IMPORTANCE Bilateral medial rectus muscle recession and one lateral rectus muscle resection surgery for the correction of large-angle infantile esotropia may be associated with a favorable long-term motor outcome. A consecutive exotropic drift was encountered more commonly than a recurrent esotropic drift in the long run, especially in the smaller (50-69 prism diopters [Δ]) range of preoperative esodeviation.

OBJECTIVE To outline the short- and long-term motor outcomes of graded bilateral medial rectus muscle recession and one lateral rectus muscle resection for the correction of large-angle esotropia (≥50Δ).

DESIGN Retrospective analysis.

SETTING Strabismus service, tertiary care university referral center.

PARTICIPANTS A total of 194 consecutive patients with infantile or presumed infantile esotropia.

EXPOSURE All patients underwent bilateral medial rectus recession and a lateral rectus resection in the non-dominant eye by the same surgeon.

MAIN OUTCOMES AND MEASURES Short-term (8 weeks) and long-term rates of postoperative successful alignment (±10Δ), undercorrection, and overcorrection.

RESULTS The median age of patients at surgery was 2.7 years (range, 20 months–36 years). The median follow-up time was 4.5 years (range, 6 weeks–25 years). The mean preoperative deviation was 68.2Δ. Of the 194 patients, 121 (62.4%) were successfully aligned at the last follow-up visit or prior to reoperation, and 154 (79.4%) were successfully aligned at the 8-week postoperative evaluation. A comparison of early vs late outcomes revealed a higher rate of late overcorrections (5.15% vs 24.1%, respectively, P = .001) but the same rate of undercorrections (15.4% vs 15.1%; P = .85). The outcome of surgery was not associated with the presence of amblyopia, high hyperopia, or the total amount of millimeters of surgery but was adversely influenced by the presence of inferior oblique overaction and the magnitude of the preoperative esodeviation. Delayed consecutive exotropia was more prevalent in the 50Δ to 69Δ range of preoperative esodeviation.

CONCLUSIONS AND RELEVANCE Three horizontal muscle surgery for the correction of large-angle esotropia is associated with a high success rate. Long-term follow-up indicated that an exotropic drift may be expected 3 times more often than an esotropic drift.
he management of large-angle esotropia is challenging for the strabismologist. Popular surgical options include large bilateral medial rectus muscle recessions and selective surgery on 3 or even 4 extraocular muscles. Alternative approaches include large unilateral medial rectus muscle recession and lateral rectus muscle resection or adding conjunctival recession, medial pulley fixation, or botulinum toxin treatment to the medial rectus muscle recession.

Many strabismologists would opt for large bilateral medial rectus muscle recessions because this is a simple symmetrical approach, involves a shorter operating time, and leaves the lateral rectus muscles untouched for subsequent surgery, if needed. Others prefer to add 1 or even 2 lateral rectus muscle resections to minimize the rate of undercorrections, which has variably been reported between 13% and 60% for large bilateral medial rectus muscle recessions.

Another attribute of interest to the family and to health care providers is the long-term stability of outcome. Surgeries are challenged to correct strabismus with one surgical procedure; however, population-based studies have shown that reoperation rates may reach 66% at a follow-up time of 20 years. These studies, however, have not specifically addressed the rates of overcorrection as opposed to undercorrection. In our study, we report on the early and late outcomes of a large series of patients who underwent bilateral medial rectus muscle recessions and a unilateral lateral rectus muscle resection for large-angle esotropia.

Methods

We reviewed the medical charts of all patients who underwent 3 horizontal muscle surgery by the same surgeon for primary correction of early-onset esotropia during the period from 1973 to 2008. Our study met the requirements of institutional review board approval in our institution.

Patients were included in our study if they had a recorded follow-up time of at least 8 weeks and if the preoperative esodeviation was equal to or greater than 50 prism diopters (Δ) at distance (with glasses when applicable) without an accommodative component. Patients were considered to have an accommodative component if they had a more than 10Δ decrease in the angle of esodeviation with hyperopic correction (or esodeviation at near exceeding distance deviation by >10Δ). They were excluded if there was obvious neurological impairment or mental retardation, or if there was a history of extraocular muscle surgery or simultaneous cyclovertical muscle surgery.

Infantile esotropia was defined as esotropia that is present by history in the first 6 months of life and confirmed by an ophthalmologist by the first year of life and that is not associated with obvious neurological impairment or mental retardation. The following parameters were recorded for all patients: type of esotropia (infantile esotropia or other), initial and final visual acuity, preoperative cyclovertical refraction analyzed as the average spherical equivalent between the 2 eyes, history of amblyopia and occlusion therapy or atropine penalization, presence of inferior oblique overaction, preoperative esodeviation, age at primary esotropia surgery, amount of medial rectus muscle resected and of lateral rectus muscle resected in millimeters, postoperative deviation at 8 weeks and the final follow-up examination, time of conversion to secondary exotropia or recurrent esotropia, and type of reoperation when applicable.

Spectacles were regularly prescribed for patients with a cycloplegic refractive error of >2.50 diopters (D) or greater. Amblyopia was treated aggressively with patching (only occasionally with atropine penalization) preoperatively, with surgery delayed until the patient’s fixation freely alternated. Data from the alternate cover test using the synoptophore in primary position, with the patient wearing glasses (when applicable), were analyzed in our report. All orthoptic measurements were performed by the same examiner (E.C.) and were retrieved from the patient’s medical records by the same observer (K.I.C.).

Surgical intervention consisted of graded bilateral medial rectus muscle recessions and a unilateral rectus muscle resection based on the following planning rationale: the combination of bilateral medial rectus muscle recessions of 5 mm and a unilateral lateral rectus muscle resection of 7 mm in the nondominant eye was the most commonly performed procedure. If the preoperative angle was smaller than 60Δ to 65Δ or in the presence of an A or V pattern, the amount of medial rectus muscle recession would decrease by 0.5 to 1.0 mm, and/or the amount of lateral rectus muscle recession would decrease to 6.0 mm. For select cases with a very large preoperative angle, the amount of medial rectus muscle recession was increased to a maximum of 6 mm, and the amount of lateral rectus muscle recession was increased to a maximum of 7.5 mm.

For all strabismus procedures, a Swan incision (a circumferentially oriented incision at 5 mm from the limbus) was performed while the patient is under general anesthesia. The muscle was reattached to the sclera with two 6-0 Vicryl (Polyglactin 910; Ethicon) sutures with all recession measured by calipers from the original insertion.

A successful outcome was defined as an alignment within 10Δ of orthotropia at distance with appropriate refractive correction. The short-term outcome was based on alignment at the 8-week postoperative visit (ranging for the individual patient from 6 to 9 weeks) because, by convention, this is the time point when the result that is solely attributable to the mechanical effects of surgery is assessed, shortly after completion of the healing process. The final outcome was designated by the alignment at the last follow-up examination or prior to the first horizontal muscle reoperation, when applicable. The length of elapsed time between surgery and the onset of consecutive exotropia or recurrent esotropia was either deduced from reliable history or approximated to the time of the postoperative visit, when the change in alignment status was documented for the first time.

The 3 outcome groups (successful alignment, undercorrection, and overcorrection) were compared for a number of patient characteristics both at the 8-week and the final evaluation. Data are described as mean (SD) values and median values with interquartile range. For quantitative data, the Kruskal-Wallis test was used, followed by the Mann-Whitney test to compare 2 groups. Associations between qualitative data were...
examined using the χ² test or the Fisher exact test, when appropriate. The McNemar test was used to test differences between paired proportions.

Furthermore, multinomial logistic regression analysis was performed to identify significant predictors of the postoperative results (successful alignment, undercorrection, and overcorrection). The probability of outcome success over time after surgery for esotropia was estimated by use of the Kaplan-Meier correction. The probability of outcomes success overtime after surgery results (successful alignment, undercorrection, and overcorrection) was assessed at 8 weeks and at final examination (≥6 months).

Results

Of 654 patients identified in the hospital database who underwent surgery by the same surgeon for esotropia, 284 (43.4%) had large-angle esotropia (≥50Δ), and of these patients, 264 underwent bilateral medial rectus muscle recessions and a unilateral lateral rectus muscle resection. Twenty-one patients were identified as having an accommodative component, 33 patients were identified as having undergone cyclovertical muscle surgery simultaneously, and 16 patients had missing follow-up data and were excluded from the analysis. A total of 194 patients form the basis of this report, including 53 patients for whom the date at onset of esotropia was not clearly documented yet an accommodative component was not present. We labeled this subgroup “presumed infantile esotropia,” even though we realize that some patients may have acquired nonaccommodative esotropia.

The mean (SD) age of patients at surgery was 4.3 (4.9) years (median, 2.7 years; range, 20 months–36 years). The mean (SD) preoperative deviation was 68.2Δ (12.06Δ) (range, 50Δ-100Δ). Sixteen patients had mild inferior oblique overaction or a V pattern that did not necessitate an inferior oblique weakening procedure. The mean postoperative follow-up duration was 6.6 years (median, 4.5 years; range, 6 weeks–25 years).

Overall, medial rectus muscle recessions of 4 to 5 mm and lateral rectus muscle resections of 6 to 7 mm were performed for deviations up to 80Δ, with the total amount of muscle retracted or resected ranging from 14 to 17 mm. Only 4 patients had medial rectus muscle recessions of 5.5 to 6.0 mm, and 9 patients had a lateral rectus muscle resection of 7.5 mm for deviations exceeding 80Δ. Of 194 patients, 130 (67.0%) underwent bilateral medial rectus muscle recessions of 5 mm and a lateral rectus muscle resection of 7 mm in the nondominant eye.

At the last follow-up visit or prior to reoperation, of 194 patients, 121 (62.4%) were successfully aligned, 28 (14.4%) were esotropic, and 45 (23.2%) were exotropic. The postoperative success rates, mean angles of deviation, and dose-response ratios assessed “early” (8 weeks postoperatively) as opposed to “late” (≥6 months) are summarized in Table 1. No cases of clinically significant limitation of adduction were noted postoperatively.

The percentage of overcorrected patients at the final examination (24.2%) was significantly higher than the percentage of overcorrected patients at 8 weeks after surgery (5.2%) (P < .001, determined by use of the McNemar test), but there was no difference in the rates of undercorrection (15.5% vs 15.2%, respectively; P = .85) (Figure 1A). The rates of exotropic or esotropic drift were assessed over time: 36 patients converted to late consecutive exotropia, whereas 12 patients converted to recurrent esotropia, making a clinically significant exotropic drift 3 times more common than an esotropic drift.

The mean (SD) time from surgery to the appearance of recurrent esotropia was 2.2 (4.9) years (median, 4 months; range, 3 months–17.5 years), and the mean (SD) time to the appearance of consecutive exotropia was 4.3 (3.9) years (median, 3 years; range, 3 months–16 years). Figure 2 shows the Kaplan-Meier life survival curves after 1 surgery in which the failure of surgery is due to residual esotropia, consecutive exotropia, and their cumulative effect.

Indications for reoperation were a cosmetically objectionable deviation usually larger than 20Δ. The rate of final successful alignment after reoperation for esotropia (6 patients) or exotropia (18 patients) by the same surgeon was 73.7% in this cohort. No cases of a stretched scar or a slipped muscle were identified in the medical records of the reoperations.

The 3 outcome groups (successful alignment, undercorrection, and overcorrection) were assessed at 8 weeks and at the final examination (Table 2 and Table 3), and they did not differ statistically in terms of type of esotropia (infantile vs presumed infantile esotropia), history of amblyopia, refractive er-
ror larger than 3.00 D, age at surgery (the age range is shown in Figure 3), or the total number of millimeters of surgery performed (including the amount of lateral rectus muscle resected). For patients who were identified as having been undercorrected at the 8-week follow-up examination, the preoperative esodeviation was larger, and the follow-up time was longer; however, these values did not differ among patients with different final outcomes.

None of the parameters tested by multinomial logistic regression (ie, type of esotropia, age at surgery, history of amblyopia, magnitude of refractive error, or total amount of muscle recessed or resected) were identified as prognosticators of the outcome of surgery, except for the magnitude of preoperative esodeviation and the presence of inferior oblique overaction. The presence of inferior oblique overaction increased the chance of a late undercorrection (odds ratio [OR], 4.522; \( P = .04 \)) and a late overcorrection (OR, 5.056; \( P = .013 \)).

Eight weeks after surgery, patients with a larger preoperative esodeviation had a higher chance of undercorrection than successful alignment (OR, 1.047; \( P = .001 \)). Patients with a larger preoperative deviation had a significantly lower chance of developing a consecutive exotropia as opposed to a successful alignment (OR, 0.964; \( P = .04 \)) and had a higher chance of being esotropic than exotropic at the final examination (OR, 1.058; \( P = .010 \)) (Figure 4).

Adjusting for the amount of muscle recessed or resected did not affect the observed relationship between the preoperative angle and either the early outcome of surgery (\( P = .65 \) when comparing undercorrections with successful alignments) or late outcome of surgery (\( P = .65 \) when comparing overcorrections with successful alignments and \( P = .40 \) when comparing undercorrections with overcorrections).

The predominance of late consecutive exotropia was confined to patients with smaller (<70Δ) preoperative angles. Surgery became balanced as to the rate of late undercorrections (16.8%) and overcorrections (16.8%) for patients with a preoperative deviation of 70Δ or greater. Early undercorrections outnumbered overcorrections at a ratio of 2.83:1 to 3.25:1 for both subgroups of preoperative angles (Figure 1B and C). Half of these early undercorrections measured between 12Δ and 14Δ (Table 1). The follow-up time did not differ among the 3 final outcome groups across the smaller (\( P = .15 \), determined by use of the Kruskal-Wallis test) or larger (\( P = .63 \)) range of preoperative esodeviations.

Discussion

Our study, based on a large cohort of patients with large-angle infantile esotropia managed by a single surgeon, shows that undergoing 3 horizontal muscle surgery is associated with both short- and long-term favorable motor outcomes, with an
exotropic drift occurring more often than an esotropic drift over time, especially in patients with smaller preoperative esodeviations.

There is no consensus in the existing literature on rates of overcorrection as opposed to undercorrection after undergoing 3 horizontal muscle surgery. As shown in Table 4, which summarizes results of previous studies on this topic, only a study18 of 10 patients who were younger than 2 years of age at the time of esotropia surgery outlined a prominent exotropic drift over time.

Large bilateral medial rectus muscle recessions, however, have been implicated in late consecutive exotropia in several studies.14,15 Stager et al14 reported that 27% of 88 patients who underwent 7.0-mm bilateral medial rectus muscle recessions and who were followed up for an average of 3.4 years developed consecutive exotropia despite a high (92%) rate of initially successful alignments. In their concluding remarks, Stager et al14 note that no long-term study of patients who underwent 3 muscle surgery has been performed to compare rates of consecutive exotropia between the 2 procedures.

It is hard to compare the results of different studies addressing different age groups and using different methods (eg, different methods of surgical planning and surgical technique and different lengths of follow-up time). One methodological difference between our study and previously published studies is that we analyzed the measurements from the alternate cover test using the synoptophore. In our hands, these measurements were obtained from patients starting at the age of 2 years. We believe that synoptophore measurements may be more standardized, minimizing potential errors inherent in the use of prisms or Krimsky tests for large-angle strabismus in this age group.10,18-20 It has been suggested that the synoptophore may overestimate esotropic deviations owing to presumed induced proximal convergence. It could be hypothesized that this approach might have resulted in the overestimation of undercorrections. Indeed, 15 of 30 patients categorized as undercorrected at the 8-week follow-up had deviations of 12Δ to 14Δ, and most of them were not cosmetically noticeable undercorrections. However, this method may further strengthen our conclusion on the predominance of the exotropic drift over time.

Our study shares the limitations inherent in a retrospective study. Follow-up times varied among patients, and, to our knowledge, this is a drawback of all published studies.9,18 on patients undergoing 3 horizontal muscle surgery, including the recent single prospective study by Camuglia et al.10 Analysis of data from variable follow-up periods is difficult and may introduce the potential for error.21,22 The reason for this is the uncertainty about the reasons of loss to follow-up. The mean
duration of follow-up did not differ statistically among pa-
tients with a successful alignment, undercorrected patients,
and overcorrected patients in our series (across the range
of preoperative esodeviation), which may indirectly argue
against the possibility that the reasons for dropping out were
primarily influenced by the type or direction of surgery out-
come. However, only 25% of patients had recorded alignment
data beyond the tenth postoperative year, which weakens the

power of conclusions drawn from late follow-up examinations. In our analysis of the Kaplan-Meier survival rates, we provide an alternative curve generated by the “optimistic” assumption that patients who were not followed up after a certain time were asymptomatic and satisfied with their ocular alignment. Obviously this is an overoptimistic approach, yet we believe that the actual prevalence of unsuccessful outcomes lies between the 2 curves.

Long-term population-based studies have shown that the duration of follow-up is the critical parameter for assessing success rates of strabismus surgery, with longer follow-up times associated with increasing numbers of “failures.” We suggest that the mean follow-up time (6.6 years) in our series may have allowed time for the appearance of secondary exotropia. It is of note that, in our series, the average time was 4.3 years for the appearance of consecutive exotropia and 2.2 years for the appearance of recurrent esotropia. Previous studies have also outlined the long latent period before the appearance of consecutive exotropia after esotropia surgery.

It is not clear from the currently available literature whether a specific surgical approach or whether particularities inherent in the management of large-angle esotropia, per se, may be accountable for the late exotropic drift. A larger preoperative deviation has generally been associated with a less favorable outcome of esotropia surgery and a larger number of reoperations. Addressing concerns related to late consecutive exotropia after large bilateral medial rectus muscle recessions, Calhoun argued that factors other than surgical planning or a particular surgical procedure may be implicated in alignment outcomes beyond 6 months after surgery.

Our search for prognosticators identified only the presence of inferior oblique overaction and the magnitude of the preoperative deviation predisposing to an untoward late outcome of surgery, with late overcorrections overrepresented among patients in the smaller (<70Δ) preoperative angle range. We would expect dosology-related overcorrections to become apparent at the 8-week postoperative angle range. We would expect dosology-related overcorrections to become apparent at the 8-week postoperative evaluation. In fact, adjusting for the amount of millimeters of recession and resection that was performed did not affect the observed correlation between the preoperative angle and either the early or late outcome of surgery. Even so, we cannot exclude the possibility that further grading of the surgical dosing, by reducing the amount of medial rectus muscle recessed or lateral rectus muscle resected for smaller preoperative angles, might have limited the observed trend toward late overcorrections. Alternatively, one might argue that the age at which these patients underwent surgery (ie, >20 months) may underlie the observed tendency to become exotropic with time. However, several studies have reported a higher incidence of horizontal realignments for patients who were very young at the time of primary esotropia surgery.

We conclude that the large volume of patients and the long follow-up time of our study are valuable in confirming the high success rates reported in the literature (61%-82%) of undergoing 3 muscle surgery. They may also allow for a reliable depiction of trends over time. A relatively long interval of orthotropia may be achieved even in the subgroup of patients with consecutive exotropia. We suggest that reserving the option of undergoing 3 muscle surgery to larger presenting angles of esodeviation may increase the chances of a stable outcome by decreasing the rate of late

Table 4. Data from Previous Studies on Patients Who Underwent 3 Horizontal Muscle Surgery for Large-Angle Esotropia

<table>
<thead>
<tr>
<th>Source</th>
<th>No. of Patients</th>
<th>Mean Age at Surgery</th>
<th>Mean Follow-up Time, y</th>
<th>Successful Alignment, %</th>
<th>Undercorrection %</th>
<th>Overcorrection %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lee and Dyer, 1983</td>
<td>36</td>
<td>17.9 mo</td>
<td>3.87</td>
<td>61 (no reoperation)</td>
<td>19.5</td>
<td>19.5</td>
</tr>
<tr>
<td>Scott et al, 1986</td>
<td>48</td>
<td>2.7 y</td>
<td>2.6</td>
<td>64.8 (±10Δ)</td>
<td>20.8</td>
<td>14.6</td>
</tr>
<tr>
<td>Forrest et al, 2003</td>
<td>49</td>
<td>12.7 mo</td>
<td>2.7</td>
<td>77.5 (±10Δ)</td>
<td>10.2</td>
<td>12.2</td>
</tr>
<tr>
<td>Minkoff and Donahue, 2005</td>
<td>10</td>
<td>13 mo</td>
<td>2.6</td>
<td>30 (no reoperation)</td>
<td>10</td>
<td>60</td>
</tr>
<tr>
<td>Camuglia et al, 2011</td>
<td>51</td>
<td>11.8 mo (median)</td>
<td>4.1</td>
<td>73.6 (±10Δ)</td>
<td>7.8</td>
<td>9.8</td>
</tr>
<tr>
<td>Present study</td>
<td>194</td>
<td>4.3 y</td>
<td>6.6</td>
<td>62.4 (±10Δ)</td>
<td>14.4</td>
<td>23.2</td>
</tr>
</tbody>
</table>

* Note: ±10 prism dioplers (Δ) to orthotropia at the final examination or prior to reoperation.

* Reoperated for esotropia.
overcorrections. Whether this exotropic drift over time is related to the type of surgery or associated with the particularities in the management of large-angle strabismus cannot be answered by our study. To address this question, a prospective randomized long-term study designed to compare standard protocols of large bilateral medial rectus muscle resections with standard protocols of 3 horizontal muscle surgery is needed.

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