-17]

Utilizing the basis of compartmentalization of the EOM muscle fiber groups, we developed an algorithm for the treatment of varying degrees of CI-XT. This algorithm employs selective surgical techniques involving portions of the MR and LR, including LR marginal tenotomy, MR inferior plication/advancement, and LR slanted recession. The lack of prior consistent success in the treatment of CI-XT results from frequent overcorrection at distance following MR resection. This results in persistent diplopia and patient dissatisfaction. Utilizing a new understanding of the underlying physiology of EOMs, we may be better equipped to prevent overcorrection at distance. We hypothesize that this focused algorithm will assist surgeons in the selection of the specific surgical technique best suited for each patient based on their severity of CI-XT.

Methods

This cohort consisted of seven consecutive patients with exotropia (XT) greater at near than distance by ≥8 PD who also reported symptoms of diplopia at near and significant asthenopia. Patients were treated between May 2013 and December 2015. Data were collected retrospectively. The research was approved by the institutional review board of our institution and adhered to the tenets of the Declaration of Helsinki. Health Insurance Portability and Accountability Act compliance was maintained throughout the study.

All consecutive patients with CI exotropia were included in the study, regardless of age or prior surgical history. Patients with underlying neurological conditions or follow-up <4 months were excluded. All patients underwent full ophthalmologic examinations pre and postoperatively. The distance and near deviations were measured with the alternate prism cover test in the five cardinal diagnostic positions of gaze as well as at near using an accommodative target. Measurements were obtained with patients wearing spectacle correction allowing for best visual acuity. A binocular test for stereopsis was performed with the Titmus test at near, using prescription if required. The most recent post-operative examination values were used for comparison.

All patients were operated on by the same surgeon (FGV). Under general anesthesia, the following procedures were performed based on the patients' measured deviation. Patients with a NDD <15 PD and a distance deviation of <10 PD were treated with LR inferior marginal tenotomy. The tenotomy was performed at the muscle insertion for 50% of the muscle insertion width (1–2 PD of correction for every 1 mm of tenotomy). This may be performed asymmetrically in cases of incomitance. Patients with a NDD >15 PD and a distance deviation of >10 PD were treated with bilateral LR slanted recessions. The slanted recessions were performed in an oblique fashion with the upper pole recessed according to the distance deviation angle (4 mm) and the lower pole recessed according to the near deviation (6 mm). Those with limitation in adduction with negative forced duction testing (FDT) were treated with MR inferior muscle fiber plication based on the near angle of deviation or inferior muscle fiber advancement for muscles with previous MR recession [Table 1]. MR inferior muscle fiber plication was performed on the inferior 1/3 of the muscle-tendon width.

All patients were examined initially in the post-operative area, where any necessary adjustments were made to achieve orthotropia at near. Small angles of esotropia in the immediate post-operative period (≤10 PD) were not adjusted as the angles were expected to improve with time. The patients were examined again within the first 2 weeks and then at variable time periods, thereafter, up to 2.5 years post-operative. The examinations included the angles of deviation at distance and near as well as stereopsis. The impact of selective muscle fiber surgery was calculated as follows: The mean deviations were calculated pre and postoperatively and standard deviations were calculated. The near-difference disparity was calculated as the average deviation at distance subtracted by the average deviation at near.

Success was defined as <8 PD of XT at distance and near without overcorrection, a NDD ≤8 PD, as well as lack of symptoms of diplopia or asthenopia.

Results

This cohort study was composed of seven patients, including four males and three females between the ages of 29 and 72 years of age (average age 61.7 years). Four patients had a constant XT and three had an intermittent XT at near. Four patients (57%) demonstrated lateral incomitance of their exotropia. Six patients

Table 1: Algorithm for surgical correction of convergence insufficiency

Distance deviation	Distance/near disparity	Surgical treatment
<10 PD	<15 PD	Lateral rectus inferior marginal tenotomy
>10 PD	>15 PD	Lateral rectus slanted recession
Negative forced duction test with limitation to adduction on examination		Medial rectus surgery

(86%) had a history of prior strabismus surgery. Follow-up ranged from 4 to 31 months (average 12.6 months).

In our cohort [Table 2], patients with the smallest deviations (<10 PD at distance and NDD <15 PD) underwent bilateral LR inferior marginal tenotomy. One of two patients was left with residual exotropia at near and both experienced a 100% PD collapse in NDD (8 and 12 PD reduction). Patients with larger exodeviations (>10 PD and NDD >15 PD) showed an improvement in the NDD of an average of 11.5 PD (37.5–100% reduction) after bilateral LR slanted recession. The third group, which consisted of patients with limitation to adduction, underwent selective muscle fiber surgery to strengthen the inferior fibers of the MR using plications or inferior pole advancement in the case of prior MR recession. This technique achieved a decrease in the NDD by an average of 84.2% (9–10 PD) with complete resolution of distance exotropia with minimal residual near deviations (ET' 2–XT' 4). Those patients with residual near deviation did not report diplopia at near.

Overall, the study group showed a significant post-operative reduction in both the distance and near exodeviation. The overall distance deviation was reduced from 7.71 ± 6.87 PD (range 0–18 PD XT) to an overcorrection of 1.43 ± 3.78 PD (range ET 10–0 PD), and the near deviation from 20.29 ± 9.57 PD (range 12–35 PD XT) to 0.86 ± 1.57 PD (range orthotropic - XT' 4 PD). Importantly, all patients experienced a collapse of their NDD. The NDD was reduced from 12.57 ± 3.15 (range 8–17 PD) to 2.29 ± 3.73 PD (range 0–10 PD). Six of the 7 (85.7%) patients met criteria for success. One patient was overcorrected at distance with residual small-angle exotropia at near in two patients without diplopia.

Discussion

CI-type exotropia remains a challenge to all strabismus surgeons, as there is no single approach that guarantees reliable results at both distance and near. Our study proposes a strategy for treatment of CI-XT based on the degree of exotropia. According to Demer, the horizontal rectus muscles are divided into superior and inferior poles with evidence that the poles exert different contractile forces during convergence and adduction. Findings indicate that the superior pole of the MR exerts 3 times the force of the inferior pole of the MR during conjugate adduction. The contractility during convergence is only 1/3 that of the force for conjugate gaze; therefore, this may predispose patients to CI with any additional weakening of the MR, or contraction of the LR due to surgery or natural processes. This fact supports the rationale for performing selective strengthening of the inferior pole of the MR, which shows weakness in contractility in all horizontal gazes compared to the superior pole. In addition, even though the LR superior and inferior poles appear to demonstrate equal contractility in convergence and conjugate gaze, slanting procedures can, in turn, create an effect of preferential strengthening of the inferior pole fibers in order dampen NDD. We also speculate that weakening the inferior pole of the LR may increase the torque of the MR during convergence. Utilizing the findings of compartmentalization of the muscle fiber groups acting variably at scleral insertion points we believe that a selective surgical algorithm such as the one presented in this paper may improve collapse of NDD in patients with CI-XT.[15,17]

Noninvasive treatment of convergence-type insufficiency may be effective for small degrees of CI and should be

Table 2: Patient characteristics and results following the use of the convergence insufficiency treatment algorithm

Pt.	Age (years) /Sex	Prior Strabismus surgery	Distance deviation	Near deviation	NDD	Surgery	Post-operative distance deviation	Post-operative near deviation	Post-operative NDD	Follow-up (months)
1	67 M	Yes	X(T)4	X(T)'12	8 PD	BLR inferior marginal tenotomy	Ortho	Ortho	0 PD	10
2	29 M	Yes	Ortho	X(T)'12	12 PD	BLR inferior marginal tenotomy	Ortho	Ortho	0 PD	18
3	67 F	Yes	XT 14	XT' 30	16 PD	BLR slanted recession	ET 10	Ortho	10 PD	6
4	61 F	Yes	LX(T) 18	LX(T)' 35	17 PD	BLR slanted recession	Ortho	Ortho	0 PD	8
5	72 M	Yes	X(T) 2	XT' 14	12 PD	BMR inferior plication	Ortho	XT'2	2 PD	11
6	68 M	No	XT 12	XT' 25	13 PD	BMR inferior plication	Ortho	XT' 4	4 PD	4
7	68 F	Yes	XT 4	XT' 14	10 PD	BMR inferior pole advancement	Ortho	Ortho	0 PD	31
Mean±SD	61.7		XT 7.1±6.9 PD	XT 20.3±9.6	12.6±3.2 PD		ET 1.4±3.8 PD	ET 0.9±1.6 PD	2.3±3.7 PD	12.6±9.3

NDD: Near-distance disparity, BLR: Bilateral lateral rectus, BMR: Bilateral medial rectus

considered as a first line treatment if indicated. A non-surgical approach includes prism glasses, pencil push-ups, home-based computer vergence/accommodative therapy, or other orthoptic and binocular activities to stimulate fusion.[3] If patients do not respond to vision therapy, or if their exotropia is large, surgical intervention is warranted to relieve the symptoms of diplopia and asthenopia associated with CI-XT.

As mentioned previously, an array of surgical procedures is currently performed for CI-XT. Wang *et al*. found the success rate of unilateral R&R to be superior to either bilateral LR recession, bilateral MR resection, or unilateral MR resection in children with CI-XT.[14] In this study, the amount of MR resection was based on the near deviation and the LR recession based on the distance deviation. Utilizing this technique, a success rate of 85.7% was achieved, which was defined as the distance deviation in primary gaze to be between ≤10PD of exophoria/tropia and ≤5 PD of esotropia.

Snir *et al*. demonstrated that slanted bilateral LR recessions were superior to standard bilateral LR recessions in a non-randomized, comparative trial.[5] By recessing the upper pole according to the distance deviation and the lower pole according to the near deviation, they achieved success in over 90% of patients. Importantly, they found all patients with standard bilateral LR recessions to have residual exodeviations >8 PD at near, demonstrating the effectiveness of the slanting technique. Utilizing a similar surgical technique for bilateral LR recession, Chun and Kang achieved a success rate of 83.9% in children.[6] Success in both studies was defined with the same criteria as this study: A post-operative residual deviation at near or distance of ≤8 PD and a NDD ≤8 PD.

The term selective surgery in this study refers to treatment of selective muscle groups; therefore, a MR inferior muscle plication treats the same muscle fiber compartment as a MR inferior pole advancement. In this cohort of adults, all patients with small deviations at baseline who underwent bilateral LR inferior marginal tenotomy met the criteria for success (2/2, 100%). Half of the patients who underwent bilateral LR slanted recessions (inferior pole > superior pole) met our criteria for success (1/2, 50%). All three patients who underwent MR surgery met our criteria for success (3/3, 100%). To the best of our knowledge, no prior study has attempted to stratify surgical strategies based on the degree of deviation and presence or absence of limitation to FDT. We are the first study to discuss bilateral MR slanted resection or plication specifically for patients with limitation in adduction, giving surgeons a less invasive option for this subset of patients. We are also the first to employ bilateral LR inferior marginal tenotomy for patients with smaller deviations. MR plication and LR inferior marginal tenotomy involve smaller surgical incisions and can be performed in the office if necessary for cooperative patients, offering an appealing alternative to traditional procedures. These procedures also maintain anterior segment circulation, reducing the risk of anterior segment ischemia. In addition, prior studies primarily studied the effects of surgery in children, and all excluded patients with a prior history of strabismus surgery. In contrast, 6/7 (86%) of the patients in this cohort reported a history of strabismus surgery, which we believe best reflects the general patient population presenting with CI-XT. Therefore, this algorithm may be this first applicable to all patients presenting with CI-XT regardless of their age or prior surgical history.

It is important to note the limitations of this study, which include small sample size, variable follow-up, as well as lack of a control group. An additional limitation of this study includes disparate initial angles of deviation; which make comparisons between groups difficult. However, despite these limitations, we believe this algorithm provides an additional decision-making tool for the treatment of this often difficult to treat condition. In addition, given that, CI rarely requires surgery, most studies assessing surgical interventions for it are limited in size.

Conclusions

Although there are many limitations to this study, we believe it sets the foundation for further studies involving treatment of strabismus with selective muscle fiber operations based on the latest anatomical evidence of compartmentalization of the individual muscle fiber groups.[15] Preliminary data reveal that selective techniques may eliminate diplopia while collapsing NDD in adult patients with CI exotropia, regardless of age, or surgical history. A focused algorithm will help surgeons select the procedure most likely to benefit each individual patient.

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