https://doi.org/10.31288/oftalmolzh202351621

Preoperative visual function characteristics having an effect on the success of exotropia surgery

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Background: *There are individual reports on the effect of some preoperative characteristics of visual functions (like convergence, angle of deviation, presence of fusion and type of binocular vision) on the success of exotropia surgery. To date, however, it has not been established what are the major diagnosis-related prognostic factors for the success of surgery for exotropia.*

Purpose: *To identify the preoperative characteristics of visual functions which have an effect on the success of surgery for exotropia.*

Material and Methods: *Of the 59 exotropes (age range, 10 to 21 years) included in this study, 33 had basic constant exotropia (group 1) and 26, intermittent exotropia (group 2). Patients underwent an ophthalmological and ortoptic examination of the motor and sensory systems of the eye. Patients with surgery success (postoperative orthotropes) were compared to those who had a residual exotropia of more than 10 prism diopters (PD) postoperatively in terms of the preoperative accommodative convergence–accommodation (AC/A) ratio, near point of convergence (NPC), distance stereopsis and near stereoacuity threshold.*

Results: *Our analysis of the preoperative NPC, AC/A ratio and stereopsis for the group with postoperative orthotropic alignment and the group with postoperative exotropic alignment found 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 second of arc image on the Lang II stereo card) and the absence of medial rectus hypofunction of hyperfunction in 83.05% of patients of the former group.*

Conclusion: *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 second of arc image on the Lang II stereo card) and the absence of medial rectus hypofunction of hyperfunction can be the factors favoring the success of exotropia surgery.*

Keywords:

exotropia, surgical treatment, stereopsis, near point of convergence

Introduction

Exotropia is a form of strabismus (eye misalignment) in which one or both of the eyes turn outward. Exophoria and exotropia can be caused by congenital or acquired abnormalities of orbital structure, globe structure, extraocular muscle attachment and/or extraocular muscle location [1-8].

Exotropia 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 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]. Numerous exotropia classification systems based on clinical factors have been developed and used for treatment [1, 2]. Duane's classification system 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]. It has been, however, not established whether the insufficiency or excess of convergence is an innervation abnormality that can cause exotropia. Most current classification systems of exodeviations are derived from the classification system 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 the Duane's etiologic concept, his classification system has survived and is still used today. More recently, von Noorden and Campos [1] have classified exodeviations into the following patterns:

(a) Divergence excess was defined as an exodeviation of at least 15Δ greater at distance than at near fixation.

(b) Basic exodeviation was defined as an exodeviation in which the distance deviation is approximately equal to the near deviation.

(c) Convergence insufficiency was defined as an exodeviation of at least 15Δ greater at near fixation than at distance.

(d) 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 [8, 9] in the literature on the effect of some preoperative characteristics of visual functions (like convergence, angle of deviation, presence of fusion and type of binocular vision) on the outcome of surgery for exotropia. These reports are, however, related to the incidence of the presence of fusion and/or binocular vision, but not the particular amounts of abnormalities. Hatt and colleagues [10] 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. Others [11, 12] found that the preoperative presence of distance stereopsis was more commonly seen in patients with a good outcome of surgery for intermittent exotropia [13]. We have previously reported [11] that the presence of stereopsis after treatment for strabismus indicates that a stable treatment outcome has been achieved and binocular vision regained. Thorisdottir and colleagues [14] and Jung and colleagues [15] considered the postoperative state of stereopsis as an efficacy endpoint in the evaluation of strabismus surgery. To date, it has not been established what are the major diagnosis-related prognostic factors for the outcome of surgery for exotropia. 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 for exotropia.

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

Material and Methods

Fifty nine exotropes were included in this study and most of them had bilateral exotropia. Of the 59 patients, 33 had basic constant exotropia and 26 patients, intermittent exotropia (group 1 and group 2, respectively). Patient age ranged from 10 years to 21 years. The mean corrected visual acuity in group 1 was 0.83 ± 0.33, and in group 2, 0.82 ± 0.35. In both groups, the refractive error ranged from -5.5 D 7.5 D.

Of the 59 patients, 34 (56.7%) 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 and ortoptic examination. In addition, the near point of convergence (NPC) was determined by the proximeter. The proximeter consists of a 50-cm ruler along which slides a test object in the form of an optotype (print no.4) for assessing near visual acuity. During the examination, the test object is moved nearer to the nose and, at the moment when double vision appears, the distance between the bridge of the nose and the point where double vision occurs is measured. 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, using the color test. Lateral and medial rectus muscle hyperfunction or hypofunction were scored 1 to 4 or -1 to -4, respectively, according to Whrite and Ryan [16], 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 latent deviation. 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 or not stereopsis was present at a 5-m distance.

The surgery was performed in one or both eyes in a routine manner [1, 17]: (a) unilateral lateral rectus muscle recession in 12 patients (20%);(b) bilateral lateral rectus muscle recession in 23 patients (39.9%); (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 four-muscle surgery involving two-stage lateral rectus muscle recession and medial rectus muscle resection in 17 patients (28%) [17]. Success of surgery was defined as an orthotropia of 10 PD or less, and patients with a postoperative exotropia exceeding 10 PD required a re-surgery [15].

Statistica 8.0 (StatSoft, Tulsa, OK, USA) software was used for statistical analysis. Mean (M) and standard deviations (SD) were calculated for quantitative variables. The level of significance $p \leq 0.05$ was assumed. Analysis of variance (ANOVA) with the Newmans-Keuls multiple comparisons test and Chi-square test were used for comparisons of a group with postoperative orthotropia with a group with postoperative residual exotropia as appropriate.

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 1 presents mean values for the preoperative characteristics of the motor and sensory systems of the eye for the two groups (a group with constant exotropia and a 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 characteristics examined. 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 1), indicating the presence of partial binocular functions.

There was no significant difference in postoperative angle of deviation between the groups. Table 2 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 2), 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 83.05%, and postoperative residual exotropia was seen in 16.95% of patients in the study sample.

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 NTC ($F = 13.8$, $p = 0.0001$), 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

Table 1. Mean values for the preoperative characteristics of the motor and sensory systems of the eye for the group with preoperative constant exotropia and the group with preoperative intermittent exotropia and Chi square values for comparison between these groups for some of characteristics examined

Characteristic	Preoperative exotropia		X^2	P
	Constant exotropia n = 33	Intermittent exotropia n = 26		
Near point of convergence (NPC; cm)	8.8 ± 0.9	8.6 ± 0.6	0.33	>0.05
Accommodative convergence–accommodation (AC/A) ratio (prism diopters/ diopter)	4.1 ± 2.08	3.6 ± 1.35	0.29	>0.05
Fusion	24.4% (8)	53.8% (14)	5.45	0.01
Functional scotoma	75.6% (26)	46.2% (12)	6.76	0.009
Presence of distance stereopsis	0 (33)	57.7 (15)		>0.05
Absence of distance stereopsis	-	42.3% (11)	25.53	0.00000
Lang-Stereotest II (second of arc)	“0”- 84.5% (28)	“0”-75.8% (18)	28.5	0.00000
	200-600 -15.5% (5)	400 - 24.2% (8)		>0.05
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	>0.05
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	>0.05

Note: n, number of patients

Table 2. Preoperative and postoperative angles of deviation in patients with preoperative 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	$p_{1=}0{,}0001$		$p_{2=}0{,}0001$	

Note: n, number of patients

Table 3. 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)

Group	Post-operative angle of deviation (prism diopter)	Preopera-tive accommo-dative conver-gence–accommo-dation (AC/A) ratio (prism diopters/ diopter)	Preopera-tive near point of conver-gence (NPC; cm)	Preoperative Lang-Stereotest II (second of arc)	Preoperative presence (1) or absence (0) of distance stereopsis	Preoperative lateral rectus muscle hyperfunction (a score of 1 to 4) or medial rectus muscle hypofunction (a score of -1 to -4)
Postopera-tive orthotropia (n=49)	2.5 ± 3.35	4.0±1.65	8,.03± 3.02	«0» -13.5% 200.0 - 36.6% 400-600 - 49.9%	« 0» -65% «1»- 35%	0.92±1.42
Postopera-tive exotropia (n=10)	13.0±1.84	2.4±1.77	10.25 ± 3.86	«0» - 40% 200,0 - 20% 400-600 - 40%	«0» - 100%	-1.33 ±1.03
P and Chi-square test (χ^2) values	0.00015	0.04	0.7	χ^2=1,6, p=0.2	χ^2=10.76, p=0.01	0.0005

Note: n, number of patients

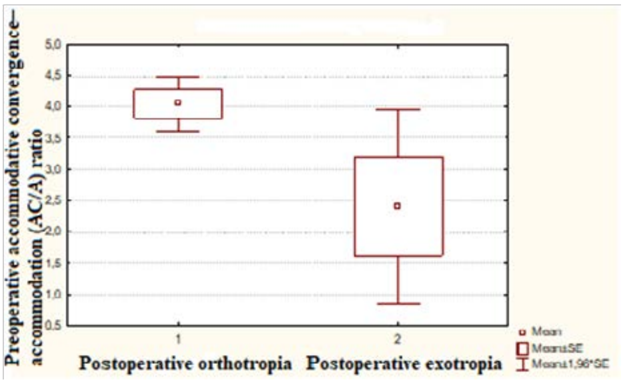

Fig. 1. Preoperative values of accommodative convergence–accommodation (AC/A) ratio (prism diopters/ diopter) in groups of patients with postoperative orthotropia and postoperative residual exotropia

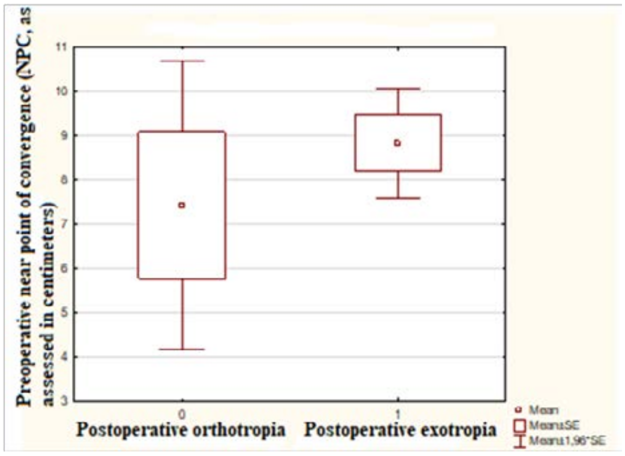

Fig. 2. Preoperative values of near point of convergence (NPC, as assessed in centimeters) in groups of patients with postoperative orthotropia and postoperative residual exotropia

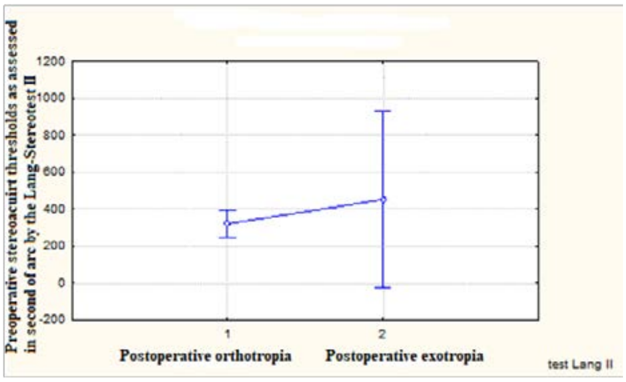

Fig. 3. Preoperative near stereoacuity thresholds (as assessed in second of arc by the Lang-Stereotest II) in groups of patients with postoperative orthotropia and postoperative residual exotropia

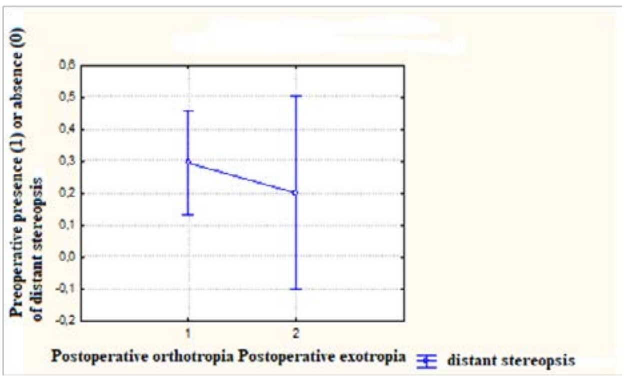

Fig. 4. Preoperative presence or absence of distance stereopsis in groups of patients with postoperative orthotropia and postoperative residual exotropia

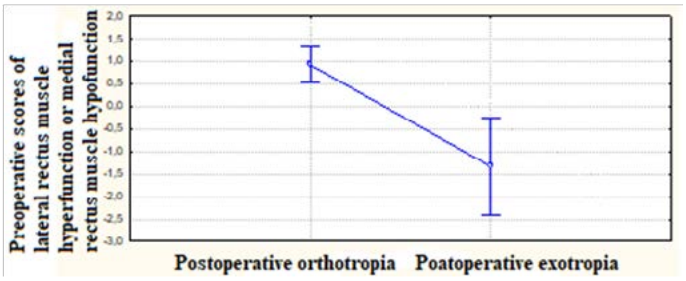

Fig. 5. Preoperative scores of lateral rectus muscle hyperfunction or medial rectus muscle hypofunction in groups of patients with postoperative orthotropia and postoperative residual exotropia

is an integral characteristic of binocular vision [18], we considered the preoperative state of stereopsis in the group of postoperative orthotropia and the group of postoperative residual exotropia (Table 3).

The mean preoperative AC/A ratio value was larger (4.0 ± 1.65 PD/D versus 2.4 ± 1.77 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 versus 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 3; Figs. 1 and 2). Of the 49 postoperative orthotropes tested preoperatively with the Lang II Stereotest, 7 (14.29%) failed the test and 18 (36.73%) were able to perceive the 200 sec of arc image (Table 3, Fig. 3). In addition, of the 49 postoperative orthotropes, 32 (65.31%) had no distance stereopsis preoperatively (Table 3, Fig. 3). Of the 10 postoperative residual exotropes tested preoperatively with the Lang II Stereotest, 4 (40%) failed the test, while the rest exhibited higher thresholds than normal subjects or orthotropes (Fig. 4).

Preoperative medial rectus hypofunction and lateral rectus hyperfunction scores in postoperative orthotropes and postoperative residual exotropes are presented in Fig. 5. In patients developing postoperative orthotropia, preoperatively, lateral rectus muscle hyperfunction (a score of 0.5 to 1.3) preoperatively 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.

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 [19] 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. There are individual reports [20, 21, 22] in the literature on that better preoperative statuses of convergence, angle of deviation, fusion and binocular vision are associated with success of exotropia surgery. Preoperative and postoperative stereopsis has been assessed as a measure of the efficacy of (a) restoration of binocular functions and (b) surgery. Hyperopic refractive error is a favorable prognostic sign for normal near stereoacuity and long-term success of surgery [21-24]. Others [22, 23] reported that the preoperative deviation was the factor affecting success of exotropia surgery, with smaller deviations having a better outcome, but we did not find such a relationship. Smaller initial deviations with hyperopic correction and fusion at distance indicated a favorable prognosis for stereoacuity improvement with surgery for exotropia [25]. It has been, however, concluded that (a) successful motor alignment did not guarantee recovery of suppression when the preoperative angle of exotropia was greater than 20 PD [25] and (b) the development of vergence did not account for the onset of stereopsis [26].

Studies [9, 10, 26-28] assessed near stereoacuity thresholds and the state of convergence before and after surgery for constant and 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 NTC 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.

Conclusion

First, preoperative fusion and distance and near stereopsis indicate the presence of partial binocular functions, and we found that they were more frequently present in patients with intermittent exotropia than in those with constant exotropia ($p < 0.05$). We, however, found no significant difference in surgery success rates in patients with intermittent exotropia versus those with constant exotropia ($p > 0.05$).

Second, 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 second of arc image on the Lang II stereo card) and the absence of medial rectus hypofunction were characteristic for patients with postoperative orthotropia.

Finally, findings of the current study should be taken into account while defining the expected outcome for exotropia surgery.

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Disclosures

Received 28.08.2023

Accepted 18.10..2023

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Authors' contributions. *Boychuk I. M. - conceptualization, data analysis and interpretation, writing and editing; Alui Tarak - literature review, data analysis, writing.*

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Conflict of interest: *None*

Sources of support: *None.*