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STEREOSCOPIC VISUAL ACUITY IN STRABISMIC AND AMETROPIC/REFRACTIVE AMBLYOPIA

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SUMMARY – Reduced stereoscopic visual acuity is commonly found in association with reduced visual acuity or strabismus. These findings belong to clinical features of amblyopia. Strabismic and refractive amblyopia account for the vast majority of amblyopia. The aim of this study was to assess and describe stereoacuity in strabismic and ametropic amblyopia. Cases of strabismic and ametropic/refractive amblyopia were separated from all amblyopic patients examined during a one-year period. The group of strabismic amblyopia included patients with amblyopia, usually unilateral, mostly associated with early onset of strabismus. The group of refractive amblyopias included patients with amblyopia associated with or attributed to previously uncorrected high but equal refractive errors (mostly hyperopia and astigmatism). Stereoscopic visual acuity was tested by Titmus test (housefly, circles, row of animals) and both Lang stereotests (Lang I and Lang II). More than a half (57.8%) of the amblyopia group were patients with strabismic (35%) and ametropic (22.8%) amblyopia. The type and magnitude of ocular deviation, and the amount and type of refraction error clearly influenced the measured values of stereoacuity, indicating stereopsis impairment. Impaired stereopsis was noticeable in severe amblyopia, esotropia or greater hyperopic astigmatism.

Key words: *Stereoscopic visual acuity; Strabismic amblyopia; Ametropic/refractive amblyopia*

Introduction

Amblyopia is reduction of visual acuity with the best refractive correction that cannot be attributed directly to any structural abnormality of the eye or posterior visual pathway. The known causes of amblyopia are abnormal visual experiences in early life such as ocular misalignment, uncorrected refractive errors or disorders that change the quality of image transmission from the eye to the brain[1]. More sophisticated characteristics of amblyopia are decreased contrast sensitivity, decreased recognition acuity, decreased resolution acuity, decreased acuity of lateral displacement and decreased space localization[2]. A special type of resolution acuity, in distinction from resolution acuity in minimum separabile, is Vernier acuity, which tests the recognition of minute displacement threshold. That kind of localization visual acuity is determined by the smallest distance that the subject does not perceive as a shift between two lines. This visual acuity is 8 to 10 times higher than the aforementioned visual acuities and is in accordance with stereoacuity, i.e. depth perception which thanks to binocular viewing enables detection of the slightest localization difference in space[3].

In general population, the prevalence of amblyopia is *2%-4%*. In strabismic population, it is higher (about 8%). The etiologic classification of amblyopia is the most general one[4,5]. Amblyopia has traditionally been subdivided according to major disorders that may be the reason for its occurrence. So, strabismic, anisometropic, refractive/ametropic and deprivation amblyopias have been distinguished.

Strabismic amblyopia is the most common form. It develops in constantly deviating children's eyes. Constant misalignments of the eye, i.e. tropias, are the main reason for the development of different degrees of amblyopia. Strabismic amblyopia is the result of competitive or inhibitory interaction between neurons carrying

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the non-fusible inputs from the two eyes, thus leading to predominance of cortical vision centers by the fixation eye and reduced responsiveness to the non-fixating eye's inputs. It is the mechanism responsible for eliminating diplopia in strabismic children through suppression[1].

Several features are typical for strabismic amblyopia but uncommon in other types of amblyopia. In the same eye, examined in two ways, Snellen's acuity is more reduced than grating acuity. Grating acuity is represented through the ability to detect patterns composed of uniformly spaced stripes, which closely corresponds to Snellen's acuity.

Refractive/ametropic or isoametropic amblyopia is bilateral reduction of visual acuity that results from large, usually equal, uncorrected refractive errors of both eyes. The degree of amblyopia is the same on both eyes, or different depending on difference in the refractive error of the eyes. Amblyopia results from the effect of blurred retinal images through uncorrected refractive error. Hyperopia exceeding +5 diopters and myopia higher than 10 diopters induce amblyopia. Uncorrected bilateral astigmatism in early childhood may result in the loss of the resolving power ability[1].

Stereoscopic acuity or depth perception is the highest level of binocular function; it is present with orthophoria and good visual acuity in both eyes. It is the binocular estimate of relative depth as a result of slight image disparity between the two eyes. The reason for this image disparity of the same object is the difference in the viewing angle between the two eyes. Stereoscopic visual acuity is the smallest difference of two objects perceivable by stereopsis cues, ordinarily specified as angle of stereopsis[3]. Stereoacuity threshold is 2-4 seconds of arc. Normal variations are between 5'' and 15', but it can also be under 2'' in trained persons. Stereoacuity varies according to age (the best is in children and adolescents) and increases with light intensity and exposition time[3,6].

Stereoacuity can be determined in several ways. Quick practical information can be obtained by Lang two pencil test[7,8], but more accurate quantitative examination uses tests with stereoscopic pictures, e.g., polaroid stereotest Titmus O.C., Lang I and II, TNO test, etc. (major amblyoscope, stereoscope, polarized light test in space)[8]. Reduced stereoacuity is frequently associated with reduced visual acuity or strabismus[9].

The aim of this study was to assess and describe stereoscopic visual acuity and its degree in strabismic and refractive/ametropic or isoametropic amblyopia.

Patients and Methods

This paper reports on a part of a study launched in 2005 and completed in spring 2007. Some parts of the study were presented at our annual congress 2006, and published last year[10]. The last part of the study, stereoacuity in strabismic and refractive/ametropic amblyopia, is reported herewith.

The search through the Children's Eye Center database for the period from January 1, 2005 to March 30, 2007 produced data on 434 patients aged 1-25 years with the main diagnosis of amblyopia. During the study period, some of them were examined on 1-4 occasions[10]. According to classic amblyopia classification[4,5], strabismic amblyopia was found in 162 of 434 (37%) and refractive/ametropic amblyopia in 98 of 434 (22.6%) amblyopia patients[10] (Table 1).

Table 1. Clinical types of amblyopia

Material.: 434 patients with amblyopia	
Period: 01. 01. 2005 to 31.03.2006 to 30.03. 2007.	
Classification:	
visual deprivation amblyopia	26 (6,0%)
Organic amblyopia	59 (13,6%)
Anisometropic amblyopia	98 (22,6%)
• Ametropic / refractive amblyopia	86 (20 %)
• Strabismic amblyopia	162 (37.3%)

All patients underwent general ophthalmologic and orthoptic examination on their first visit to Children's Eye Center. Visual acuity was examined using different methods depending on the age and degree of amblyopia. Visual acuity was assessed at distance and at near, with or without correction. Visual acuity varied from light perception, hand motion to finger count, or it was measured using single E-optotypes, Lea vision chart and standard Snellen's chart. Visual acuity at near was examined using Rodenstock Near Vision Tester and near Lea vison charts[10].

Objective refraction testing and refractive errors were determined by retinoscopy using cycloplegic eyedrops: for preschool children 0.5% or 1% Atropine 3 times a day in the course of 3 days or 1% Tropicamide 3 times, in the office. Refractive errors were corrected with specta-

cles or contact lenses, in the standard manner, after retinoscopy.

Other clinical examinations included ophthalmoscopy, fixation, ocular motility, and cover test at distance or at near. Strabismic deviation was measured using prism/cover test at distance and at near with or without correction, also using a synoptophore.

Sensory testing of binocular vision was performed at distance using Worth four-dot test and Bagolini striated glasses.

Stereoacuity was measured using Lang I and Lang II tests[3,8,10], Titmus test [3,8,10] or Rodenstock Near Vision Tester[10]. Titmus test was performed at 40 cm with the patient wearing polarized spectacles. As children preferred examinations without wearing polarizing spectacles, we used Lang tests at 40-cm distance.

All these tests and examination methods have been previously described in detail[10]. All stereotests were compared with the aim to obtain the same range of stereoacuity irrespective of the test employed. So, rough stereovision between 3000" and 800" was obtained using Titmus[11] and Lang I test. Good stereoacuity from 600" to 300" was found with Titmus, Lang I and II, Pola test and Rodenstock Near Vision Tester. Excellent stereoacuity between 140" and 40" was obtained using Titmus test (rings).

At the last control, visual acuity and stereoacuity of each patient were taken as final results.

Results

Strabismic amblyopia was divided into two groups according to the mode of treatment, operative or conservative. Stereoacuity was ranged as previously mentioned (Table 2). Stereoacuity in different types of squint and treatment is presented in Table 3. The state of stereoacuity in non-operated squinting patients according to the degree of amblyopia and strabismus type is shown in Table 4, and stereoacuity in operated patients with different degrees of amblyopia in Table 5. Relationships between the type of squint and the angle of deviation are shown in Tables 6 and 7.

Ametropic/refracitive amblyopia was found in 86 patients, i.e. 20% of 434 study patients (Table 8). Stereoacuity and refractive errors in the ametropic/refractive amblyopia group are shown in Table 9. The state of good stereoacuity (600"-200') and depth of amblyopia in the ametropic amblyopia group are presented in Table 10.

Table 2. *Strabismic amblyoipia* total: 162

Stereoacuity	Nonoparated squint		Operated squint		Total	
Absent	49	30,2%	47	29,0%	96	59,3%
Rough 3000"-800"	18	11,1%	8	4,9%	26	16,0%
Good 600"-200"	22	13,6%	10	6,2%	32	19,8%
Excellent 140"-40"	5	3,1%	1	0,6%	6	3,7%
Unknown	2	1,2%	–	–	2	1,2%
Total	96	59,3%	66	40,7%	162	100,0%

Table 3. *Stereoacuity in different types of squint and treatment*

Treatment/Types										
Stereoacuity	Nonoperated squint						Operated squint			
	ET		XT		MicroT		ET		XT	
Absent	41	25,3%	4	2,5%	4	2,5%	36	22,0%	11	6,8%
3000"- 800"	12	7,4%	–	–	6	3,7%	3	3,0%	5	3,6%
600"- 200"	15	9,3%	5	3,0%	2	1,2%	3	3,0%	7	4,3%
140"- 40"	3	1,9%	1	0,6%	1	0,6%	1	0,6%	–	–
Unknown	2	1,2%	–	–	–	–	–	–	–	–

Table 4. *Stereoacuity in different degrees of amblyopia*
Nonoperated squint

Degree of Ambl.	< 0,1 – 0,3			0,4 – 0,7			0,8 – 1,0		
Stereoacuity	ET	XT	MicroT	ET	XT	MicroT	ET	XT	MicroT
Absent	10	1	1	17	1	2	14	2	1
3000"- 800"	1	–	1	6	–	2	5	–	3
600"- 200"	–	1	–	6	2	–	9	2	2
140"- 40"	–	–	–	1	1	–	2	–	1

Table 5. *Stereoacuity in different degrees of amblyopia*
Operated squint

Degree of Ambl.	< 0,1 – 0,3			0,4 – 0,7			0,8 – 1,0		
Stereoacuity	ET	XT	MicroT	ET	XT	MicroT	ET	XT	MicroT
Absent	10	–	–	7	5	–	19	6	–
3000”- 800”	1	1	–	–	1	–	2	3	–
600”- 200”	–	–	–	1	12	–	2	6	–
140”- 40”	–	–	–	–	–	–	1	–	–

Table 6. *Stereoacuity and deviation in different types of strabismus*
Nonperated squint

Deviation in Δ	< 10 Δ			10 – 20 Δ			25 – 30 Δ			> 30 Δ		
Stereoacuity	ET	XT	MicrT	ET	XT	MicrT	ET	XT	MicrT	ET	XT	MicrT
Absent	5	–	3	23	2	1	7	–	–	6	?	–
3000” – 800”	3	–	6	6	–	–	1	–	–	–	–	–
600” – 200”	9	2	2	5	3	–	1	–	–	–	–	–
140” – 40”	2	1	1	–	–	–	–	–	–	–	–	–

Table 7. *Stereoacuity and deviation in different types of strabismus*
Operated squint

Deviation in Δ	< 10 Δ		10 – 20 Δ		25 – 30 Δ		> 30 Δ	
Stereoacuity	ET	XT	ET	XT	ET	XT	ET	XT
Absent	18	7	14	24	4	–	–	–
3000” – 800”	2	–	1	–	–	–	–	–
600” – 200”	2	6	1	1	–	–	–	–
140” – 40”	1	–	–	–	–	–	–	–

Table 8.

Ametropic/ refractive amblyopia

	total: 86
• Stereoacuity:	
– Absent 6	(7.0%)
– Rough (3000”-800”) 6	(7.0 %)
– Good (600”-200”) 67	(78.0 %)
– Excellent (140”-40”) 7	(8.0 %)

Table 9.

Stereoacuity andrefractive errors in ametropic / refractive amblyopia group

Refractive Error	Hy / HyAs		My / MyAs		Mix As		Total	
Stereoacuity								
Absent	1	2,3%	1	1,2%	3	3,5%	6	7%
3000” – 800”	1	1,2%	4	1,2%	1	1,2%	6	7%
600” – 200”	35	40,6%	22	25,5%	10	12 %	67	78%
140” – 40”	5	5,8%	–	–	2	2,3%	7	8%
	43	49,8%	27	31,3%	16	18,6%	86	100%

Discussion

Absent stereoacuity was found in an equal proportion of non-operated and operated squint patients. Roughly, good and excellent stereoacuity was better in the non-operated strabismic group. In this group, good stereovision was recorded in 22/96 (13.6%) patients. In operated squint group, good stereoacuity was found in 10/66 (6.2%) patients. Stereoacuity in different types of squint and different modes of treatment showed interesting results (Table 3). Patients with esotropia either operated or non-operated had a highest prevalence of absent stereoacuity among different types of squint (esotropia, exotropia, microtropia). Absence of stereoacuity was recorded in more than

Table 10.

Good stereoacuity (600" – 200") and amblyopia's depth in Ametric amblyopia group

Refractive Error / Visual acuity	Hy/HyAs		My/MyAs		Mix As		Total	
0,1 – 0,3			1				1	1,5%
0,4 – 0,7	17		14		3		34	50,7%
0,8 – 1,0	18		7		7		32	47,8%
	35	40,6%	22	25,5%	10	12%	67	100%

half of non-operated esotropias (41/73; 55%) and 36/43 (83%) of operated esotropias. Absence of stereoacuity was recorded in a significant proportion of both exotropic groups (non-operated and operated), being higher in the group of operated exotropias. Absent stereoacuity was found in 2/3 of the microtropic group of patients. Good stereoacuity (5/10; 50%) was found in the group of all non-operated exotropias.

Stereoacuity is a very fine but fragile ocular function. Amblyopia and strabismus are some of the causes that can break it up. The state of stereoacuity in the non-operated squint group depended on the degree of amblyopia and type of squint (Table 4). Absent stereovision was predominant in esotropias, depending on the degree of amblyopia.

When stereoacuity was present, our results pointed to the following conclusions: when visual acuity improved (amblyopia of a lower degree), stereoacuity started to be finer, ranging from rough to good and excellent in all types of squint. In the operated squint group (Table 5), the stereoacuity behavior in different degrees of amblyopia was similar to that observed in the non-operated group. Esotropia showed the highest proportion of absent stereoacuity cases in all degrees of amblyopia. Stereoacuity, when present, was better in amblyopia of lower degree irrespective of the type of squint (microtropic patients were not operated on).

Stereoacuity also depended on the type of squint and angle of deviation (Tables 6 and 7). When stereoacuity was absent, it was so primarily in esotropia, in all angles of deviation, from less than 10' to more than 30'. When stereoacuity was present, our results showed that it was finer with a smaller angle of deviation, irrespective of the type of strabismus. Absent stereovision was found in only 7% of 86 patients with ametropic/refractive amblyopia. The greatest number of subjects had good stereoacuity (78%); excellent stereoacuity was recorded in 8% (Table 8).

Different refractive errors influenced the state of stereoacuity (Table 9). Hyperopia and hyperopic astigmatism (Hy/HyAs), myopia and myopic astigmatism (My/MyAs), and mixed astigmatism (Mix As) influenced the absence of stereoacuity in a small yet quite comparable number of cases. Good stereoacuity was present in highest percentage in all types of refractive errors. Excellent stereoacuity was recorded in patients with hyperopia and hyperopic astigmatism and in several patients with mixed astigmatism. Good stereoacuity was present in highest percentage in moderate and mild amblyopia in all types of refractive errors (Table 10). Deep amblyopia had absent stereoacuity in all refractive errors.

Conclusion

Stereoacuity as a fine and gentle visual function is very fragile. The causes that can destabilize it are different. In the ametropic/refractive amblyopia group the causes were type of refractive error and degree of amblyopia. In the strabismic amblyopia group, the main causes were type of refractive error, degree of amblyopia, type of squint, angle of deviation and state of binocular vision. Comparison of the state of stereoacuity between these two groups clearly indicated great difference in the quality and quantity of stereoacuity.

Refractive errors and amblyopia of different degrees were present in both groups; however, stereoacuity differed considerably according to its presence or absence. So, in the strabismic amblyopia group, other causes had great influence on the state of stereoacuity as a fine visual function.

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Sažetak

STEREOSKOPSKA VIDNA OŠTRINA KOD STRABIZMIČKE I AMETROPSKE/REFRAKCIJSKE AMBLIOPIJE

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Smanjena stereoskopska vidna oštrina često se nalazi sa smanjenom vidnom oštrinom i strabizmom. Ovi nalazi pripadaju kliničkim značajkama ambliopije. Strabizmičke i ametropske/refrakcijske ambliopije čine veliku većinu ambliopija. Cilj ovoga rada je prikazati stereoskopsku vidnu oštrinu kod strabizmičke i ametropske ambliopije. Od svih naših bolesnika s ambliopijom pregledanih tijekom jedne godine izdvojili smo one sa strabizmičkom i ametropskom ambliopijom. Skupinu sa strabizmičkom ambliopijom činili su bolesnici obično s nalazom ambliopije na jednom oku, kao i oni s uglavnom ranom pojavom strabizma. Refrakcijsku ambliopiju predstavljaju ambliopije nastale zbog izostanka pravodobnog ispravljanja visoke, ali na oba oka podjednake refrakcijske greške (većinom hipermetropija i astigmatizam). Stereoskopska vidna oštrina ispitivana je pomoću Titmus testa (kućna muha, krugovi, niz životinja) i oba stereotesta prema Langu (Lang I. i Lang II.). Više od polovice (57,8%) svih naših bolesnika s ambliopijom imali su strabizmičku (35%) i ametropsku/refrakcijsku (22,8%) ambliopiju. Vrsta i veličina očnog otklona te tip i visina refrakcijske greške značajno su utjecali na dobivene vrijednosti stereoskopske vidne oštrine, pokazujući oštećenje stereopsije. Oštećenje stereopsije zabilježeno je osobito kod teže ambliopije, ezotropije i većih hipermetropnih astigmatizama.

Ključne riječi: *Stereoskopska vidna oštrina, strabizmička ambliopija, ametropska/refrakcijska ambliopija*