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Diagnosis-related factors favoring the success of exotropia surgery

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ABSTRACT

Aim of the study: To identify factors favoring the success of surgery for exotropia.

Material and methods: Fifty-nine patients with mostly bilateral exotropia were enrolled, 33 with basic constant exotropia (group 1) and 26 with intermittent exotropia (group 2). Patient age ranged from 10 years to 21 years, the mean corrected visual acuity was 0.8 ±0.3, and the mean refractive error was 0.61 ±2.3 D (range, –5.0 D to 7.0 D). The ocular motor and sensory system was assessed through eye examination and orthoptic methods. Success of surgery was defined as orthotropia of 10 prism diopters (PD) or less. Analysis of variance with the Newman-Keuls multiple comparisons test and the chi-square test were used for group comparisons. A multiple regression analysis was used to determine the relationships between the preoperative characteristics of the ocular motor and sensory systems and the outcome of surgery.

Results: Our comparison of the surgery success group to the surgery failure group for preoperative values of accommodative convergence–accommodation (AC/A) ratio, near point of convergence (NPC) and state of stereopsis showed that near-normal preoperative levels of AC/A ratio (4.0 ±1.65 PD/D) and NPC (8.03 ±3.02 cm), the preoperative presence of distance stereopsis, near stereopsis of 200 seconds of arc, and the absence of medial rectus muscle hypofunction were characteristic for the former group. The multiple regression model developed confirmed that the NPC and the presence of distance stereopsis can be used as predictors of the success of exotropia surgery.

Conclusion: NPC and the presence of distance stereopsis can be used as predictors of the success of exotropia surgery.

KEY WORDS: exotropia, diagnostics, surgery, stereopsis, fusion.

INTRODUCTION

Exotropia is a form of strabismus (eye misalignment) in which one or both of the eyes turn outward.

It is much less frequent than esotropia (only approximately 23-25% of all cases of squint) [1] and differs from other types of strabismus in that a change in the angle of deviation may occur at any time of the day or night. In addition, the angle of deviation may be larger at near (convergence insufficiency) or at distance (divergence excess), and an increase in the angle may occur under the influence of bright light, fatigue, a disease, etc.

The mechanisms of these oculomotor abnormalities involve (a) various degrees to which fusion and vergence may be compromised, and (b) the relation between accommodation and convergence [1-4]. Exophoria and exotropia can be caused by congenital or acquired abnormalities of orbital structure, globe structure, extraocular muscle attachment and/or extraocular muscle location [1, 5-7].

Numerous exotropia classification schemes based on clinical factors have been developed and used for treatment. Duane's classification scheme takes into account only the primary deviation or the difference between the distance deviation and near deviation depending on the state of fusion and the presence of convergence insufficiency or divergence excess [2, 3, 6, 8]. It has been, however, not established whether the insufficiency or excess of convergence is an innervation abnormality that can cause exotropia. Most current classification schemes of exodeviations are derived from the scheme developed by Duane [2], who theorized that exodeviations are caused by an innervational imbalance that upsets the reciprocal relationship between active convergence and divergence mechanisms. He believed that an exodeviation greater at distance than at near is caused by hypertonicity of divergence (excess), and a deviation greater at near than at distance, by convergence insufficiency. Although some authors opposed Duane's etiologic concept, his classification system has survived and is still used today.

More recently, von Noorden and Campos [1] classified exodeviations into the following patterns:

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- *Divergence excess* was defined as an exodeviation of at least 15^{Δ} greater at distance than at near fixation.
- *Basic exodeviation* was defined as an exodeviation in which the distance deviation is approximately equal to the near deviation.
- *Convergence insufficiency* was defined as an exodeviation of at least 15^{Δ} greater at near fixation than at distance.
- Simulated divergence excess pattern was defined as a pattern in which the prism and the cover test will show an exodeviation that is significantly greater at distance than at near fixation.

There are individual reports [9, 10] in the literature on the effect of some preoperative characteristics (like convergence, angle of deviation, presence of fusion and character of binocular vision) on the outcome of surgery for exotropia. Boichuk and Tarak [11] reported that the presence of distance stereopsis and a near stereoacuity threshold of not less than 200 seconds of arc promoted a favorable outcome of surgery for constant or intermittent exotropia. Studies by Beneish and Flanders [12] and Thorisdottir *et al.* [13] found that the preoperative presence of distance stereopsis was more commonly seen in patients with a good outcome of surgery for intermittent exotropia. In their opinion [12], the presence of stereopsis after treatment for strabismus indicates that a stable treatment outcome has been achieved and binocular vision regained. The state of stereopsis is believed to be an efficacy endpoint in the evaluation of strabismus surgery [14].

To date, the major diagnosis-related prognostic factors for the outcome of surgery for exotropia not been established. The methods of diagnostic assessment of the motor and sensory systems of the eye should be improved to enable better planning for the extent and time point of surgical interventions.

The purpose of this study was to identify the factors favoring the success of surgery for exotropia.

MATERIAL AND METHODS

Thirty-three patients with basic constant exotropia and 26 patients with intermittent exotropia (group 1 and group 2, respectively; in total, 59 patients with mostly bilateral exotropia) were included in this study. Patient age ranged from 10 years to 21 years, the mean corrected visual acuity was 0.8 ±0.3, and the mean refractive error was 0.61 ±2.3 D (range: −5.0 D to 7.0 D). Of the 59 patients, 34 (57.6%) were myopes and 25 (43.4%), hyperopes. Inclusion criteria were patients with concomitant exotropia, well-corrected visual acuity, mild amblyopia, astigmatism and anisometropia of 2.0 D or less, and no limitation of ocular motility. Mean angles of deviation measured at distance and at near were 31.3 ±16.7 prism diopters (PD) and 14.78 ±12.7 PD, respectively, for group 1, and 32.1 ±4.1 PD and 15.3 ±9.0 PD, respectively, for group 2, with no statistically significant difference between the groups ($p > 0.05$).

Patients underwent a routine eye examination. In addition, the near point of convergence (NPC) was determined by the proximeter; the accommodative convergence–accommodation (AC/A) ratio was calculated by the heterophoria method (AC/A = ipd + (phoria at distance – phoria at near)/3, where ipd is the interpupillary distance in centimeters) and expressed in PD/D; fusional reserves were measured using the synoptophore; and binocular vision at distance and near was evaluated using the color test. Lateral and medial rectus muscle hyperfunction or hypofunction were scored 1 to 4 or −1 to −4, respectively, according to Whright [15], based on the position of the iris margin with respect to the angle of the palpebral fissure in adduction or abduction. Moreover, the occlusion test of Scobee-Burian [1] was used to differentiate between true divergence excess and simulated divergence excess. The angles of strabismus in patients with exotropia were measured at distance and at near after 30-45 min of monocular occlusion to uncover a deviation that was kept latent. Stereoacuity thresholds were assessed with the Lang-Stereotest II and Titmus Stereo Fly (circles and animals) tests at daylight at a viewing distance of 30 cm, under conditions of best-corrected vision. In addition, a Huvitz CCP3100 Chart Projector was used to assess whether stereopsis was present at a 5-m distance.

The surgery was performed in one or both eyes in a routine manner [1, 16]: (a) unilateral lateral rectus muscle recession and unilateral medial rectus muscle resection in 12 patients (20%); (b) bilateral lateral rectus muscle recession in 23 patients (40%); (c) bilateral lateral rectus muscle recession and unilateral medial rectus muscle resection in a more frequently strabismic eye, with the extent of resection tailored to the strabismus angle, in 7 patients (12%), and (d) four-muscle surgery involving two-stage lateral rectus muscle recession and medial rectus muscle resection in 17 patients (28%). Success of surgery was defined as orthotropia within 10 PD, and patients with postoperative exotropia exceeding 10 PD required re-surgery [14].

Statistica 8.0 (StatSoft, Tulsa, OK, USA) software was used for statistical analysis. Mean (M) and standard deviation (SD) were calculated for quantitative variables. The level of significance $p \leq 0.05$ was assumed. Analysis of variance (ANOVA) with the Newman-Keuls multiple comparisons test and chi-square test were used for group comparisons as appropriate. A multiple regression analysis was used to determine the relationships between the preoperative characteristics of the motor and sensory systems of the eye and the outcome of surgery for exotropia.

The study followed the ethical standards stated in the Declaration of Helsinki, the European Convention on Human Rights and Biomedicine and relevant laws of Ukraine.

RESULTS

Table I presents mean values for the preoperative characteristics of the motor and sensory systems of the eye for the group with constant exotropia and the group with intermittent exotropia, p-values for differences between these groups at baseline, and chi square values for comparison between these groups for some of the characteristics examined.

Table I. Mean values for the preoperative characteristics of the motor and sensory systems of the eye for the group with constant exotropia and the group with intermittent exotropia and chi square values for comparison between these groups for some of characteristics examined

Characteristic	Groups		*p*- value	χ^2 test
	Constant exotropia (*n* = 33)	Intermittent exotropia (*n* = 26)		
Near point of convergence (NPC; cm)	8.8 ±0.9	8.6 ±0.6	0.33	
Accommodative convergence–accommodation (AC/A) ratio (prism diopters/diopter)	4.1 ±2.08	3.6 ±1.35	0.29	
Fusion Functional scotoma	24.2% (8) 75.7% (25)	53.8% (14) 46.2% (12)		5.45, *p* = 0.01 6.76, *p* = 0.009
Presence of distance stereopsis Absence of distance stereopsis	– 0 (33)	42.3% (11) 57.7 (15)		25.53, *p* = 0.000
Lang-Stereotest II (seconds of arc)	0 (failed the test) – 84.5% (28) 400-600 – 15.5% (5)	0 (failed the test) – 75.8% (18) 400 – 24.2% (8)		28.5, *p* = 0.000
Angle of deviation at distance (prism diopters)	31.3 ±16.7	32.1 ±4.1	0.07	
Angle of deviation at near (prism diopters)	14.78 ±12.7	15.3 ±9.0	0.17	
Horizontal rectus muscle hyperfunction (a score of 1 to 4) or hypofunction (a score of –1 to –4)	0.56 ±1.61	0.66 ±1.34	0.74	

Table II. Preoperative and postoperative angles of deviation in patients with constant exotropia and those with intermittent exotropia (mean ±standard deviation)

Characteristic	Constant exotropia (*n* = 33)		Intermittent exotropia (*n* = 26)	
	Before surgery	After surgery	Before surgery	After surgery
Angle of deviation at distance (prism diopters)	31.3 ±16.7	7.0 ±4.3	32.1 ±4.1	7.0 ±4.4 (*n* = 10)
Angle of deviation at near (prism diopters)	14.78 ±12.7	7.4 ±3.5 (*n* = 7) 0 (*n* = 26)	15.3 ±9.0	7.0 ±2.5 (*n* = 4) 0 (*n* = 16)
P-value for the difference between preoperative and postoperative measurements	$p_1 = 0.0001$		$p_2 = 0.0001$	

Preoperatively, fusion and stereopsis at distance and at near were more frequently present in patients with intermittent exotropia than in those with constant exotropia ($p < 0.05$; Table I), indicating the presence of partial binocular functions.

There was no significant difference in the postoperative angle of deviation between the groups. Table II shows data for preoperative and postoperative mean exotropia for groups 1 and 2.

Postoperatively, there was a significant reduction in the angle of deviation in both groups ($p = 0.0001$; Table II), and no esotropia was noted.

After surgical correction of strabismus, we conducted a one-way ANOVA of the preoperative characteristics of the motor system (NPC, AC/A ratio, hypofunction and hyperfunction of the horizontal muscles, and angle of deviation) and sensory system (near and distance stereopsis, and fusion on the synoptophore) of the eye for groups of patients who had orthotropia within 10 PD and those who had residual exotropia of more than 10 PD postoperatively. Surgery was a success (i.e., postoperative orthotropia) in 49 patients (83.05%), and postoperative residual exotropia was seen in 10 patients (16.95%) of the current study. Of the preoperative clinical characteristics examined, a significant difference between the group of postoperative orthotropia and the group of postoperative residual exotropia was found in the NPC (F = 13.8, $p = 0.0001$), AC/A ratio (F = 12.6, $p = 0.0006$), and score of hypophoria or hyperphoria (F = 16.45; $p = 0.0001$). Based on the literature data and given the fact that stereopsis is an integral characteristic of binocular vision [17], we considered the preoperative state of stereopsis in the group of postoperative orthotropia and the group of postoperative residual exotropia (Table III).

The mean preoperative AC/A ratio value was larger (4.0 ±1.65 PD/D vs. 2.5 ±3.35 PD/D; $p = 0.04$) and closer to the norm of 4 to 6 PD/D, and the mean NPC value was smaller (8.03 ±3.02 cm vs. 10.25 ±3.86, but the difference was not statistically significant $p = 0.7$) and closer to the norm of 5 to 6.5 cm, in postoperative orthotropes, compared to patients who had a residual exotropia of more than 10 PD postoperatively (Table III, Figures 1 and 2). Of the 49 post-

Table III. Preoperative characteristics of the ocular sensory and motor systems in groups of patients with postoperative orthotropia and postoperative residual exotropia (mean ±standard deviation of the characteristic or percentages and numbers of patients, as appropriate)

	Postoperative orthotropia ($n = 49$)	Postoperative exotropia ($n = 10$)	p and χ^2 test values
Post-operative angle of deviation (prism diopter)	2.5 ±3.35	13.0 ±1.84	$p = 0.00015$
Preoperative accommodative convergence–accommodation (AC/A) ratio (prism diopters/ diopter)	4.0 ±1.65	2.4 ±1.77	$p = 0.04$
Preoperative near point of convergence (NPC; cm)	8.03 ±3.02	10.25 ± 3. 86	$p = 0.7$
Preoperative Lang-Stereotest II (seconds of arc)	0 (failed the test) – 14.29% [7] 200.0 – 36.73% [18] 400-600 – 48.98% [24]	0 (failed the test) – 40% [4] 200.0 – 20% [2] 400-600 – 40% [4]	$\chi^2 = 1.6$ $p = 0.2$
Preoperative presence (1) or absence (0) of distance stereopsis	0 – 65.31% [32] 1 – 34.69% [17]	0 – 100%	$\chi^2 = 10.76$ $p = 0.01$
Preoperative lateral rectus muscle hyperfunction (a score of 1 to 4) or medial rectus muscle hypofunction (a score of –1 to –4)	0.92 ±1.42	–1.33 ±1.03	$p = 0.0005$

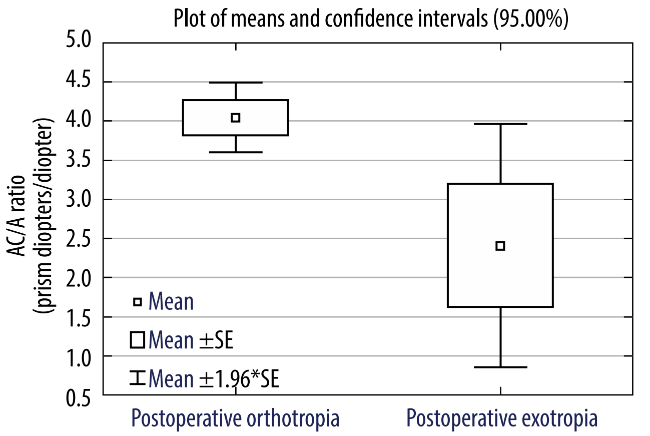

Figure 1. Preoperative values of accommodative convergence–accommodation (AC/A) ratio (prism diopters/diopter) in patients with postoperative orthotropia and in those with postoperative residual exotropia

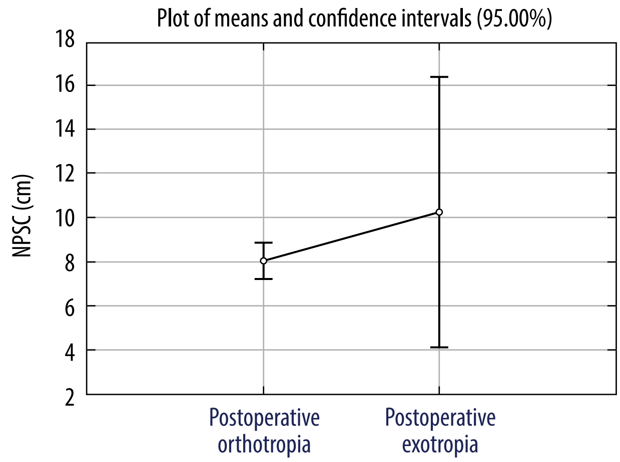

Figure 2. Preoperative near point of convergence (NPC) values (cm) in patients with postoperative orthotropia and in those with postoperative residual exotropia

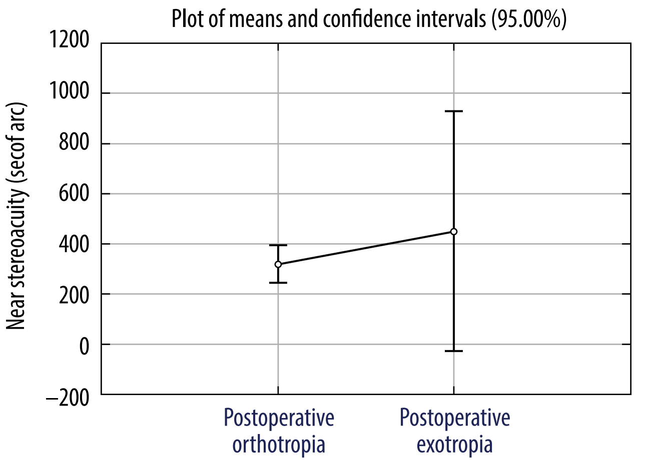

Figure 3. Preoperative values of near stereoacuity as assessed by the Lang II stereoacuity test (seconds of arc) in patients with postoperative orthotropia and in those with postoperative residual exotropia

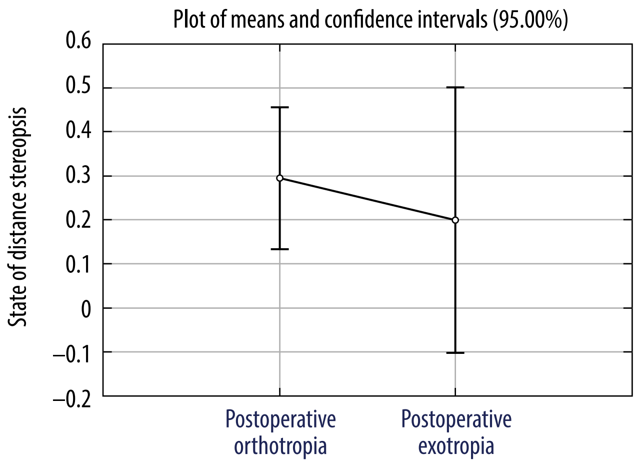

Figure 4. Preoperative state of stereopsis (0: absence of stereopsis; 1: presence of stereopsis) at 5 meters with a Huvitz CCP3100 Chart Projector in patients with postoperative orthotropia and in those with postoperative residual exotropia

operative orthotropes tested preoperatively with the Lang II Stereotest, 7 (14.29%) failed the test, 18 (36.73%) were able to perceive the 200 seconds of arc image, and 24 (48.98%), were able to perceive the 400 and/or 600 seconds of arc images (i.e., exhibited stereoacuity thresholds worse than the norm of 40-100 seconds of arc) (Table III, Figure 3). In addition, of the 49 postoperative orthotropes, 17 (34.69%) had, and 32 (65.31%) had no distance stereopsis preoperatively (Table III, Figure 3). Of the 10 postoperative residual exotropes tested preoperatively with the Lang II Stereotest, 4 (40%) failed the test, 2 (20%) were able to perceive the 200 seconds of arc image, and 4 (48.98%) were able to perceive the 400 and/or 600 seconds of arc images (Table III, Figure 4). Postoperative orthotropes had better preoperative near stereopsis than postoperative residual exotropes, and none of the latter had distance stereopsis preoperatively (*p* = 0.01; Table III, Figure 4).

Preoperative medial rectus hypofunction and lateral rectus hyperfunction scores in postoperative orthotropes and postoperative residual exotropes are presented in Table III and Figure 5. In patients developing postoperative orthotropia, preoperatively, lateral rectus muscle hyperfunction (a score of 0.5 to 1.3) was more common than medial rectus muscle hypofunction (66.6% vs. 16%). In patients developing postoperative residual exotropia, medial rectus muscle hypofunction (a score of –0.2 to –2.5) was more common and seen in 66.6% of cases.

To identify the relationships of the study characteristics with the outcome of surgery for exotropia (i.e., the dependent variable: 1, orthotropia within 10 PD, and 0, a postoperative exotropia exceeding 10 PD), we included 10 preoperative independent variables (visual acuity; refractive error; angle of deviation; difference between the distance and near angles of deviation; presence or absence of binocular vision assessed by the color test; NPC; AC/A ratio; presence or absence of distance stereopsis; near stereopsis (stereoacuity threshold as assessed by the Lang II Stereotest) and horizontal rectus muscle hyperfunction or hypofunction score) in the model for multiple regression analysis. Table IV shows the results of the performed analysis.

Two variables remained in the model after stepwise data processing (Table V).

The resultant model is presented in Table VI.

Based on the data from Tables IV to VI, we established the effects of the preoperative independent variables (NPC

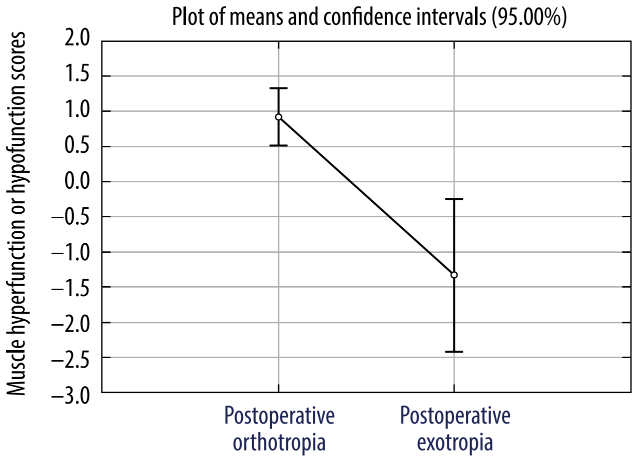

Figure 5. Preoperative scores of horizontal rectus muscle hyperfunction or hypofunction in patients with postoperative orthotropia and in those with postoperative residual exotropia

Table IV. Regression summary for dependent variable: outcome of exotropia surgery (OES)

n = 26	Regression Summary for Dependent Variable: NewVar (Spreadsheet110. 08.sta) *R* = 0.93026914, *R?* = 0.86540068, Adjusted *R?* = 0.83976271 F(4.21) = 33.755 *p* < 0.00000 Std Error of estimate: 0.19860					
	Beta	Std Err	B	Std Err	t(21)	*p*-level
Intercept			2.162538	0.182932	11.82152	0.000000
NPC	–0.776161	0.087828	–0.138402	0.015661	–8.83730	0.000000
PDS	0.806383	0.088434	0.931131	0.102114	9.11852	0.000000
= v26* 0.33	–0.449826	0.088332	–0.128313	0.025197	–5.09245	0.000048
HRMHS	0.404863	0.090145	0.129000	0.028723	4.49123	0.000201

NPC – near point of convergence; PDS – presence or absence of distance stereopsis; HRMHS – horizontal rectus muscle hyperfunction or hypofunction score

Table V. Summary of stepwise regression for dependent variable: outcome of exotropia surgery (OES)

Variable	Summary of Stepwise Regression; DV: NewVar (Spreadsheet110. 08.sta)						
	Step +in/–out	Multiple R	Multiple R-square	R-square change	F – to entr/rem	*p*-level	Variables included
NPC	1	0.490368	0.240461	0.240461	7.59812	0.010983	1
PDS	2	0.804304	0.646904	0.406443	26.47495	0.000033	2

NPC – near point of convergence; PDS – presence or absence of distance stereopsis

Table VI. Final results of multiple regression analysis

Regression Summary for Dependent Variable: NewVar (Spreadsheet110. 08.sta) $R = 0.80430355$, $R? = 0.64690421$, Adjusted $R? = 0.61620022$, F(2,23) = 21.069						
	Beta	Std Err of Beta	B	Std Err of B	t(23)	*p*-level
Intercept			1.630841	0.217848	7.48615	0.000000
X1 (NPC)	–0.720658	0.131739	–0.128505	0.023491	–5.47035	0.000015
X2 (PDS)	0.677847	0.131739	0.782710	0.152119	5.14538	0.000033

NPC – near point of convergence; PDS – presence or absence of distance stereopsis

and the presence or absence of distance stereopsis) on the outcome of exotropia surgery ($R = 0.80430355$), i.e., 80% of the dependent variable can be explained by the presented independent variables.

Based on the data from Table VI, the following multiple regression equation was obtained to define a positive outcome of surgery, i.e., orthotropia (1), or a negative outcome, i.e., postoperative exotropia (0):

$Y = 1.630841 + (-0.128505)\ X1 + 0.782710 \times X2$

In the regression equation, we can replace the independent variables with their values to get the outcome for a particular case.

Therefore, the analysis conducted allows us to conclude that, in the model obtained, the preoperative NPC value of less than 8.03 ±3.02 cm and the preoperative presence of distance stereopsis can be used as predictors for the success of surgery for exotropia.

DISCUSSION

Since achieving successful correction of strabismus is important not only for patients and medical specialists, but also for the society, ophthalmologists evaluate approaches to improve treatment outcomes through the assessment of patients' preoperative diagnosis-related data. A review on the treatment of intermittent strabismus by Wang and Zhao [18] pointed that long-term outcomes of the surgery are related to many factors, such as age, course of the disease, perceptual state of visual cortex, timing of surgery, types of intermittent exotropia, the surgical methods, preoperative measurements of exodeviations, target angle of surgery, and clinical factors of binocular functions. Preoperative and postoperative stereopsis has been assessed as a measure of the efficacy of (a) restoration of binocular functions and (b) surgery. Kim *et al.* [19] evaluated and compared surgical outcomes with respect to refractive errors in strabismus surgery for the treatment of intermittent exotropia (IXT). They concluded that, in the surgical treatment of IXT, hyperopia was not an indicator of poor prognosis and, taking into consideration the age effect, follow-up period after IXT surgery, and stereopsis improvement, hyperopic refractive error is rather a good prognostic factor. Thorisdottir *et al.* [13] reported that the only factor affecting success of unilateral surgery for constant or intermittent exotropia surgery was the preoperative deviation, with smaller deviations having a better outcome. Smaller initial deviations with hyperopic correction and fusion at distance indicate a favorable prognosis for stereoacuity improvement [20-22]. Huh *et al.* [23] investigated recovery from suppression when the target motor alignment was achieved following surgery for intermittent exotropia. They concluded that successful motor alignment did not guarantee recovery of suppression when the preoperative angle of exotropia was greater than 20 PD. Birch and co-authors [24] found that the development of vergence does not account for the onset of stereopsis. Studies [25-29] assessed near stereoacuity thresholds and the state of convergence before and after surgery for constant or intermittent exotropia, but the impact of preoperative AC/A ratio, NPC and distance stereopsis on the outcome of exotropia surgery has not been sufficiently explored, and there is no agreement on this point.

That is why we conducted analysis of the preoperative characteristics of the sensory system (near and distance stereopsis, and fusion on the synoptophore) and motor system (NPC, AC/A ratio, hypofunction and hyperfunction of the horizontal muscles, and angle of deviation) of the eye for the groups of patients who had orthotropia and those who had residual exotropia postoperatively. The analysis demonstrated that the preoperative AC/A ratio and NPC were closer to normal values and preoperative distance and near stereopsis was more frequently seen in patients who had orthotropia than in those who had residual exotropia postoperatively. In addition, medial rectus muscle hypofunction was preoperatively seen in 66.1% of the latter patients. Our multiple regression analysis enabled us to obtain a model demonstrating that the preoperative characteristics of the motor and sensory systems of the eye (NPC and the presence of distance stereopsis) can be used as predictors of the success of exotropia surgery.

CONCLUSIONS

We found that preoperative fusion and distance and near stereopsis were more frequently present in the intermittent exotropia group than in the constant exotropia group ($p < 0.05$). However, there was no difference in the postoperative angle of deviation at distance (7.0 ±4.3 PD vs. 7.0 ±4.4 PD) or the postoperative angle of deviation at near (7.4 ±3.5 PD vs. 7.4 ±3.5 PD) between these groups.

In addition, we conducted a comparative analysis of the postoperative orthotropia group and the postoperative exotropia group to identify the factors impacting the success of exotropia surgery. A one-way ANOVA of the preoperative NPC, AC/A ratio and stereopsis for the postoperative orthotropia group and the postoperative exotropia group found that preoperative close to normal values of AC/A ratio (4.0 ±1.65 PD/D), NPC (8.03 ±3.02 cm), the presence of distance stereopsis and near stereopsis (passing the 200 seconds of arc image on the Lang II stereo card) and the absence of medial rectus hypofunction were characteristic for patients with postoperative orthotropia. The multiple regression model developed confirmed that the preoperative characteristics of the motor and sensory systems of the eye (the NPC and the presence of distance stereopsis) can be used as predictors of the success of exotropia surgery.

DISCLOSURE

The authors declare no conflict of interest.

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