Comparison between medial rectus pulley fixation and augmented recession in children with convergence excess and variable-angle infantile esotropia

Heba M. Fouad, MD, Mohamad A. Abdelhakim, MD, Ahmed Awadein, MD, and Hala Elhilali, MD

PURPOSE To compare the outcomes of medial rectus (MR) muscle pulley fixation and augmented recession in children with convergence excess esotropia and variable-angle infantile esotropia.

METHODS This was a prospective randomized interventional study in which children with convergence excess esotropia or variable-angle infantile esotropia were randomly allocated to either augmented MR muscle recession (augmented group) or MR muscle pulley posterior fixation (pulley group). In convergence excess, the MR recession was based on the average of distance and near angles of deviation with distance correction in the augmented group, and on the distance angle of deviation in the pulley group. In variable-angle infantile esotropia, the MR recession was based on the average of the largest and smallest angles in the augmented group and on the smallest angle in the pulley group. Pre- and postoperative ductions, versions, pattern strabismus, smallest and largest angles of deviation, and angle disparity were analyzed.

RESULTS Surgery was performed on 60 patients: 30 underwent bilateral augmented MR recession, and 30 underwent bilateral MR recession with pulley fixation. The success rate was statistically significantly higher ($P = 0.037$) in the pulley group (70%) than in the augmented group (40%). The postoperative smallest and largest angles and the angle disparity were statistically significantly lower in the pulley group than the augmented group ($P < 0.01$).

CONCLUSIONS Medial rectus muscle pulley fixation is a useful surgical step for addressing marked variability of the angle in variable angle esotropia and convergence excess esotropia. (J AAPOS 2016;20:405-409)

Variability of the angle of strabismus in the absence of paralysis or restriction may be due to supranuclear abnormalities, for example, high ratio of accommodative convergence to accommodation ratio (AC/A).[1-3] Esotropia in infancy may also manifest as a variable-angle or intermittent deviation.[4] Surgical alignment before 6 months of age on those patients has the potential benefit of improving long-term stereopsis.[5,6]

Surgical management of variable-angle esotropia and convergence excess esotropia includes augmented muscle surgery,[7-9] slanted medial rectus (MR) recession,[10,11] MR pulley fixation,[12-15] and posterior scleral fixation sutures.[16-19] While augmented recession does not seem to address variability directly, its outcome has been encouraging.[7-9] MR pulley fixation and posterior scleral fixation, on the other hand, aim to check angle variability by creating a force that increases as the eye is adducted, perhaps by hindering the telescoping of the muscle through its pulley sleeve.[12-19]

Several formulas are available for augmented recession. Studies targeting the near angle measured with distance correction have reported up to 20% incidence of consecutive exotropia.[9,20] Mitchell and Kowal[14] conducted a study targeting the average of distance and near angles of deviation, and combined the recession with pulley fixation. Because it was difficult from their study to isolate the effect of pulley fixation from that of augmented recession, we conducted a study aiming to compare the results of MR muscle pulley fixation alone to those of augmented recession in children with convergence excess esotropia and in variable-angle infantile esotropia.

Subjects and Methods

The study protocol was approved by Cairo University Research Ethics Committee and conformed to all local laws and was

Author affiliations: Cairo University Faculty of Medicine, Cairo, Egypt
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Correspondence: Ahmed Awadein, MD, 16 Abd El-Hady Street, Manial, Cairo, Egypt 11451 (email: ahmedawadein@yahoo.com).

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compliant with the principles of the Declaration of Helsinki. A prospective controlled interventional study was performed on patients with convergence excess esotropia and variable-angle infantile esotropia during the period from January 2010 through December 2012. An informed consent for the surgery was obtained from all patients. Patients' parents received a thorough explanation of the study design and aims and provided written informed consent.

Sample size was estimated considering a study power of 0.8 with an alpha error of 0.05 aiming to detect a difference of 5^{Δ} in the postoperative angle disparity between the two groups, assuming a postoperative standard deviation of 6^{Δ}.[11] Based on this estimation, a total of 24 eyes were found to be adequate in each group, and considering a 25% dropout during follow-up, recruitment of 30 study subjects was targeted.

All patients received a full ophthalmologic evaluation including measurement of visual acuity, cycloplegic refraction, anterior segment examination, and dilated fundus examination. A detailed motor examination was performed during the initial evaluation and at each follow-up examination. The ductions and versions in all cardinal directions of gaze were analyzed. The angle of misalignment was measured by the prism and alternating cover tests for both distance and near with and without spectacle correction. In instances in which the angle could not be reliably measured with the cover tests, the Krimsky method was used. The angle of horizontal misalignment was also measured in side gazes and in straight up and down gazes.

For cycloplegic refraction, cyclopentolate 1% eyedrops were instilled 3 times 10 minutes apart, with the last time 30 minutes before refraction. Patients with hypermetropia with a spherical equivalent $\geq +1.5$ D were then prescribed the full cycloplegic refraction and then reevaluated with spectacles one month later. Patients with residual esotropia $>8^{\Delta}$ for distance or near with spectacles had repeat refraction using atropine 1% eyedrops 3 times daily for 3 days before refraction. After ensuring that glasses for the full cycloplegic refraction were prescribed, patients were then evaluated with glasses to identify those with convergence excess esotropia. Convergence excess esotropia was diagnosed when the angle of deviation with glasses for near exceeded that for distance by $\geq 15^{\Delta}$. Patients with convergence excess esotropia were managed according to the distance deviation. Patients with esotropia or a poorly controlled esophoria for distance $>8^{\Delta}$ were included in the study. Patients who had only a very small $<8^{\Delta}$ or intermittent esotropia for distance with residual larger esotropia/esophoria for near were prescribed executive bifocals with a +3.0 D near add and were rechecked 1 month later with bifocals. Those patients were then included only if the esotropia for near was poorly controlled by bifocals, or if the bifocals were poorly tolerated.

Patients with infantile esotropia were included only if they showed significant variability in the angle of strabismus after prescription of hypermetropic correction with a spherical equivalent $\geq +1.5$ D. Significant variability was defined as variability in the angle of strabismus at different times on the same visit for at least 2 visits, measured using an accommodative target, in the absence of any uncorrected hypermetropia, pattern strabismus, or oblique muscle dysfunction. Patients were included only if the variability—difference between the largest and smallest angles measured—was $\geq 20^{\Delta}$.

Amblyopia was defined as a difference of 0.3 logMAR in verbal children or a strong unilateral fixation preference in infants and preverbal children. Patients with amblyopia were treated before surgery according to the Pediatric Eye Disease Investigative Group (PEDIG) guidelines of amblyopia therapy using part-time occlusion.[21]

Patients with neurologic, ocular, or developmental disorders or follow-up of <6 months were excluded. In addition, patients were excluded if they showed oblique muscle dysfunction, vertical deviation, significant A or V patterns, paralytic or restrictive forms of strabismus, or had a history of eye surgery (strabismus or otherwise).

The smallest angle of deviation was defined as the corrected angle for distance in the convergence excess subgroup and as the smallest angle measured in the variable-angle esotropia subgroup. The largest angle was defined as the corrected angle for near measured through the distance prescription for the convergence excess subgroup and the largest angle measured in the variable angle esotropia subgroup. The angle disparity was defined as the difference between the largest and smallest angles in both subgroups.

Patients were randomly allocated using a random table to one of two groups. In one group bilateral augmented MR muscle recession was performed (augmented group); in the other group bilateral MR muscle pulley posterior fixation was performed (pulley group).

Both surgeries were performed by one of three surgeons (HE, AA, HMF). In the augmented group, the MR muscle MR was recessed using standard tables using scleral sutures through a fornix approach,[22] with the surgical dose targeting the average of the largest and smallest angles.

In the pulley group, surgeries were performed via a limbal approach, and MR muscle recession was performed with the surgical dose targeting the smallest preoperative angle; in cases where the smallest angle was 0, a bilateral 3 mm recession was performed. The muscle was then fixated to its pulley as described.[12,13]

Patients were examined at 1 week, 1 month, 3 months, and 6 months after surgery. Patients were considered to have successful outcome if both the smallest and largest angles were within 8^{Δ} of orthophoria in the infantile esotropia subgroup and if the distance and near angles with spectacles were $<8^{\Delta}$ esotropia/phoria in the convergence excess subgroup. Patients with convergence excess who developed any exophoria/tropia or in whom hyperopic correction needed to be reduced for treatment of a consecutive exotropia were considered to be unsuccessful.[8,14,23]

Comparisons between groups were made using *t* test for continuous variables and the Fisher exact test for categorical variables. Statistical analysis was performed with SPSS for Windows (SPSS Inc, Chicago, IL).

Results

A total of 60 patients were included in the study; all patients completed the follow-up period. Of the 60 patients, 30 were in the augmented group and 30 in the pulley group. In the augmented group 20 patients (66.6%) had variable-angle esotropia and 10 patients (33.3%) had convergence excess esotropia. In the pulley group 22 patients (73.3%) had variable-angle esotropia and 8 patients (26.6%) had convergence excess esotropia (eTable 1). The mean age at surgery was 5.1 years in the augmented group and 4.6 in the pulley group ($P = 0.16$).

The mean MR recession was 5.8 ± 0.7 mm (range, 5–7 mm) in the augmented group and 4.0 ± 1.1 mm (range, 3–6 mm) in the pulley group. The smaller amount of MR recession in the pulley group was statistically significant ($P < 0.01$).

The postoperative smallest and largest angles were statistically significantly lower ($P < 0.01$) in the pulley group ($0^\Delta \pm 4^\Delta$ and $3^\Delta \pm 10^\Delta$, resp.) than in the augmented group ($2^\Delta \pm 6^\Delta$ and $12^\Delta \pm 8^\Delta$, resp.). The difference in the postoperative largest angle between the pulley and the augmented groups remained statistically significant in both the variable infantile esotropia ($2^\Delta \pm 10^\Delta$ and $13^\Delta \pm 10^\Delta$, resp.) and the convergence excess ($5^\Delta \pm 8^\Delta$ and $17^\Delta \pm 5^\Delta$, resp.) subgroups when each subgroup was analyzed separately ($P < 0.01$). The postoperative angle disparity was statistically significantly lower ($P < 0.01$) in the pulley group ($7^\Delta \pm 8^\Delta$) than in the augmented group ($12^\Delta \pm 7^\Delta$) and remained statistically significant in both the variable infantile esotropia ($7^\Delta \pm 7^\Delta$ and $13^\Delta \pm 6^\Delta$, resp.) and the convergence excess ($6^\Delta \pm 4^\Delta$ and $17^\Delta \pm 6^\Delta$, resp.) subgroups when each group was analyzed separately (Figure 1 and eTable 2, available at jaapos.org). Normalization of the angle disparity to $<10^\Delta$ was achieved in 20 patients (63.33%) in the augmented group (15 patients [75%] in the variable angle esotropia subgroup and 5 [50%] in the convergence excess subgroup) and 25 patients (83.3%) in the pulley group (19 patients [86.4%] in the variable angle esotropia subgroup and 6 [75%] in the convergence excess subgroup). The difference was however statistically insignificant ($P = 0.23$).

The success rate was statistically significantly higher ($P = 0.037$) in the pulley group (70%) than the augmented group (40%). The success rate was higher in the pulley group than the augmented group for the variable esotropia (73 and 50%, resp.) and the convergence excess subgroups (63% and 20%, resp.; eTable 3, available at jaapos.org). However, the difference in the success rate was statistically insignificant in both subgroups ($P = 0.204$ and 0.154, resp.). Four patients (13%) in the augmented group and 5 patients (17%) in the pulley group had postoperative overcorrection (range, 0^Δ-10^Δ and 0^Δ-25^Δ, resp.). Reduction of hyperopic correction was done to improve the overcorrection in 1 patient in the augmented group and 1 patient in the pulley group, with improvement of alignment. Surgery was offered to 2 patients in the pulley group with overcorrection of $>10^\Delta$, but only 1 patient consented. Bilateral lateral rectus recession was performed with successful outcome.

Before surgery, 8 patients in the convergence excess subgroup wore bifocals (5 patients [50%] in the augmented group and 3 [38%] in the pulley group). At the time of surgery, the esophoria/tropia was poorly controlled through the near add in 6 patients (4 patients in the augmented group and 2 in the pulley group), and the bifocals were poorly tolerated in the other 2 patients (1 patient in the augmented group and 1 in the pulley group). After surgery, 2 of 5 patients who were undercorrected only for the near angle through the distance prescription were prescribed bifocals and the near angle was adequately controlled through a +3.00 D near add in one patient and a +2.50 near add in another patient. The 1 patient in the pulley group who was undercorrected for the near angle through the distance prescription was not controlled with bifocals; thus none of the patients in the pulley group were using bifocals after surgery.

None of the patients in either group had a preoperative oblique muscle dysfunction or pattern strabismus. After surgery, 8 patients (27%) in the augmented group developed unilateral (n = 2) or bilateral (n = 6) overelevation in adduction with a clinically significant V pattern (range, 15^Δ-30^Δ). In the pulley group, 4 patients developed bilateral overelevation in adduction (13%) with a clinically significant V pattern (range, 15^Δ-25^Δ). All patients who developed oblique muscle dysfunction had a variable angle infantile esotropia. None of the patients in both groups had limitation in ductions or versions postoperatively.

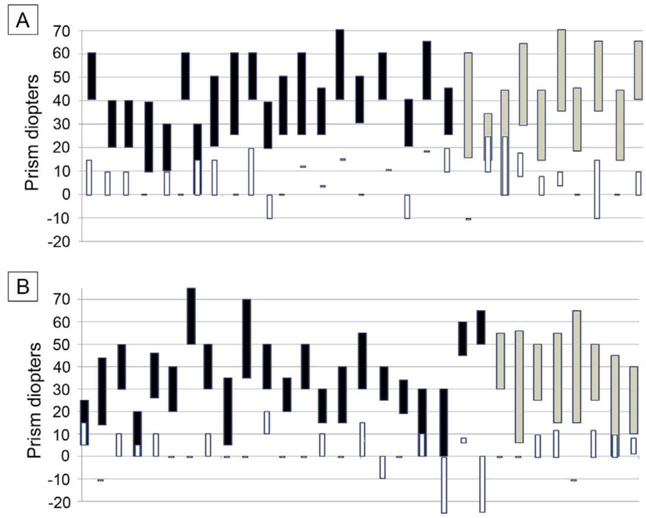

FIG 1. Graphical representation of the smallest angle, largest angle, and angle disparity of each patient in the augmented group (A) and the pulley group (B) before surgery (black boxes represent variable esotropia patients; gray boxes, convergence excess patients), and after surgery (white boxes). Positive numbers represent esophoria/tropia and negative numbers represent exophoria/tropia.

Discussion

To our knowledge, this is the first study comparing the results of augmented MR recession to pulley fixation in the management of variable-angle esotropia and convergence excess esotropia. Prior studies either compared augmented MR recession with posterior scleral fixation sutures and slanted MR recession[10,11] or compared pulley fixation with posterior scleral fixation sutures.[13] It is also the first prospective study to assess the effect of pulley fixation; previous studies were retrospective.[12-15]

In the current study, patients with variable-angle infantile esotropia and convergence excess esotropia who had pulley fixation achieved a statistically significantly greater reduction in the largest angle of strabismus and in the angle disparity after surgery. Clark and colleagues[12,13] performed 2 retrospective studies to evaluate the effects of pulley fixation. They compared the effects of posterior scleral fixation and pulley fixation in patients with high AC/A ratio esotropia and variable-angle infantile esotropia. Their results were slightly better than ours. However, the preoperative near-distance disparity in their study was lower. Mitchell and Kowal[14] performed another retrospective study to assess the effect of pulley posterior fixation on partially accommodative esotropia and also achieved good results.

It may be thought that the pulley fixation suture, being not anchored to the sclera, may migrate through the soft tissue pulley, potentially diminishing the effects of the surgery over time. Nevertheless, Wabulembo and Demer[15] reported a long-term stability of the results at a mean follow-up of 3.5 years.

While variability in the angle is a known feature of infantile esotropia, little in the literature addresses treatment in such cases. Fu and colleagues[4] reported that infants <1 year of age with variable-angle esotropia later progressed to constant esotropia. Although successful surgical alignment before 6 months of age on such patients has the potential benefit of improved long-term stereopsis,[5,6] the surgical algorithm is unknown. In the current study, we investigated two different approaches for management of such patients. Pulley fixation achieved a statistically significantly greater reduction in both the smallest and largest angles of deviation, as well as the angle disparity. It is noteworthy that some of those patients developed inferior oblique overaction and pattern strabismus after surgery in both groups. It is possible that the inferior oblique overaction could have been the cause of preoperative variability of the angle, although it was not obvious clinically before surgery.

There are several formulas for augmented recession. Mitchell and Kowal[14] conducted their study using the average of distance and near angles, but they combined the recession with pulley fixation. It was not obvious from their study whether the pulley fixation offered an advantage over augmented MR muscle recessions alone; however, Archer[24] argued that it does not matter as long the results are good and the pulley posterior fixation sutures do no harm. In the current study, in order to evaluate the effects of augmented recession separately from that of pulley fixation, the amount of MR recession was based on the average of distance and near angles of deviation with distance correction in the augmented group and on the distance angle of deviation in the pulley group. The undercorrection rate in our augmented recession group was higher than that reported in prior studies that targeted the near angle measured with distance correction. Further augmentation of the amount of recession might have reduced the undercorrection rate, but perhaps on the expense of a higher overcorrection rate.

Many factors can be included in the definition of success, including satisfactory motor alignment, discontinuation of bifocals or even spectacles, and the achievement of a bifoveal fixation.[25] Although initial studies defined satisfactory motor alignment as within 8^{Δ} of orthophoria, most studies now favor considering of any degree of exophoria as failure, as small degrees of exophoria tend to decompensate with time.[8,14,22] We chose to use the more rigid criteria of considering any exophoria as a failure. The number and the age of our studied patients were too small to allow a meaningful analysis of sensory outome.

A limitation of our study is the small number of patients in each subgroup. This may make meaningful analysis of the success rate in each group separately of little value. Nevertheless, the difference in the postoperative angle disparity between both groups was statistically significant.

In conclusion, MR muscle pulley fixation is a useful additional step for addressing variability of the angle and convergence excess. Although a bit more difficult to perform than a simple recession, the technique can help to achieve a satisfactory motor alignment in those patients. More data is still necessary to assess the appropriate surgical dose for this procedure.

Literature Search

PubMed was searched on March 27, 2016, using the following terms: *pulley sutures* OR *pulley suture* OR *pulley posterior fixation* OR (*pulley* AND *strabismus*).

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Seeing Is Believing

Thus, from 1325 to 1331 the hospital retained the services of seven different medical specialists on a wide range of contracts. The most stable employee was Maestro Silvestro, who received a regular salary and was employed as 'nostro medico', 'our physician.' Others were brought in on a more ad hoc basis as consultants, like Ser Cione, who specialised in external lesions such as wounds, ulcers or sores, and Maestro Filippo, 'who treats eyes.' The latter's job was probably the removal of cataracts, a complex operation that involved using a needle to lower the lens behind the pupil.

John Henderson, *The Renaissance Hospital* (London: Yale University Press, 2006), 27.

eTable 1. Preoperative characteristics of the studied patients[a]

Characteristic	Group analysis	Augmented group (n =30)	Pulley group (n = 30)
Age at surgery, years: mean ± SD (range)	Both groups	5.1 ± 4.6 (1-16)	4.5 ± 3.7 (1-15)
	Variable angle	2.5 ± 1.7 (1-5)	1.9 ± 1.5 (1-5)
	Convergence excess	10.3 ± 4.2 (6-16)	7.6 ± 4.5 (5-15)
Females, n (%)		12 (40)	13 (43)
Cycloplegic refraction, D: mean ± SD (range)		+2.70 ± 1.28 (+1.00 to +7.00)	+2.32 ± 1.05 (+0.50 to +7.00)
Smallest angle, PD, mean ± SD (range)	Both groups	24 ± 12 (0-40)	21 ± 14 (0-50)
	Variable angle	27 ± 15 (0-40)	23 ± 16 (0-50)
	Convergence excess	18 ± 12 (0-30)	16 ± 12 (0-30)
Largest angle, PD, mean ± SD (range)	Both groups	51 ± 11 (30-70)	47 ± 14 (20-75)
	Variable angle	51 ± 12 (30-70)	45 ± 13 (25-75)
	Convergence excess	50 ± 11 (35-70)	53 ± 13 (40-65)
Angle disparity, PD, mean ± SD (range)	Both groups	27 ± 7 (20-45)	26 ± 10 (15-50)
	Variable angle	23 ± 5 (20-35)	22 ± 6 (15-35)
	Convergence excess	32 ± 7 (20-45)	37 ± 11 (25-50)

D, diopter; *PD*, prism diopter; *SD*, standard deviation.
[a]All differences were statistically insignificant, with *P* values of >0.15.

eTable 2. Postoperative data of studied patients

Angle of deviation	Group analysis	Augmented group	Pulley group	*P* value
Smallest angle, PD, mean ± SD (range)	Both groups	2 ± 6 (XT 10 to ET 12)	0 ± 4 (XT 10 to ET 10)	0.061
	Variable angle	4 ± 4 (ET 0 to 18)	1 ± 3 (XT 10 to ET 10)	0.028
	Convergence excess	1 ± 7 (XT 10 to ET 10)	1 ± 4 (XT 10 to ET 2)	0.61
Largest angle, PD, mean ± SD (range)	Both groups	12 ± 8 (XT 10 to ET 25)	3 ± 10 (XT 20 to ET 25)	0.01
	Variable angle	13 ± 10 (XT 10 to ET 20)	2 ± 10 (XT 25 to ET 20)	0.01
	Convergence excess	17 ± 5 (ET 8 to 25)	5 ± 8 (XT 10 to ET 12)	0.01
Angle disparity, PD, mean ± SD (range)	Both groups	12 ± 7 (0-25)	7 ± 8 (0-30)	0.01
	Variable angle	13 ± 6 (0-20)	7 ± 7 (0-25)	0.01
	Convergence excess	17 ± 6 (8-25)	6 ± 4 (0-12)	0.01

D, diopters; *ET*, esotropia; *PD*, prism diopter; *XT*, exotropia.

eTable 3. Success rate in both groups

Convergence excess esotropia		Variable-angle infantile esotropia		Whole group		
Pulley group (n = 8)	Augmented group (n = 10)	Pulley group (n = 22)	Augmented group (n = 20)	Pulley group (n = 30)	Augmented group (n = 30)	Outcomes
5 (63%)	2 (20%)	16 (73%)	10 (50%)	21 (70%)	12 (40%)	Satisfactory outcome for smallest and largest angles, n (%)
0	2 (20%)	1 (5%)	2 (10%)	1 (3%)	4 (13%)	Undercorrection for smallest and largest angles, n (%)
1 (13%)[a]	5 (50%)[a]	2 (9%)	5 (25%)	3 (10%)	10 (33%)	Undercorrection for largest angle only, n (%)
1 (13%)	0	1 (5%)	0	2 (7%)	0	Overcorrection for smallest and largest angles, n (%)
1 (13%)	1 (10%)	2 (9%)	3 (15%)	3 (10%)	4 (13%)	Overcorrection for largest angle only, n (%)

[a]Two of 5 patients who had undercorrection for only the largest angle (near angle through the distance prescription) in the augmented group continued to used bifocals and the near angle was adequately corrected through a +3.00 D near add in one patient and a +2.5 D near add in another. The single patient who had undercorrection for the largest angle only in the pulley group was not controlled with bifocals.