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STEREOSCOPIC VISUAL ACUITY IN DIFFERENT TYPES OF AMBLYOPIA

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SUMMARY – The signs of amblyopia include decreased visual acuity, enhanced crowding phenomenon, decreased accommodation ability, afferent pupillary defect, eccentric viewing, and also the loss of precise stereoscopic ability. The aim of the study was to assess stereoscopic visual acuity in different types of amblyopia. Stereoscopic visual acuity was tested and recorded in all of our amblyopic patients examined during one year. The Titmus polarized stereotest (housefly, set of circles, row of animals), and both Lang I and Lang II stereotests were used. The threshold levels of stereopsis determined in strabismic, anisometropic, ametropic and other forms of amblyopia are presented and discussed. In addition, tesults were compared with other parameters (visual acuity, refraction, binocular vision, and fixation). In organic amblyopias, stereopsis was absent. In visual deprivation amblyopias, stereopsis was partially present, only in a minor proportion of patients. In anisometropic amblyopias, however, a half of patients had normal and full stereopsis. The type of refractive error and the depth of amblyopia influence the presence of stereopsis. It is interesting to note that partial or absent stereopsis was not recorded in patients with mixed astigmatism. Determination of the level of stereopsis is a useful method in the diagnosis and classification of amblyopia.

Key words: *stereoscopic visual acuity, amblyopia*

Introduction

Amblyopia is a state of the eye which is characterized by low visual acuity but without latent or manifest eye disease or without defined disturbance of visual pathway, which persists after correction of refractive error and removal of any pathologic obstacle of vision. It is known that amblyopia is quite a common problem in the developmental period of children's eyes. The prevalence of amblyopia in general population is between 1% and 5%[1].

Amblyopia is the consequence of inadequate visual stimulus or visual impression during the sensitive period of vision development, in particular before the second year of life[2]. The main characteristics of amblyopia are decreased contrast sensitivity, decreased recognition acuity, decreased resolution acuity, decreased acuity of lateral displacement, and decreased space localization. In distinction from resolution acuity between two dots or lines (minimum separable), a special type of resolution acuity is denoted by Vernier acuity which tests the recognition of minute displacement threshold. This kind of localization visual acuity is determined by the smallest distance that the proband 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 or depth perception that thanks to binocular viewing enables detection of the slightest localization difference in space[3].

The etiologic classification of amblyopia is the most general one[1,4]. Stereoacuity or depth perception is the highest level of binocular function, and it is present with orthophoria and good visual acuity in both eyes. Stereoacuity 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

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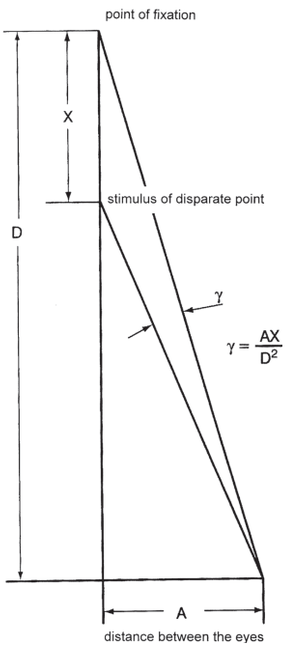

Fig. 1. Stereoscopic visual acuity according to Campbell et al.[5]: A=distance between the eyes (interpupillary distance); D=distance from the target (fixation point); X=distance between the disparate point and fixation point; angle ã=angle of stereoscopic visual acuity.

the difference in the viewing angle between the two eyes. The angle is formed by the visual axes of each eye fixing the same object.

This viewing angle is also called binocular parallax of a particular object. The difference between binocular parallax of two spots is called stereoscopic or instantaneous parallax. The minimal stereoscopic parallax determination gives the stereoacuity[3].

Stereoacuity is determined as a minimal angle that can be perceived between the proband eyes, fixation point and another stimulus (e.g., disparate spot) (Fig. 1)[5]. This angle is proportional to the proband interpupillary distance (A), the distance between the fixation point and disparate point stimulus (X), and inversely proportional to the square distance of the fixation point (D): $\gamma=AX/D^2$ [(5)].

Stereoacuity threshold is between 2 and 4 seconds of arc. It depends on the test object quality, the time of exposition, lighting conditions, and other environmental factors. Normal variation is between 5'' and 15', but it can also be less than 2'' in trained persons. Stereoacuity varies according to age (the best is in children and adolescents), and increases with light intensity and exposition time. Stereoacuity can be determined in several ways. Quick practical information can be obtained by two Lang pencil tests[3,6], but more accurate quantitative examination uses tests with stereoscopic pictures: Titmus O.C. polaroid stereotest, Lang I and II, TNO test and others (major amblyoscope, stereoscope, polarized light test in space). Reduced stereoacuity is frequently associated with reduced visual acuity or strabismus[7].

The aim of the study was to examine and present stereoscopic visual acuity in different types and depth of amblyopia.

Patients and Methods

From January 1, 2005 to March 31, 2006, records on 434 patients aged 1-25 with the main diagnosis of amblyopia were found in the computerized database of the Children's Eye Center. During the study period, some of them were examined on 1 to 4 occasions. General ophthalmologic and orthoptic examinations were performed in each patient at the first visit to the Children's Eye Center. Visual acuity was examined using different methods depending on the patient age and degree of amblyopia. Visual acuity was determined at distance and at near, with or without correction. Assessed visual acuity varied form light perception, hand motion to finger count, or it was measured using single E-optotypes, Lea vision chart and standard Snellen chart. Visual acuity at near was examined using Rodenstock's Near Vision Tester and near Lea vision charts.

Objective refraction testing and refractive errors were determined using cycloplegic eye drops: in 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, before retinoscopy. Refractive errors were corrected with spectacles or contact lenses, in the standard manner, after retinoscopy.

Ophthalmoscopy and fixation were also assessed. In the newly detected cases of amblyopia treatment was inititated.

Results of ocular motility test, cover/uncover test and alternate cover test at distance or at near were recorded. Strabismic deviation was measured using prism/cover test at distance and at near, with or without correction.

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

Stereoacuity was measured using Lang I and Lang II tests[6], Titmus test[8] or Rodenstock's Near Vision Tester. Titmus test is performed at 40 cm with the patient wearing polarized spectacles. As children preferred examinations without wearing polarized spectacles, we used Lang tests at 40-cm distance. Lang-test I contains

Fig. 2. Examination of stereopsis with Lang I stereotest.

the following shapes: cat 1200", star 600" and car 550 seconds of arc. The shapes in Lang-test II are: elephant 600", car 400" and moon 200 seconds of arc. Lang stereoacuity tests are very useful for examination in children. The test plate is presented at 40 cm in front of the child and the examiner controls the child's reactions, eye movements and face expressions (Fig. 2). The result is positive when the child recognizes the figures and names the pictures with determination of their position in the space (older children).

The Titmus stereotest[8] provides assessment of stereoacuity in the range from 3000" (housefly wings appear above the background plane and the child tries to catch the wings of the fly) to 40 seconds of arc (nine circles in stereoacuity at 800", 400", 200", 100", 80", 60", 50' and 40 seconds of arc, preferably used in adults) (Fig. 3).

Fig. 3. Examination of stereopsis with Titmus test. Stereoacuity on Titmus house fly test is 3000".

The depth illusion in three sets of five animals is very useful for young children. In each row one of animals appears raised over the background. The stereoacuity range is 400", 200" and 100 seconds of arc.

The Rodenstock's Near Vision Tester also has two stereoacuity tests, mainly for adults. Stereoacuity is in the range from 5' to 10 minutes of arc. Positive result is when the patient sees upper double streaks displaced back, and under double streaks displaced forward (Fig. 4)[3].

Following the cause of amblyopia, additional examinations were performed (VEP, ERG, ultrasound, visual field examinations, intraocular pressure, etc.). The visual acuity and stereoacuity determined in each patient at the last control were taken as definitive result.

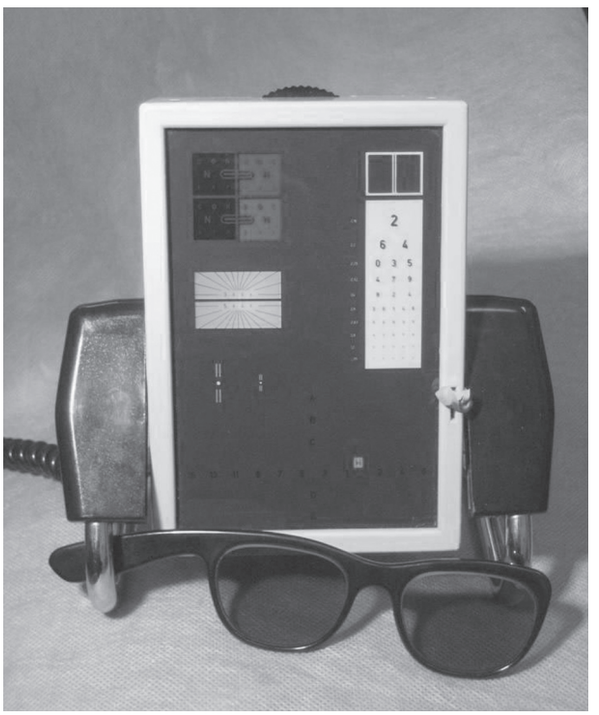

Fig. 4. Multipurpose Rodenstock Near Vision Tester. Stereotest on the screen is on the left, third from above. There are two figures with two parallel streaks and with a dot between them. The figures are seen at a stereo angle of 5' and 10'. In normal binocular perception, the upper streak is seen in space behind the dot; the lower streak is seen before the dot. In binocular vision disorder, e.g., in phorias, the streaks are seen double or blurred, and the space impression disappears. The subject uses polarized glasses.

Results

Amblyopias found in 434 patients were classified into standard groups according to clinical type (Table 1). The smallest group was the one with deprivation amblyopia, with only 26 (6.0%) patients (Table 2). Visual acuity varied from light perception to 0.4 with correction on the better eye. Only two patients had stereoacuity of 1200 seconds of arc. One of the main causes of so deep amblyopia and poor stereoacuity was previously operated congenital cataract (aphakia or pseudophakia on one or both eyes).

Table 1. Clinical types of amblyopia recorded in patients aged 1-25 from January 1, 2005 to March 31, 2006

Type of amblyopia	n	%
Visual deprivation amblyopia	26	6.0
Organic amblyopia	59	13.6
Anisometropic amblyopia	98	22.6
Ametropic/refractive amblyopia	99	22.8
Strabismic amblyopia	22.8	35.0
Total	434	100.0

The organic amblyopia group had 59 (13.6%) patients (Table 3). This group was predominated by deep amblyopia. Visual acuity varied from light perception to 0.2 on the better eye. Stereoacuity was not found in this group.

The ametropic amblyopia group had 99 (22.6%) patients. The main causes were different types of refraction errors, high myopia and/or myopic astigmatism, hyperopia exceeding +5 diopters and/or hyperopic astigmatism.

The strabismic amblyopia group was greatest, including 152 (35.0%) patients. This group of amblyopia included different types of strabismus treated conservatively or surgically.

Table 2. Visual deprivation amblyopia (n=26)

• Visual acuity: light perception and projection 0.4 cc	26
• Stereopsis: partial from 1200''	2
• Causes:	
Congenital cataract (aphakia, pseudophakia)	15
Congenital ptosis	4
Albinism	2
Corneal leukoma	2
Keratoconus	3

Table 3. Organic amblyopia (n=59)

• Visual acuity: from light perception to <0.2 cc	
• Stereopsis: defective in 59 patients	
• Causes:	
Congenital optic nerve hypoplasia	15
Atrophy of optic nerve	12
Degenerative high myopia	12
Optic nerve coloboma and sequels of central chorioretinitis	6
Retinopathy of prematurity in regression	5
Agenesis of corpus callosum	2
Macular heredodegenerations	3
Others	4

The anisometropic amblyopia group had 98 (22.6%) patients. This group of amblyopia was carefully analyzed. All anisometropic amblyopias of different main causes were initially excluded from this group and allocated to the respective groups (Table 4).

Table 5 shows that a half of anisometropic amblyopia patients had full stereoacuity, nearly 1/5 had partial, and 1/3 had absent stereoacuity. The distribution of refractive errors in this group showed the greatest number of hyperopic astigmatism or hyperopia (AsH/H; 49/98), followed by myopic astigmatism or myopia (MyAs/My; (35/98), and mixed astigmatism (AsMix; (12/98).

Normal, full stereoacuity was find in one half of hyperopic astigmatism or hyperopia patients, and in myopic astigmatism or myopia patients. All patients with mixed astigmatism had full stereoacuity. Partial stereoacuity was recorded in 7/49 AsH/H and 10/31 AsMy/My.

Data on partial stereoacuity showed the threshold stereoacuity level to be quite comparable between AsH/H and AsMy/My in the anisometropic amblyopia group (Table 6).

Table 7 shows data on partial stereoacuity and level of amblyopia. Deep amblyopia with visual acuity at near under 0.1 cc was not found. Most AsMy/My had mild

Table 4. Anisometropic amblyopia (n=98)

• Stereopsis:	
– Normal	51
– Partial	17
– Defective	24
– Unknown	6

Table 5. Stereopsis and refractive errors in anisometropic amblyopia

	AsH/H (n)	AsMy/My (n)	AsMix (n)	Unknown (n)	Total (n)
Normal	24	15	12	–	51
Partial	7	10	–	–	17
Defective	18	6	–	6	30
Total	49	31	12	6	98

AsH/H=hyperopic astigmatism or hyperopia; AsMy/My=myopic astigmatism or myopia; AsMix=mixed astigmatism

amblyopia, and AsH/H were almost equally present in moderate or mild amblyopia.

Absent stereoacuity was recorded in 18/49 AsH/H and only 6/31 AsMy/My. It should be noted that that all patients with mixed astigmatism had full stereoacuity.

The degree of amblyopia in the anisometropic amblyopia group was responsible for the lack of stereoacuity, independently of refractive errors. The patients with deep amblyopia had absent stereoacuity, nearly equal in all refractive errors (Table 8).

Absent stereoacuity was found in half of patients with moderate degree of amblyopia. This group was predominated by AsH/H (9/24), with only 3/24 AsMy/My.

Absent stereoacuity was only recorded in AsH/H (7/24) with a mild degree of amblyopia. Moderate and mild degrees of amblyopia and absent stereoacuity were not found in AsMy/My.

Accordingly, the lack of stereoacuity was found to also depend on the type of refractive error in the anisometropic amblyopia group.

Discussion

Anisometropia is the causative factor of amblyopia and one of the causes of strabismus. The true prevalence of anisometropia is not known; according to literature data, it ranges between 4% and 4.7%[9]. Anisometropia is the difference in refractive error between the eyes: >1.5 D in astigmatism, >1.5 D in hypermetropia, and >3.0 D in myopia. The general rule is to start with refractive error correction and amblyopia treatment as soon as possible, with maximal tolerable spectacles or contact lens correction. Amblyopia treatment with constant spectacles correction, training spectacles

Table 6. Partial stereopsis in anisometropic amblyopia

Stereoscopic threshold	AsH/H (n)	AsMy/My (n)	Total
600'' - 1200''	1	2	3
800'' - 200''	3	2	5
140'' - 80''	3	4	7
60'' - 40''	-	2	2
Total	7	10	17

AsH/H=hyperopic astigmatism or hyperopia; AsMy/My=myopic astigmatism or myopia

Table 7. Partial stereopsis, amblyopia and types of refractive errors in anisometropic amblyopia

Type of refractive error	Depth of amblyopia (visual acuity with correction) <0.1	0.1-0.3	0.4-0.8
Hyperopia and hyperopic astigmatism	–	4	3
Myopia and myopic astigmatism	–	3	7
Total	–	7	10

Table 8. Defective stereopsis in anisometropic amblyopia and refractive errors

Type of refractive error	Depth of amblyopia (visual acuity with correction) <0.1	0.1-0.3	0.4-0.8
Myopia and myopic astigmatism	3	3	–
Hyperopia and hyperopic astigmatism	2	9	7
Total	5	12	7

correction, occlusion, reading and drawing exercises, and separation exercises should be commenced immediately[9]. Occlusion is a widely accepted modality of amblyopia treatment. Richardson *et al.* report on amblyopia treatment results in preschool children with full refraction error correction, spectacles wear and occlusion. Significant stereoscopic visual acuity improvement was observed, up to normal levels[7]. In our study, relatively good near stereoacuity in anisometropic ambylopia was found, especially in those with myopic refractive errors. In strabismus, strabismic amblyopia and refractive amblyopia, distance stereoacuity assessment was more sensitive than near stereoacuity assessment, which yields better stereoacuity values than distance stereoacuity assessment[10]. It is advisable to use several stereotests on stereoacuity assessment, because some, for example Lang II stereotest, have a limited value[11]. Normal depth perception and stereoscopic visual acuity undergo marked improvement and development between the 4th and 5th year of life, and reach adult levels at age 5.5[12].

Conclusion

The organic form of amblyopia is not so rare. Amblyopia is very deep and, unfortunately, without satisfactory results of treatment. Stereoacuity is absent in this form of amblyopia. The most common causes are congenital and developmental optic nerve anomalies, morphological and functional changes of retinal elements, and post-inflammatory or hypoxic retinal consequences.

Deprivation amblyopia is the most uncommon but most damaging and difficult to treat form of amblyopia. Amblyopic visual loss is resulting from the lack of form vision (recognition visual acuity). Congenital cataracts are rather dense and they must be considered as the main cause of severe amblyopia. Stereoacuity threshold is very low.

Anisometropic amblyopia develops when unequal refractive errors in the two eyes cause the image on one retina to be chronically defocused. Relatively mild degrees of hyperopic or astigmatic anisometropia (less than 2 D) can induce mild amblyopia. Mildly myopic or astigmatic anisometropia (less than 3 D) usually does not cause amblyopia. The state of stereoacuity depends on the type of refractive error and degree of amblyopia.

The lack of stereoacuity is more common in hyperopic or astigmatic anisometropia patients.

In anisometropic amblyopia patients, among different refractive errors, stereoacuity is best in mixed astigmatism patients.

Amblyopia accounts for more unilateral vision reduction than all other causes. So, the treatment of amblyopia involves several different procedures depending on the cause: optimal correction of refractive error, timely cataract removal, and in most unilateral or asymmetric cases forcing use of the poorer eye due by limiting the of the better eye. The desired endpoint of therapy for unilateral amblyopia is to achieve linear Snellen acuity that differs by no more than one line between the two eyes.

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Sažetak

STEREOSKOPSKA VIDNA OŠTRINA KOD RAZLIČITIH VRSTA AMBLIOPIJE

Lj. Dorn i *J. Petrinović-Doršić*

Poznato je da ambliopiju obilježava više znakova kao što su smanjena vidna oštrina, otežana separacija, prisutnost relativnog pupilarnog aferentnog defekta, ekscentrična fiksacija, ali i slabost ili odsutnost stereoskopskog vida. Cilj rada bio je ispitati i prikazati stanje stereoskopskog vida kod različitih tipova i različite dubine ambliopije. Kao materijal uzeti su svi bolesnici s ambliopijom koji su prošli kroz Dječji očni centar u razdoblju od 1. siječnja 2005. do 31. ožujka 2006. godine, kod kojih se je, uz ostalo, ispitivala stereoskopska vidna oštrina. Upotrebljeni su polarizirani stereo test Titmus i oba stereotesta po Langu (Lang I. i Lang II.). Upotrebljenim testovima određen je prag stereoskopske vidne oštrine, kako kod strabizmičke tako i kod anizometropske ambliopije, te ostalih vrsta ambliopija. Rezultati su uspoređeni i s drugima parametrima (vidna oštrina, refrakcija, binokularni vid, fiksacija). Kod organske ambliopije stereopsija je bila odsutna. Kod vizualno deprivacijske ambliopije stereopsija je bila djelomice prisutna, ali samo u neznatnog broja bolesnika. Kod anizometropne ambliopije oko polovice bolesnika su imali normalnu stereopsiju. Vrsta refrakcijske greške i dubina ambliopije utječu na prisutnost stereopsije. Zanimljivo je opažanje da među bolesnicima s miješanim astigmatizmom nije nađena djelomična odnosno odsutna stereopsija. Pokazalo se da je određivanje stupnja stereoskopske vidne oštrine korisna metoda u dijagnostici i klasifikaciji ambliopija, ali isto tako i kao jedna od metoda praćenja uspješnosti liječenja.

Ključne riječi: *stereoskopska vidna oštrina, ambliopija*