COMPARATIVE ANALYSIS OF VISUAL ACUITY AND BINOCULAR VISION BEFORE AND AFTER STRABISMUS SURGERY

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Abstract

Binocular vision is the ability to focus on an object with both eyes simultaneously in order to create a single visual image. Although lack of binocular function is normal in infants, it is not the case in children and adults as it is necessary to have a good depth perception. Aim of this paper was to showcase postoperative binocular vision results after strabismus surgery. For that purpose, we utilized medical records of 72 patients who had their first strabismus surgery done at the Clinic for Eye Diseases in Tuzla between February 2017 and February 2023. Pre-operative deviation, diagnosis, binocular function, visual acuity and age were analyzed as factors that influence the success of the surgery. In order to assess set goals of the research, Chi square test, Wilcoxon matched-pairs signed-rank test and logistic regression analysis with forced entry were used. Patients were divided into two groups, first with esotropy and the second with exotropy, both groups were under the age of 7. Surgery success rate for respondents under the age of 7 was 67.1% and for the respondents over the age of 7 was 81.1% and no statistically significant improvement in visual acuity was observed. Success rate of achiving binocular vision, after strabismus surgery, was 49.3 for esotropy and 97.3 fir exotropy. Factors that influenced success rate were pre-operative deviation and age group.

Keywords: *binocular vision, visual acuity, strabismus*

INTRODUCTION

Binocular vision is the ability to mentally combine two images of a single object, each created in one of the retinas, into a single image (Feric-Seiwerth 1965). If brain does not combine images from both eyes, person will see double images. Preconditions for binocular vision can be split into two groups: motor and sensory components (Vesley and Synek 2013). Sensory components encompass good visual acuity on both eyes and equal size of the images getting to retinas in each eye (Civicic 2015). Motor preconditions of binocular visions are symmetrical position of the eyes i.e. parallel sight direction when looking at larger distances, good eye mobility in all directions and good ratio of accommodation and convergence with the purpose of keeping single images (Vesley and Synek 2013). Stereovision, as the highest level of binocular vision, refers to the ability to obtain information about the distance of an object based on the relative position of those objects in both eyes. (Read, 2015). We can get information about depth and distance from many monocular traces that provide us with indirect information about depth but do not allow the quality we get through stereo vision. (Fielder and Moseley, 1965). Reduced depth perception has been consistently confirmed as a risk factor for falls and fractures in elderly people. (Lord and Dayhew, 2001). The brain uses binocular disparity to estimate the relative depth of objects around us relative to the fixation point. This process is called stereoscopic depth or stereovision. Binocular disparity is the difference in relative separation between a pair of salient images in the two eyes. This difference is the result of the fact that the two eyes are laterally separated and look at the world from two slightly different points (Arsenault and Ware, 2004). Deviation from parallel position of the eyes indicates strabismus. Strabismus is a common condition in ophthalmology and prevalence is between 3% and 5% in total population (Abrahamsson M, 2002). Treatment includes thorough diagnostics, treatment of amblyopia, correction of refractive errors and, after conservative treatment, surgery can begin. Strabismus surgery is especially successful in patients who underwent conservative treatment aiming to achieve binocular vision. Different research studies suggest success rates for strabismus surgery ranging from 30% to 80% (Segal ZI, 2000). Aim of this paper was to determine if there is a difference between current results from other studies considering there are no documentation on conventional surgery of horizontal strabismus in Bosnia and Herzegovina.

METHOD

Sample

Sample contained medical records of 72 patients that underwent first surgery of horizontal strabismus at the Clinic for Eye Diseases between February 2017 and February 2023, out of which 35 patients (48.6%) were younger than 7 and 37 patients (51.4%) were older than 7. Respondents in relation to their gender were 34 (47.2%) male and 38 (52.8%) female. In the total sample of 72 respondents, 35 (47.9%) had esotropia and 37 (52.1%) had exotropia. Clinical data included: diagnosis, age, visual acuity, binocular vision, bulbomotorics, preoperative and postoperative deviation, complications and need for repeated surgery. Visual acuity was measured with the Snellen chart or Lea symbols in preverbal children. Binocular function was evaluated according to the Titmus fly test, the Lang I and Lang II test, and Worth-four test. The patients were divided into

two age groups, the first group was 7 years or less, and the second group was over 7 years. Guidelines for planning surgical procedures for esotropia and exotropia were modeled after the Marshall Parks formula (tables 1, 2) (Forrest MP, 2003).

Table 1. Surgical sizes for esotropia (modified according to Marshall Parks formula)

	Symmetrical surgery		Unilateral surgery	
Deviation (Δ)	Recession MR OU (mm)	Resection LR OU (mm)	Recession MR OU (mm)	Resection LR OU (mm)
15	3.0	3.5	3.0	3.5
20	3.5	4.5	3.5	4.0
25	4.0	5.5	4.0	5.0
30	4.5	6.0	4.5	5.5
35	5.0	6.5	5.0	6.0
40	5.5	7.0	5.5	6.5
50	6.0	8.0	6.0	7.0
60	6.5		6.5	7.5
70	7.0		7.0	8.0

Table 2. Surgical sizes for exotripia (modified according to Marshall Parks formula)

	Symmetrical surgery		Unilateral surgery	
Deviation (Δ)	Recession MR OU (mm)	Resection LR OU (mm)	Recession MR OU (mm)	Resection LR OU (mm)
15	4.0	3.0	3.0	3.5
20	5.0	4.0	3.5	4.0
25	6.0	5.0	4.0	5.0
30	7.0	5.5	4.5	5.5
35	7.5	6.0	5.0	6.0
40	8.0	6.5	5.5	6.5
50	9.0		6.0	7.0
			6.5	7.5
			7.0	8.0

Research data was processed with parametric and non-parametric statistic method. Basic statistical parameters, central tendency measures, dispersion measures, frequencies and percentages were calculated. Arithmetic mean, median and mode were calculated from measures of central tendency, and standard deviation, minimum and maximum results from measures of dispersion. The obtained results are shown in tabular view. In order to verify the research objectives, the chi-square test, the Wilcoxon test of equivalent pairs and logistic regression analysis with the forced entry were used. Research data was processed in the statistical package SPSS 20 for Windows

RESULTS

Study included 72 patients. Table 3 shows the distribution of respondents in relation to age group, gender and diagnosis. Table 3 shows that research included a total sample of 72 respondents, of which 35 (48.6%) were younger than 7, and 37 (51.4%) were older than 7. Looking at the respondents in relation to their gender, 34 (47.2%) were male and 38 (52.8%) were female. In the total sample of 72 respondents, 35 (47.9%) had esotropia, and 37 (52.1%) had exotropia (Table 3).

Table 3. Respondents demographics

Demographics	N = 72 cases (No. %)
Gender	
Male (%)	34 (47.2%)
Female (%)	38 (52.8%)
Age	
Mean + SD	9,67±4,15
Median (min, max)	8 (5, 20)
Age group 1 (< 7 years)	35
Age group 2 (> 7 years)	37
Deviation	
Esotropia (cases)	35(47.9%)
Exotropia (cases)	37(52.1%)
Angle of deviation preoperative	
Mean + SD (prism diopters)	3,31±21,14 (PD)

The results in Table 4 show that the average age of the respondents was 9.67±4.15 years, the median was 8 and the mode was 7, the minimum and maximum age of the respondents ranged from 5 to 20 years. The average preoperative deviation was 3.31±21.14 prismatic diopters, median 0, mode 30, while the minimum and maximum prismatic diopters ranged from -30 to 35. The average postoperative deviation was 2.73±5.03, median 3, mode -2, while the minimum and maximum scores range from -7 to 15 (Table 4).

Table 4. Measures of central tendency and measures of dispersion in relation to age, preoperative and postoperative deviation

Var.	M	SD	SG	MED	MOD	MIN	MAX
Age	9,67	4,15	0,35	8,00	7,00	5,00	20,00
PreOP deviation	3,31	21,14	1,76	0,00	30,00	-30,00	35,00
PostOP deviation	2,73	5,03	0,42	3,00	-2,00	-7,00	15,00
After 2 years	1.63	7.13	0.59	2.00	5.00	-15.00	23.00

Table 5 shows the results of Chi-square test in relation to the surgery success, diagnosis and age group.

Success rate for esotropia surgery was 49.3% and for exotropia was 97.3%. The results of the Chi-square test indicate that at the level of statistical significance of 0.01, the success rate of surgery is higher in patients with exotropia (Table 5). Surgery success rate for patients younger than 7 was 67.1%, while for subjects older than 7, it was higher and amounts to 81.1%. The results of the chi-square test showed (albeit at the limit of significance) that there was no statistically significant difference between age group and the surgery success rate (Table 5).

Table 5. The results of the chi-square test in relation to the surgery succes

Variables			Surgery successful		χ^2	
			Yes	No		
Diagnosis	Esotropia	N	17	18	43,47	**.000**
		%	49.3%	50.7%		
	Exotropia	N	35	2		
		%	97.3%	2.7%		
Total (Success rate)		N	54	18		
		%	74.3%	25.7%		
Age	Younger than 7	N	24	11	43,47	.056
		%	67.1%	32.9%		
	Older than 7	N	30	7		
		%	81.1%	18.9%		
Total (Success rate)		N	54	18		
		%	74.3%	25.7%		

Based on the results shown in Table 6, it can be seen that the average value of VOD before the surgery is 0.92±0.21, while after the surgery it is 0.90±0.21. This result indicates that the patients after the surgery have a lower average visual acuity of the right eye.

The average value of VOS before surgery is 0.91±0.22, and after surgery it is 0.89±0.24. The results of the VOS indicate that the patients after the surgery have a lower average visual acuity of the left eye. There were no surgery complications.

Table 6. Measures of central tendency and measures of dispersion in relation to age, pre-surgery and post-surgery deviation

Var.	M	SD	SG	MED	MOD	MIN	MAX
Preoperative visos VOD	0,92	0,21	0,02	1,00	1,00	0,02	1,00
Preoperative visus VOS	0,91	0,22	0,02	1,00	1,00	0,08	1,00
Postoperative visus VOD	0,90	0,21	0,02	1,00	1,00	0,08	1,00
Postoperative visus VOS	0,89	0,24	0,02	1,00	1,00	0,08	1,00

Based on the obtained results presented in table 5, it can be concluded that, at the statistical significance level of 0.05, the visual acuity of the right eye is lower after the surgery. Also, at the 0.05 level of statistical significance, the visual acuity of the left eye is lower after surgery. In order to see whether the differences in visual acuity pre-surgery and post-surgery are statistically significant, the Wilcoxon test of equivalent pairs was applied and the results are shown in table 7.

Table 7. Wilcoxon test results

Variables		N	Mean of the ranks	Sum of the ranks	Z	
PostOP VOD – PreOP VOD	Negative ranks	5	7.30	73.00	-2,70	**.007**
	Positive ranks	1	2.50	5.00		
	Smaller sum of ranks	66				
	Total	72				
PostOP VOS - PreOP VOS	Negative ranks	3	3.00	15.00	-2,12	**.035**
	Positive ranks	0	.00	.00		
	Smaller sum of the ranks	69				
	Total	72				

The representation of binocular vision is shown in table 8, where it can be seen that binocular vision was present before surgery in 7 (9%) patients, while it was not present in 65 (91%) patients. After surgery, the presence of binoculars was recorded in 40 (55.6%) patients, while it was not recorded in 32 (44.4%) patients.

Table 8. Presence of binocular vision before and after surgery

Variables	No	Yes	Total
Binocular vision before surgery	66 (91%)	6 (9%)	72
Binocular vision after surgery	32 (44,4%)	40 (55,6%)	72

In order to verify the influence of several factors (Pre-surgery deviation, diagnosis, binocular function, visual acuity and age) on the surgical success of the subjects, a logistic regression analysis was applied. The whole model with all predictors was statistically significant ($\chi 2 = 112.296$, df = 6; $p \leq 0.001$), which means that the model distinguishes between subjects who had a successful and unsuccessful surgery. The model as a whole explains 54.2% and 79.6% of the variance in the success of the surgery and correctly classifies 95.1% of the cases. The obtained results shown in table 9 indicate that four independent predictors (factors) gave a unique statistically significant contribution to the success of the surgery. At the statistical significance level of 0.01 and 0.05, the pre-surgery deviation, the pre-surgery visual acuity of the right and left eye and the age of the subject are the biggest predictors of the success of the surgery.

Table 9. Results of logistic regression analysis

Variables	B	SG	Wald	df	p	Probability ratio	Interval 95% confidence	
							Lower limit	Upper limit
Diagnosis	-0,19	1,50	0,02	1,00	,899	0,83	0,04	15,76
PreOP	-0,18	0,05	14,74	1,00	**,000**	0,83	0,76	0,91
PrVOD	8,08	4,00	4,07	1,00	**,044**	3232,27	1,26	8288547,99
PrVOS	5,95	2,90	4,21	1,00	**,040**	382,05	1,30	112157,02
BipreOP	-17,09	9838,63	0,00	1,00	,999	0,00	0,00	
Age	.295	.120	6.003	1	**.014**	1.342	1.061	1.699
Constant	8,11	9838,63	0,00	1,00	,999	3332,92		

Note: Pre-surgery VOD – Visual acuity of the right eye before surgery; Pre-surgery VOS – Visual acuity of the left eye before surgery; Bi Pre-surgery – Binocular vision before surgery.

DISCUSSION

Many scientific studies have reported success rates of strabismus surgery ranging from 30% to 80%. (Trigler L,2002). Binocular vision is developing very fast during first year of life under presumption that growth and development of the child is normal. Binocular vision is along with visual acuity and fixation reflex the most important component of vision. Didactically, binocularity is divided into three levels: simultaneous perception, then the possibility of fusion of two slightly disparate images and stereopsis as the highest form of binocularity. In clinical work, different tests are used that examine all these levels of visual perception (Busic M., 2016). While looking at the results of previous research, which indicate that people who underwent horizontal strabismus surgery achieved only an aesthetic effect (Thederan et al., 2016) and the main reason for their difficulties in everyday life is cited as the unsuccessful use of prescribed corrective glasses or the use of the ones that have not been changed for many years (Horovitz, 1994), we decided to look back at the results we obtained from the analysis of our medical records. The need for future research to determine the reasons for irregular wearing and changes in correction in preschool and school age children should be highlighted. Some of the main recommendations are regular vision checks and acquisition of an appropriate refractive correction and regular vision screening. Recommendations also include services for visually impaired, including prescribing and training in the use of optical and non-optical aids for those who have a significant degree of residual vision. (Horovitz, 1994; Lord i Dayhew, 2001). As the most important results of the assessment, considering the goal of the research, we referred to the binocular vision that the subjects showed on the synoptophore or with the help of prism scales. Many research supports the fact that postoperatively in a small number of respondents, stereo vision appears as the third degree of binocular vision. A large number of respondents with stereo blindness was found by (Wright and Wormald, 1992), in whose study of 417 people, 29% of the respondents were stereo blind. Numerous studies discuss the change in binocular vision in people who have horizontal strabismus, however, the data provided by Allen et al. (1964), Haegerstorm-Portnoy et al. (1999), Rubin et al. (1977; according to Lee et al., 2005), pointed out the disadvantage that at the time of measuring binocular vision in their subjects, the visual acuity was not at the optimal level. The frequency of horizontal strabismus in relation to esodeviations is 4:1 in children and 2:1 in adults (Nordlowu, 1964). Horizontal strabismus before 2 years of age was found in 34.5% of the respondents (Krzystkowa and Pajakowa, 1972). What is definitely necessary to mention is the fact that heredity plays an important role in the origin of exodeviation (Horwood AM, 2009).

In this study, the success rate of the surgical procedure was 49.3% for esotropia, while it was 97.3% for exotropia. Predictors of a good result in this study were age below 7 years and preoperative deviations of less than 30 diopters of the prism. This study indicated an improvement in binocular function by increasing the number of patients who had binocular function from 7 cases before surgery to 65 cases after surgery. This result demonstrated the role of good ocular alignment in the development of binocular function.

From the aforementioned, we can see that there is a difference in functionality of binocular vision at initial exam, right after surgery and a year after surgery at the final exam. This means that preoperative preparations, procedure itself and postoperative treatment i.e. orthoptic/pleoptic exercises have had a positive impact in achieving binocular vision of the respondents in both age groups. During regular control examinations, throughout the year after the surgery, status has

changed and patients could be considered esthetically and functionally cured. The surgery led to an orthophoric position of the eyes with normal binocular vision (Celic and Dorn, 2004). Alajbegović-Halimić (2000) also came to similar results, where after the exotropia operation there were positive results in terms of aesthetics and functionality. There was an improvement in binocular vision in a larger number of patients, in terms of obtaining fusion, and even the existence of coarse stereo vision, which is not often the case with esotropia.

CONCLUSION

Based on the applied methodology of research, analysis and interpretation of the obtained results we have come to following conclusions. Success rate of the surgical procedure was 49.3% for esotropia, while it was 97.3% for exotropia. Factors influencing success rate were preoperative deviation and age. Predictors of a good result in this study were age below 7 years and preoperative deviations of less than 30 diopters of the prism. Achieving binocular vision, which is of priceless value to respondents' age group, both esthetic and functional improvements were satisfied. It is important to point out that with permanent diagnostics, medical therapy and typological rehabilitation, in children at their earliest age, a lot can be done to preserve and develop visual functions and sensory and motor cooperation. The significance of this research is to point out the necessity of early detection and prevention of low vision (amblyopia) and strabismus, which implies the need for an early systematic examination of children of preschool age and the need for the work and influence of defectologists-typhlogists in health, preschool and school institutions. It is necessary to work on developing cooperation in the relationship between the pediatrician-child-parent-defectologist-typhlogist-strabologist who make up the team, and educating parents about the importance of early detection of strabismus and amblyopia, because the treatment prognosis is positive if the signs of strabismus and amblyopia are detected early enough and if the treatment is started in a timely manner. The professional team should provide professional and educational services to parents.

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