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Preoperative Factors Influencing Effectiveness of Surgery in Adult Strabismus

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Abstract: To identify preoperative factors which influence the effectiveness of strabismus surgery in adults, we retrospectively reviewed the records of 179 patients > 15 years old (131 with exotropia, 48 with esotropia) who had had combined recession and resection surgery for correction of horizontal strabismus. Eighteen preoperative variables were evaluated; those with significant influence on the surgical outcome, measured by the degree of change in deviation per millimeter of surgery, were identified by stepwise regression analysis. In patients with exotropia, preoperative distance deviation and average spherical equivalent were significant predictors of outcome at both 1 month (multiple R, 0.37) and 6 months (0.63) after surgery. In esotropic patients, significant variables at 1 month (multiple R, 0.57) and 6 months (0.77) were preoperative distance deviation and dissociated vertical deviation (DVD). Preoperative distance deviation is the common significant influence on surgical effectiveness for horizontal strabismus in adults, for both exotropia and esotropia. Additional significant predictors are average spherical equivalents in exotropic patients, and DVD in esotropic patients. **Jpn J Ophthalmol 1997;41:89–97** © 1997 Japanese Ophthalmological Society

Key Words: Adult strabismus, effectiveness of surgery, multiple regression analysis, preoperative factors, retrospective study.

Introduction

Strabismus surgery success is influenced by a number of interdependent preoperative conditions,[1,2] requiring meticulous planning by the surgeon to determine the precise extent of the procedure. Contrary to long-held beliefs, recent studies have shown that improvement in binocularity can also be achieved in adults when appropriate surgical alignment is provided.[3–7] The preoperative conditions that influence the effectiveness of adult surgical correction have not been previously clarified, even though the number of adult strabismus patients is increasing.

Surgical results in children are influenced by binocular function,[2,8,9] retinal correspondence,[2,8,9] degree of preoperative deviation,[8,10,11] axial length,[10–12] age at time of surgery,[2,8,13] and refractive errors.[1,8,14–17] Multiple regression analysis has identified preoperative deviation, age at surgery, average spherical equivalent, difference in spherical equivalents, and the recession/resection ratio as significant predictors of the effectiveness of surgery, defined as the degree of change in deviation per millimeter of surgery, in patients <20 years old who have intermittent exotropia.[1,15,16]

This study used multiple regression analysis of data obtained from retrospective reviews of surgical records of adult patients with horizontal strabismus to identify significant preoperative variables for adults.

Patients and Methods

Okayama University Medical School surgical records of patients with horizontal strabismus (January 1984 to December 1994) were retrospectively reviewed. Criteria for inclusion in this study included horizontal concomitant strabismus; minimum age, 15 years; no previous surgery; combined recession and resection of the nonfixating eye; no additional surgery to correct strabismus; and minimum follow-up of 1 month. Patients selected included 131 with exotropia, 48 with esotropia; 84 men, 95 women; ages ranged from 15 to 78 years (mean: 33.4 years). Eighteen factors, 7 continuous and 11 indicator variables, were selected as independent variables for the multiple regression analysis (Table 1).

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Table 1. Independent Variables for Multiple Regression Analysis

Variable
Sex*
Age at surgery (y)
Ratio of recession to resection†
Preoperative distance deviation (deg)
Difference between near and distance deviations (deg)
Vertical deviation (deg)
Average spherical equivalent (D)‡
Difference in spherical equivalents (D)§
Visual acuity of deviating eye ≤0.1*
Visual acuity of deviating eye 0.1< ≤0.5*
Exophoria or intermittent exotropia*
Infantile esotropia*
Fusion with Bagolini lenses test*
Motor fusion with synoptophore*
NRC*
Fusion response in prism adaptation*
Prism compensation >10Δ*
DVD*

deg: degrees. D: diopters. Δ: prism diopters. NRC: normal retinal correspondence. DVD: dissociated vertical deviation.

*Indicator variables. Sex: female, 1; male, 0. Visual acuity of deviating eye ≤0.1: ≤0.1, represented as 1; >0.1 represented as 0.

†Millimeters of recession/millimeters of resection.

‡Average spherical equivalent of right and left eyes.

§Difference in spherical equivalents between right and left eyes.

Refractive errors were measured with a retinoscope or refractometer and recorded in spherical equivalents; patients received appropriate corrective lenses to obtain the best visual acuity at 5 m, which was then recorded as log data. The strabismus angle and the results of the Bagolini striated glass (Oculus, Wetzler, Germany) test (BSG test) at 5 m and the prism adaptation test while wearing the corrective lenses were recorded.

The strabismus angle was determined in the primary position at 5 m and 0.3 m, using the alternative prism and cover test (APCT). Prism diopter units (△) were converted to degrees [angle in degrees = arc tangent (△/100)]. The 5 m angle was recorded as the preoperative distance deviation; the difference between 5 m and 0.3 m angles was recorded as the difference between near and distance deviation; vertical deviation was determined in the primary position at 5 m. The fusion response was evaluated with the BSG test at 5 m, and a synoptophore (Clement Clarke, London, UK) using F.3, F.4, F.111, F.112, F.167, and F.168 slides (Clement Clarke). The afterimage test was used to assess retinal correspondence. The prism adaptation test was done using Fresnel

Table 2. Extent of Surgery for Exotropia

Target Angle (Δ)	Target Angle (deg)	Extent of Recession/ Resection (mm)
20–24	11.3–13.5	4.0/4.0
25–29	14.1–16.2	5.0/5.0
30–34	16.7–18.8	6.0/6.0
35–39	19.3–21.3	7.0/7.0
40–44	21.8–23.8	8.0/8.0
45–49	24.2–26.1	9.0/9.0

Δ: prism diopters. deg: degrees.

Press-On Prisms® (Vision Care, 3M, St Paul, MN, USA), as previously described.[18] The fusion response was again evaluated at 5 m with the BSG test, with prisms. Prism compensation in esotropic patients (the increase in angle of deviation while wearing prisms) was also measured at 5 m.

The target angle for surgery was determined from the distance deviation measured by the APCT. The extent of surgery was decided using the formula shown in Tables 2 and 3. A combined recession-resection procedure was done on the nonfixating eye with 4% lidocaine hydrochloride topical anesthesia. An incision was made in the limbal conjunctiva to expose the muscles; the recession site was secured with 2 6-0 nylon sutures and the resection area with 3 sutures. The total extent (combined recession-resection) of surgery was measured, in millimeters, with Castroviejo calipers (Katena, Denville, NJ, USA) from the posterior border of the insertion line. The conjunctival incision was then closed with interrupted sutures (6-0 plain gut).

Since the procedures were done by several surgeons, one surgeon directed and measured the extent of all surgery in order to minimize the differences in outcome that might result with different surgeons. Surgical effectiveness was defined as the degrees of deviation change per millimeter of sur-

Table 3. Extent of Surgery for Esotropia

Target Angle (Δ)	Target Angle (deg)	Extent of Recession/ Resection (mm)
18–20	10.2–11.3	3.0/3.0
21–25	11.9–14.1	3.0/4.0
26–30	14.6–16.7	3.0/7.0
31–35	17.2–19.3	3.5/7.0
36–40	19.8–21.8	4.0/8.0
41–50	22.3–26.6	4.5/8.0

Δ: prism diopters. deg: degrees.

Table 4. Clinical Characteristics of Patients With Exotropia

Variable	1 Month (n = 131)	6 Months (n = 85)
	Mean ± SD (Range)	Mean ± SD (Range)
Age at surgery (y)	36.6 ± 16.9 (15 – 78)	36.4 ± 16.9 (15 – 78)
Extent of surgery (mm)*	14.0 ± 3.4 (8.0 – 20.0)	14.1 ± 3.3 (8.0 – 20.0)
Ratio of recession to resection†	1.00 ± 0.06 (0.75 – 1.25)	0.99 ± 0.06 (0.75 – 1.25)
Preoperative distance deviation (deg)	22.1 ± 9.1 (5.7 – 52.0)	21.91 ± 8.6 (5.7 – 47.1)
Difference between near and distance deviations (deg)	4.9 ± 5.6 (−13.9 – 23.7)	5.4 ± 5.4 (−4.7 – 23.7)
Vertical deviation (deg)	2.1 ± 2.5 (0 – 11.3)	1.7 ± 1.8 (0 – 9.1)
Average spherical equivalent (D)‡	−1.4 ± 2.6 (−10.5 – 9.1)	−1.3 ± 2.6 (−10.5 – 9.1)
Difference in spherical equivalents (D)§	1.2 ± 2.5 (0 – 16.8)	0.9 ± 2.1 (0 – 14.5)
Effectiveness of surgery (deg/mm)	1.65 ± 0.40 (0.82 – 3.03)	1.46 ± 0.35 (0.53 – 2.48)
	No. (%)	No. (%)
Sex: F	71 (54.2%)	46 (54.1%)
M	60 (45.8%)	39 (45.9%)
Visual acuity of deviating eye		
0.1≥	6 (4.6%)	2 (2.4%)
0.1< ≤0.5	5 (3.8%)	3 (3.5%)
0.5<	120 (91.6%)	80 (95.1%)
Type of deviation: XP or XPT	87 (66.4%)	59 (69.4%)
XT	44 (33.6%)	26 (30.6%)
Bagolini lenses test: fusion (+)	74 (56.4%)	52 (61.2%)
fusion (−)	57 (43.6%)	33 (38.8%)
Synoptophore: motor fusion (+)	43 (32.8%)	30 (35.3%)
motor fusion (−)	88 (67.2%)	55 (64.7%)
Retinal correspondence: NRC	65 (49.6%)	44 (51.8%)
not NRC	66 (50.4%)	41 (48.2%)
Fusion response in prism adaptation		
fusion (+)	41 (31.5%)	25 (29.4%)
fusion (−)	90 (68.5%)	60 (70.6%)
DVD: (+)	15 (11.5%)	8 (9.4%)
(−)	116 (88.5%)	77 (90.6%)

deg: degrees. D: diopters. Δ: prism diopters. deg/mm: degrees/mm. SD: standard deviation. XP: exophoria. XPT: intermittent exotropia. XT: exotropia. NRC: normal retinal correspondence. DVD: dissociated vertical deviation

*Sum of millimeters of recession and millimeters of resection.

†Millimeters of recession/millimeters of resection.

‡Average spherical equivalent of right and left eyes.

§Difference in spherical equivalents between right and left eyes.

gery (recession plus resection), and determined at 1 month and 6 months postoperatively.

Preoperative conditions, surgical extent, and surgical effectiveness were given as the mean ±SD, or number (%) of patients. Data were analyzed with the SPSS Base System, Release 6.x (SPSS, Chicago, IL, USA). The relationship of each preoperative variable to the surgical effectiveness was evaluated

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Table 5. Clinical Characteristics of Patients With Esotropia

Variable	1 Month (n = 48)	6 Months (n = 33)
	Mean ± SD (Range)	Mean ± SD (Range)
Age at surgery (y)	24.7 ± 11.7 (15 – 60)	24.4 ± 11.4 (15 – 60)
Extent of surgery (mm)*	10.7 ± 2.6 (5.5 – 14.0)	10.6 ± 2.7 (5.5 – 14.0)
Ratio of recession to resection†	0.61 ± 0.25 (0.42 – 2.00)	0.62 ± 0.30 (0.42 – 2.00)
Preoperative distance deviation (deg)	22.3 ± 9.1 (9.1 – 52.0)	22.3 ± 8.4 (9.1 – 43.6)
Difference between near and distance deviations (deg)	0.3 ± 4.8 (−8.5 – 15.8)	0.4 ± 4.1 (−6.4 – 12.9)
Vertical deviation (deg)	1.9 ± 2.7 (0 – 11.3)	1.7 ± 2.5 (0 – 9.7)
Average spherical equivalent (D)‡	−2.5 ± 6.1 (−31.0 – 5.5)	−2.9 ± 7.1 (−31.0 – 5.5)
Difference in spherical equivalents (D)§	0.9 ± 1.15 (0 – 5.8)	1.0 ± 1.3 (0 – 5.8)
Effectiveness of surgery (deg/mm)	1.72 ± 0.46 (0.93 – 2.90)	1.68 ± 0.50 (0.48 – 2.99)
	No. (%)	No. (%)
Sex: F	24 (50.0%)	19 (57.6%)
M	24 (50.0%)	14 (42.4%)
Visual acuity of deviating eye		
0.1≥	1 (2.1%)	1 (3.0%)
0.1< ≤0.5	6 (12.5%)	5 (15.2%)
0.5<	41 (85.4%)	27 (81.8%)
Type of deviation		
Infantile esotropia	20 (41.7%)	15 (45.5%)
Acquired esotropia	28 (58.3%)	18 (54.5%)
Bagolini lenses test: fusion (+)	1 (2.1%)	1 (3.0%)
fusion (−)	47 (97.9%)	32 (97.0%)
Synoptophore: motor fusion (+)	16 (39.0%)	12 (36.4%)
motor fusion (−)	32 (61.0%)	21 (63.6%)
Retinal correspondence: NRC	18 (37.5%)	13 (39.4%)
not NRC	30 (62.5%)	30 (60.6%)
Fusion response in prism adaptation		
fusion (+)	26 (54.2%)	18 (54.5%)
fusion (−)	22 (45.8%)	15 (45.5%)
Prism compensation: >10Δ	8 (16.7%)	4 (12.1%)
≤10Δ	40 (83.3%)	29 (87.9%)
DVD: (+)	9 (18.8%)	6 (18.2%)
(−)	39 (81.2%)	27 (81.8%)

deg: degrees. D: diopters. Δ: prism diopters. deg/mm: degrees/mm. SD: standard deviation. NRC: normal retinal correspondence. DVD: dissociated vertical deviation.

*Sum of millimeters of recession and millimeters of resection.

†Millimeters of recession/millimeters of resection.

‡Average spherical equivalent of right and left eyes.

§Difference in spherical equivalents between right and left eyes.

with Pearson's correlation coefficient or the Student's *t*-test. Associations between pairs of preoperative variables were calculated using Pearson's correlation coefficient, the Student's *t*-test, and the X^2 test. Predictors of the effectiveness of surgery were identified by multiple regression analysis according to the following model:

$$y = a + b_1 x_1 + b_2 x_2 + \ldots + b_n x_n$$

where a is a constant; $b_1, b_2, \ldots b_n$ represent partial regression coefficients of significant predictive variables; $x_1, x_2, \ldots x_n$ represent significant predictive variables; and y is the dependent variable. Independent variables were significant at $P < 0.05$.

Results

All 131 patients with exotropia were examined 1 month after surgery; 85 of them were again examined 6 months postoperatively (Table 4). All 48 patients with esotropia were examined at 1 month, and 33 of them again at 6 months, postoperatively (Table 5). There were no significant differences in postoperative conditions at 1 month and 6 months (Student's *t*-test or x^2 test) (Tables 4 and 5).

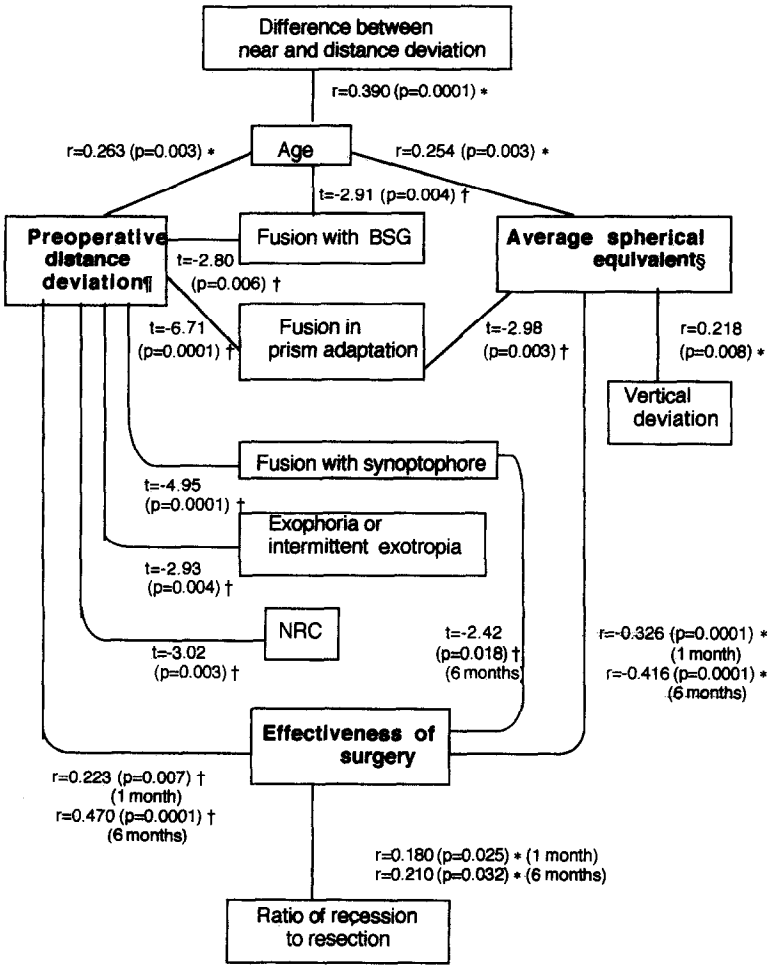

Figure 1. Significant associations between pairs of variables in patients with exotropia. BSG: Bagolini striated glasses test. NRC: normal retinal correspondence. Associations between pairs of variables were evaluated with Pearson's correlation coefficient and Student's *t*-test; variable with significant associations are summarized.
*Pearson's correlation coefficient.
†Student's *t*-test.
‡Larger preoperative distance deviations were seen in older patients, patients who demonstrated fusion with BSG or synoptophore, those who showed fusion response in prism adaptation, those with exophoria or intermittent exotropia, or those with NRC.
§Older patients or patients who demonstrated fusion response in prism adaptation had a larger average spherical equivalent.

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Pairs of Variables

Statistical analysis of pairs of variables in patients with exotropia are shown in Figure 1. Preoperative distance deviation, average spherical equivalent, and recession/resection ratio were significantly correlated with the surgical outcome at both 1 month and 6 months postoperatively. The synoptophore response was also significantly associated with the results at 6 months. Preoperative distance deviation was significantly associated with age, BSG test result, prism adaptation response, synoptophore response, exodeviation type, and retinal correspondence. Average spherical equivalent was significantly related to age, prism adaptation response, and vertical deviation. In the 110 patients with emmetropia or myopia, there was no significant correlation between average spherical equivalent and age, but there was a significant negative correlation between the average spherical equivalent and the preoperative distance deviation ($r = 0.196$, $P = 0.039$).

Results for esotropic patients are shown in Figure 2. Preoperative distance deviation and presence or absence of dissociated vertical deviation (DVD) were significantly associated with the surgical outcome at both 1 month and 6 months. Prism compensation was significantly related at 1 month; vertical deviation and average spherical equivalent were significantly correlated at 6 months. Significant associations were found between preoperative distance deviation and prism adaptation response, and between DVD and infantile esotropia.

Multiple Regression Analysis

In exotropic patients, preoperative distance deviation and average spherical equivalent were significantly related to the surgical result at both 1 month and 6 months. Surgical effectiveness was positively correlated with preoperative distance deviation, while average spherical equivalent was negatively associated. Visual acuity of the deviating eye was a significant variable at 6 months (Table 6).

In esotropic patients, preoperative distance deviation and the presence of DVD were significant variables at both 1 month and 6 months, positively correlated with outcome. The average spherical equivalent was a significant variable at 6 months (Table 7).

Discussion

The present study evaluated the influence of 18 preoperative conditions on the effectiveness of surgery for strabismus in adult patients. Because age at

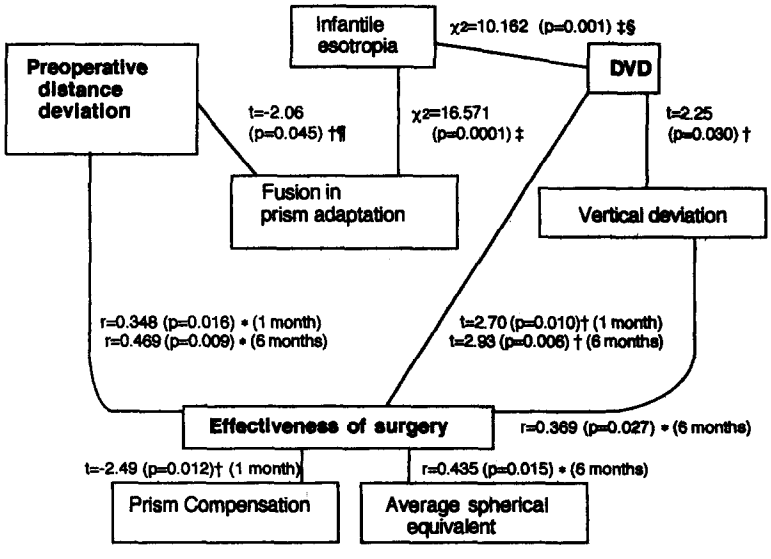

Figure 2. Significant associations between pairs of variables in esotropia.. DVD: dissociated vertical deviation. Associations between pairs of variables were evaluated using Pearson's correlation coefficient, Student's *t*-test and χ^2 test; variables with significant associations are summarized.
*Pearson's correlation coefficient.
†Student's *t*-test.
‡Chi-square test.
§Patients who showed fusion response in prism adaptation had significantly smaller preoperative distance deviations than patients who did not show fusion response.
¶There was a significant association between infantile esotropia and the presence of DVD.

Table 6. Multiple Regression Models for Predicting Effectiveness of Surgery in Exotropia

Variable	Coefficient*	Standard Coefficient†	t‡
Effectiveness at 1 month after surgery			
Average spherical equivalent	−0.045	−0.298	−3.421
Preoperative distance deviation	0.008	0.176	2.023
Constant	1.422		
Multiple R	0.37		
R^2	0.14		
Effectiveness at 6 months after surgery			
Preoperative distance deviation	0.017	0.418	4.615
Average spherical equivalent	−0.054	−0.392	−4.345
Visual acuity of deviating eye (0.1< ≤0.5)	0.355	0.191	2.111
Constant	0.997		
Multiple R	0.63		
R^2	0.40		

*Partial regression coefficient.
†Standardized regression coefficient.
‡Student's t-test.

Table 7. Multiple Regression Models for Predicting Effectiveness of Surgery in Esotropia

Variable	Coefficient*	Standard Coefficient†	t‡
Effectiveness at 1 month after surgery			
DVD	0.533	0.447	3.205
Preoperative distance deviation	0.025	0.368	2.635
Constant	0.977		
Multiple R	0.57		
Multiple R^2	0.32		
Effectiveness at 6 months after surgery			
Preoperative distance deviation	0.032	0.471	3.362
DVD	0.539	0.464	3.256
Average spherical equivalent	0.020	0.311	2.176
Constant	0.930		
Multiple R	0.77		
R^2	0.59		

DVD: dissociated vertical deviation.
*Partial regression coefficient.
†Standardized regression coefficient.
‡Student's t-test.

onset could not be determined with certainty, age at onset and duration of the condition had to be excluded from the study.

Analysis of associations between pairs of variables has previously shown that a variety of preoperative conditions influence the surgical outcome and that they are interrelated in varying degrees.[1,2] In the multiple regression model, the partial regression coefficient represents the change in a dependent variable per unit change in an associated independent variable when the values of all other independent variables remain constant.[1] The multiple regression models used in this study controlled mutually associated variables and provided essential information for determining the extent of surgery required for patients with various combinations of preoperative conditions.

We found that the preoperative distance deviation was the most important influence, positively correlated with the outcome in adult patients with both exotropia and esotropia. The multiple regression model derived by Scott et al[1] included preoperative distance deviation, age, average spherical equivalent of right and left eyes, and the recession/resection ratio as significant predictive variables in patients <20 years old with intermittent exotropia. Kushner et al[10] also reported that outcome is correlated with preoperative deviation in similar patients <18 years old. Our study supports their conclusions and suggests that overcorrection must be carefully avoided in both exotropic and esotropic adults who have large preoperative deviations.

In exotropic patients in the present study, preoperative distance deviation was also significantly associated with age, type of strabismus, retinal correspondence, and preoperative binocularity (measured by BSG, synoptophore, and prism adaptation response). We found that older patients and patients with constant exotropia, poor binocularity, and anomalous retinal correspondence (ARC) had larger preoperative deviations. Younger patients and patients with intermittent exotropia or exophoria, good binocularity, and normal retinal correspondence had smaller preoperative deviations. It is recognized that patients in these subgroups have sufficient fusion amplitude to control deviation.[7] Therefore, preoperative deviation probably appeared less than the actual deviation, apparently leading to less effective results for exotropic patients with smaller recorded preoperative deviations.

Kushner et al[10] stated that, compared with older children with acquired esotropia, younger children

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with congenital esotropia have smaller eyes, larger preoperative deviations, and greater response to surgery.[10,11] This observation does not apply to adults, however, because there is no association between age and size of the eye in adults. Some patients with acquired esotropia have an increased squint angle during prism adaptation.[18,19] In this type, known as small-angle esotropia with ARC fusion, surgery does not completely correct the deviation because of anomalous fusion movement.[18,19] Patients in our study with smaller preoperative deviation included some with small-angle esotropia for whom surgery might not give complete correction of the deviation.

Anatomic changes that normally take place in the muscles and fasciae of adults are probably more extensive in older patients or in those with larger preoperative deviations than in younger patients or in those with smaller preoperative deviations. Differences in the extent of these changes may be related to differences in surgical outcome.

Multiple regression models for exotropic patients identified the average spherical equivalent as an additional significant predictor variable, negatively correlated with surgical outcome. Kushner et al[10] reported that there is no significant correlation between outcome and average spherical equivalent for both exotropic and esotropic patients <18 years old. However, as in our study, Scott et al[1] found that the average spherical equivalent is a significant predictor in patients with intermittent exotropia who are <20 years old. Scattergood et al[17] also demonstrated that surgery is more successful in patients with myopia than in those with hyperopia; they attributed this to the peripheral prismatic effect of the corrective lenses: in exotropic patients, the high minus lenses have a base-out prism effect while high plus lenses have a base-in prism effect[14,17]; therefore, the measured deviation is greater than actual with minus lenses and less than actual with plus lenses.[17] Scattergood et al[17] suggested that these effects are significant only when refractive errors are ±5D or more, leading us to believe that the peripheral prismatic effect had very little influence on the results of the present study.

The association between average spherical equivalent and surgical outcome may also be related to the fact that insufficient correction for myopia in exotropic patients decreases the accommodative convergence and increases exodeviations.[9] In the present study, 110 (84%) of the 131 patients with exotropia had emmetropia or myopia. There was a significant negative correlation in these patients between preoperative deviation and average spherical equivalent. The preoperative and postoperative angles of deviation were measured with the patients wearing lenses that corrected for myopia and astigmatism, giving the best visual acuity at 5 m. Best visual acuity at 5 m would probably be insufficient for most myopic patients and would probably have interfered with normal accommodative convergence. Therefore, their measured preoperative exodeviation was greater than the true deviation (because of decreased accommodative convergence) and surgery was possibly more effective.

DVD effects on surgical correction of horizontal strabismus have not been previously reported. Multiple regression models for esotropic patients indicated that the presence or absence of DVD was also a significant predictor of the effectiveness of surgery, but there is currently no adequate explanation for this. Previous reports do document a high prevalence of DVD in patients with infantile esotropia[20,21]; therefore, patients with DVD are more likely to have overcorrection problems than patients without DVD. All patients with DVD in the present study, however, had ocular alignment within 10 △ of orthotropia at both 1 month and 6 months after surgery. Despite the higher prevalence of infantile esotropia, patients with DVD seem to benefit more from surgery than those without.

Evaluation of 18 preoperative factors by multiple regression analysis identified significant factors influencing surgical effectiveness in adult strabismus patients. This analysis showed that preoperative distance deviation had a significant positive correlation with the outcome of surgery. This may be attributed to latent deviation (difficult to measure preoperatively) in patients with exophoria or intermittent exotropia. It also may be related to ARC fusion in patients with small-angle esotropia, leading to undercorrection postoperatively. The effectiveness of the surgery also was influenced by the average spherical equivalent in patients with exotropia and by the presence of DVD in patients with esotropia. Appreciation of the effects of these factors can increase the precision and reliability of surgical alignment for adult strabismus.

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