http://doi.org/10.31288/oftalmolzh202363340

Optimizing the algorithm for assessing the efficacy of treatment for amblyopia in astigmats through the investigation of the features of meridional acuity characteristics as vector quantities

V. O. Kolomiyets, O. V. Kachan

SI "The Filatov Institute of Eye Diseases and Tissue Therapy of the NAMS of Ukraine"

Odesa (Ukraine)

Background: *Refractive asymmetry associated with astigmatism may cause a special form of amblyopia, meridional amblyopia (MA). MA manifests itself as alterations in selective mechanisms of visual stimulus processing during recognition of contours of a certain orientation. Current routine examination of amblyopes does not include meridional acuity assessment and thus does not allow determining whether MA is present or not, as well as performing a more detailed evaluation of the efficacy of treatment for amblyopia in astigmats.*

Purpose: *To optimize the algorithm for assessing the efficacy of stand-alone and complex methods of treatment for amblyopia in astigmats through the determination of the features of changes in visual acuities in orthogonal retinal meridians as vector quantities.*

Material and Methods: *Twenty-four hyperopic astigmats with amblyopia (48 eyes) aged 5 to 12 years were involved in the study. Patients were treated by accommodative facility training only and, in 3 months, by complex therapy (accommodative facility training plus the use of device-based methods). Treatment course duration was 10 days. The results were assessed by changes in best-corrected visual acuity (Sivtsev Chart) and meridional separable visual acuity (MSVA) determined with the software which generates Landolt ring optotypes.*

Results: *The study sample was found to be heterogeneous regarding the features of asymmetries in MSVA. Separable visual acuity in the horizontal meridian was equal in magnitude to that in the vertical meridian in 16.65% of patients. Asymmetries in separable visual acuity that may be considered MA were found in dominant and non-dominant (fellow) eyes in 83.35% of astigmats with amblyopia. Two different clusters were determined in the group with asymmetries in MSVA. Separable visual acuity in the horizontal meridian was higher than that in the vertical meridian in 35.45% of eyes in cluster 1, and lower than that in the vertical meridian in 47.85% of eyes in cluster 2. After treatment, mean separable visual acuity value in the vertical meridian was practically similar to that in the horizontal meridian in both groups for the dominant and fellow eyes, which allowed concluding that both methods were equally effective in treating the disease. However, the number of eyes with the same MSVA in orthogonal meridians increased by 10.41% after MA treatment with accommodative facility training only versus 18.75% after complex treatment.*

Conclusion: *Assessing the features of changes in visual acuities in orthogonal retinal meridians as vector quantities enables obtaining principally new information on the performance of sensory functions in patients with amblyopia and assessing more reliably the efficacy of stand-alone and complex pleoptic methods as methods of treatment for MA.*

Keywords:

astigmatism, amblyopia, integrative visual acuity, meridional acuity, pleoptic treatment

Introduction

Refractive asymmetry associated with astigmatism may cause a special form of amblyopia, meridional amblyopia (MA) [1-6]. MA manifests itself as selective alterations in visual acuity (VA) during recognition of contours of a certain orientation, which results in an alteration in the mechanisms of mechanisms of integrated processing of visual stimulus, cognitive perception and visual performance [3, 7]. It is noteworthy that current visual acuity charts do not allow to determine meridional VA and, consequently, to determine the presence or absence of MA. In addition, studies have demonstrated low sensitivity and accuracy for these charts in the evaluation of VA in amblyopes [8]. For this reason, it is still unknown whether certain individual or comprehensive pleoptic methods are effective for the treatment of MA. It is believed that including the method of determination of meridional acuity in the standard examination of patients with amblyopia will allow for a more accurate evaluation of the efficacy of treatment for amblyopia in astigmatic patients.

Study rationale

Various techniques are used for treating amblyopia. Current pleoptic methods are based on stimulation of the central and peripheral retina using structured patterns. Physiotherapeutic adjuncts (transcutaneous electric or magnetic stimulation of the retina and optic nerve, vasolidator drug magnetophoresis or electrophoresis, optical-reflection accommodation stimulation method, etc.) are used to improve the efficacy of treatment for amblyopia [9, 10]. To the best of our knowledge, no study has been performed to assess the effect of well-known pleoptic methods on meridional acuity. This is due to the fact that current routine examination of amblyopes does not include meridional acuity assessment and thus does not allow determining whether MA is present or not [8].

At present, the efficacy of pleoptic methods is assessed with the help of complex optotypes using the criterion of minimum cognoscible, an integrative index of the state of various detector systems in cortical mechanisms of visual perception. This methodological approach does not allow us to determine meridional indices of visual acuity, establish a diagnosis of MA, and assess the efficacy of treatment for meridional amblyopia with pleoptics. Selective vernier acuity or meridional separable visual acuity (MSVA) is most commonly used to determine meridional acuity.

There are individual reports aiming to assess the efficacy of optical correction and/or occlusion for the treatment of MA [11–16]. There have been several reports on the development of device-based treatments for MA which allow activating meridional retinocortical pathways by adequate structured stimuli [17-21]. It has been reported on the effect of modified computer games on meridional acuity in patients with astigmatism associated with amblyopia. A game was performed by the patient, while the foveal and macular region of his or her amblyopic eye was stimulated by the sinusoidal drifting grating pattern in the background of the computer screen. In another game performed by the patient, the grating pattern remained still with respect to the playing pattern [17-19]. These amblyopia treatment methods do not provide for selective stimulation of retinal meridians with a low acuity. Method efficacy was assessed based on changes in meridional Landolt acuity (the criterion of minimum separable). There was an improvement in corrected MSVA after treatment with the game using the sinusoidal drifting grating pattern. No statistically significant improvement in corrected MSVA was observed after exercises with the stationary grating [19].

It is noteworthy that some researchers question the necessity of using complex and expensive amblyopia treatment methods and hypothesize that using simple methods may result in treatment outcomes comparable to those achieved with complex and expensive amblyopia treatment methods [22, 23]. Many researchers, however, advocate using complex amblyopia treatment methods. They explain that each stand-alone simple method exerts an effect on a certain aspect of the pathological process, whereas using a combination of simple methods allows for many-sided effects on the visual system with improved treatment effects. The success rate of complex amblyopia treatment methods has been reported to range from 41.3% to 86.9% [24]. A wide variation in the rate among studies may be caused by different combinations of methods and different treatment success criteria used. Since no study has assessed in detail the impact of current pleoptic methods on selective indices of visual acuity, it may be expected that both stand-alone simple methods and complex methods may result in an effective improvement in meridional acuity. To check whether this hypothesis holds true, we selected the optical-reflection accommodation stimulation method as a stand-alone amblyopia treatment method. This method is based on the stimulation of the accommodation reflex by image defocusing through alternating contraction and relaxation of the ciliary muscle with the help of an optical lens with a variable power. Ciliary massage may improve hemodynamics in the ciliary body, and in the eye in general, and causes an improvement in near and far vision, normalization of accommodation, suppression of aniso-accommodation, and restoration of visual performance [25]. Accommodative therapy has been reported to result in an improvement in visual acuity in 40–76.9% of patients with both amblyopia and hypermetropic refraction [22, 26, 27].

In the current study, the efficacy of amblyopia treatment was assessed based on changes in integrative and meridional indices of visual acuity after accommodative training only versus accommodative training plus complex treatment with pleoptic methods. Meridional indices of visual acuity were determined based on the criterion of minimum separable (MSVA) which allows assessing the capacity of the visual system for the analysis of complex patterns [3, 8]. In addition, we have proposed to use a new algorithm analyzing meridional asymmetries in visual acuity to improve the reliability of the assessment of treatment outcomes. In this algorithm, meridional asymmetries in visual acuity are considered as vector quantities which take into account the interrelationship of the magnitude and direction of meridional asymmetries in visual acuity with the magnitude and direction of refractive asymmetries [28, 29]. This is due to the fact that, among amblyopes with similar type of astigmatism, one may distinguish groups differing in the direction of asymmetry in meridional acuity in relation to refractive characteristics. In one of these groups, selective visual acuity in the vertical meridian may be equal to that in the horizontal meridian; in the second group, selective visual acuity in the horizontal meridian may be larger than that in the vertical meridian, and in the third group, vice versa [29]. If this factor is not taken into account, meridional asymmetries in visual acuity in the study sample will be neglected in the statistical analysis, and average values will give false evidence of the absence of meridional amblyopia. Therefore, a change in the magnitude and type of meridional asymmetries in visual acuity in patients with astigmatism may be an indicator of the efficacy of treatment for meridional amblyopia.

The purpose of the study was to optimize the algorithm for assessing the efficacy of stand-alone and complex methods of treatment for amblyopia in astigmats through the determination of the features of changes in visual acuities in orthogonal retinal meridians as vector quantities.

Material and Methods

Twenty-four amblyopic children (48 eyes) with simple with-the-rule hyperopic astigmatism or compound with-the-rule hyperopic astigmatism were involved in the study. The children's age ranged from 5 to 12 years. Spherical and cylindrical refractive errors ranged from +0.5D to +4.5D. Best-corrected visual acuity (Sivtsev Chart) was assessed. Mild amblyopia was found in 43 eyes (89.6% of patients), and moderate amblyopia, in 5 eyes (10.4% of patients).

Special computer software was used to determine corrected MSVA. Patients were shown Landolt ring objects. Landolt ring gaps were shown consequently in the orthogonal retinal meridians which coincided with the direction of refractive asymmetry in the major meridians of the astigmatic eye. The angular size of the optotype was accurately reduced to determine the smallest optotype at which the gap in the optotype could be still recognized reliably by the examinee. Stimuli were presented monocularly at a distance of 5 m. The stimuli were presented monocularly on a 15-inch screen at a resolution of 1,600×1,200 pixels. A displacement per pixel was 0.12 arc min. A Landolt ring gap was oriented vertically to assess MSVA in the horizontal meridian, and horizontally to assess MSVA in the vertical meridian.

Optical-reflection training of accommodative facility was performed monocularly under conditions of the best lens correction. The patient was asked to look at the lowest line on the distant vision optotype he could read, and a +0.5-diopter sphere was placed just in front of the best lens correction for the study eye in order to blur this line. The +0.5-D sphere was replaced by a -0.5-D sphere after the optotypes became clearly visible. Each of the above-mentioned lenses was presented 10 times. Thereafter, the cycle was repeated using a ±0.75-D sphere and, subsequently, a ±1.0-D sphere. If the patient succeeded in fulfilling the task, lens power was gradually increased in increments of 0.25D or 0.5D until it could be compensated by accommodation.

A course of complex treatment included pleoptic methods with the use of special devices (like amblyotrainer ATR-1, ASO-3 and laser stimulator) and special software ("Crosses" and "Relax"). In addition, it included accommodative facility training as per the above methodology [30]. Treatment course duration was 10 days.

The study adhered to national bioethics regulations and the tenets of the Declaration of Helsinki of 1975 as revised in 2000. Informed consent of children as well as written informed consent of their parents was obtained.

Statistical analyses were conducted using Statistica for Windows 5.5 (StatSoft, Tulsa, OK, USA) software. The normal distribution of quantitative data was tested using the Kolmogorov–Smirnov test. Mean values and standard error of mean were calculated. Student's t test was used to compare mean values. Coefficient of variation was calculated to determine whether the sample was homogeneous or not. Pearson's chi-square test and a 2x2 contingency table were used to compare nominal values. Percentages were compared using a descriptive statistics calculator. The level of significance $p \leq 0.05$ was assumed.

Results

Table 1 shows the distribution of eyes of astigmats with amblyopia among various categories of integrative VA in the amblyopic eyes and fellow eyes before and after accommodative facility training. After treatment, visual acuity improved by 0.01 to 0.15, and the number of eyes with a VA of 0.75 to 0.9 increased.

Table 2 shows MSVA values for patients with with-the-rule hyperopic astigmatism and amblyopia before accommodative facility training. MSVA asymmetries may be an indicator of the presence of MA.

Mean separable visual acuity value in the vertical meridian was practically similar to that in the horizontal meridian in both groups for the dominant and fellow eyes (Table 3). However, MSVA variances with respect to mean values suppose that MSVA asymmetries may be present both in dominant and non-dominant (fellow) eyes. Table 3 shows the distribution of astigmats with amblyopia among categories where separable VA in the vertical meridian is equal to, greater or smaller than that in the horizontal meridian before treatment. Table 3 demonstrates that the study sample was heterogeneous regarding the features of asymmetries in separable visual acuity. No MA was found in 16.65% of study patients. Asymmetries in separable visual acuity that may be considered MA were found in 83.35% of eyes with both astigmatism and amblyopia.

Our analysis of asymmetry directions revealed that the group with asymmetries in visual acuity between meridians may be split into two different clusters. Separable visual acuity in the horizontal meridian was higher than that in the vertical meridian in 35.45% of eyes in cluster 1, and lower than that in the vertical meridian in 47.85% of eyes in cluster 2.

Table 4 shows data on the effect of accommodative facility training on separable visual acuity in meridians in astigmats with amblyopia. Accommodative facility training demonstrated a positive impact on separable visual acuity in meridians in dominant and non-dominant (fellow) eyes in astigmats with amblyopia, with the improvement being more apparent in the former eyes.

Table 5 shows data on changes in the type of asymmetry in separable visual acuity in meridians. After treatment the percentage of eyes without separable visual acuity asymmetry between the orthogonal meridians significantly increased from 16.65% to 27.08%.

Table 1. Distribution of dominant and non-dominant (fellow) eyes of patients with both hyperopic astigmatism and amblyopia among two best-corrected visual acuity categories before and after a course of accommodative facility training

Best-corrected acuity category	Statistical characteristics	Visual acuity before treatment		Visual acuity after treatment	
		Dominant eye	Non-dominant (fellow) eye	Dominant eye	Non-dominant (fellow) eye
0.75–0.9	M±m	0.83±0.01	0.83±0.02	0.84±0.01	0.83±0.02
	Number (percentage) of eyes	11 (22.92%)	6 (12.5%)	13 (27.08%)	12 (16.67 %)
0.3–0.7	M±m	0.60±0.03	0.54±0.03	0.65±0.03	0.56±0.03
	Number (percentage) of eyes	11 (22.92%)	20 (41.66%)	9 (18.75%)	14 (29.17%)
Total eyes		n=48 (100%)		n=48 (100%)	

Note: Differences were not significant (p > 0.05). M, mean value; SEM, standard error of mean

Table 2. Meridional separable visual acuity values for eyes of patients with both hyperopic astigmatism and amblyopia before accommodative facility training

Eye under examination	Direction of the meridian under investigation	Separable visual acuity (arc second)			p
		M±SD	Min	Max	
Dominant eye n = 24	Vertical	9'28''±1'02''	4'30''	23'51''	0.882146
	Horizontal	9'07''±1'18''	4'22''	22'17''	
Non-dominant (fellow) eye, n = 24	Vertical	9'17'±0'77''	3'22''	16'17''	0. 945380
	Horizontal	9'07''±1'23''	4'28''	17'17''	
Total, 48 eyes					

Note: p, significance of difference; N, number of eyes; M, mean value; SD, standard deviation; Min, minimum value; Max, maximum value;

Table 3. Distribution of patients with both hyperopic astigmatism and amblyopia among the categories related to the features of the direction of separable visual acuity asymmetry between the vertical and horizontal meridians in dominant and non-dominant (fellow) eyes before treatment by accommodative facility training

SVA in the horizontal meridian is equal in magnitude to that in the vertical meridian		SVA in the horizontal meridian is larger than that in the vertical meridian		SVA in the horizontal meridian is smaller than that in the vertical meridian	
Dominant eye	Non-dominant (fellow) eye	Dominant eye	Non-dominant (fellow) eye	Dominant eye	Non-dominant (fellow) eye
n = 5 (10.4%)	n = 3 (6.25%)	n = 9 (18.75%)	n = 8 (16.7%)	n = 9 (18.75%)	n = 14 (29.15 %)
n = 8 (16.65 %)		n = 17 (35.45%)		n = 23(47.85%)	
Total eyes, n=48 (100%)					

Note: n, number of eyes; SVA, Separable visual acuity

We used a similar approach to data array analysis to assess the efficacy of complex treatment.

Table 6 shows the distribution of eyes of astigmats with amblyopia among various categories of integrative VA in the amblyopic eyes and fellow eyes before and after complex treatment. After complex treatment, there was an increase in the number of eyes with a VA of 0.75 to 0.9.

Table 7 shows values of separable visual acuity in meridians for patients with with-the-rule hyperopic astigmatism and amblyopia before complex treatment. Mean separable visual acuity value in the vertical meridian was practically similar to that in the horizontal meridian in both groups for the dominant and fellow eyes (Table 7), allowing to make a preliminary conclusion on the absence of MA. However, variances in separable visual acuity in meridians with respect to mean values suppose that asymmetries in separable visual acuity in meridians could be present both in dominant and non-dominant (fellow) eyes.

Table 4. Changes in separable visual acuity between orthogonal meridians in dominant and non-dominant (fellow) eyes of patients with both hyperopic astigmatism and amblyopia after treatment by accommodative facility training

Eye under investigation	Direction of the meridian under investigation	Separable visual acuity before and after treatment (arc second)			
		M±SD		Δ	p
Dominant eye, n = 24	Vertical	Before	9'28"±1'02"	2'09"	0.045525
		After	7'37"±0'47"		
	Horizontal	Before	9'07"±1'18"	2'38"	0.023057
		After	7'29"±0'50"		
Non-dominant (fellow) eye, n = 24	Vertical	Before	9'17"±0'77"	1'47"	0.045391
		After	7'30"±0'48"		
	Horizontal	Before	9'07"±1'23"	1'08"	0.017587
		After	7'09"±0'49"		
Total eyes, n = 48					

Note: p, significance of difference <0.05; n, number of eyes; Δ, difference between post-treatment and pre-treatment visual acuity values (arc second)

Table 5. Distribution of eyes with both hyperopic astigmatism and amblyopia among categories related to types of asymmetry in separable visual acuity between orthogonal meridians before and after treatment by accommodative facility training

Type of asymmetry in separable visual acuity between orthogonal meridians of the retina	Distribution of eyes among categories related to types of SVA asymmetry between orthogonal meridians before and after treatment (number and percentage of eyes)			
	before		after	
	n	%	n	%
Horizontal = Vertical	8	16.66	13	27.08
Horizontal > Vertical	17	35.42	20	41.7
Horizontal < Vertical	23	47.92	15	31.22
Total eyes	48 (100%)		48 (100%)	

Note: p, significance of difference >0.05; n, number of eyes; SVA, separable visual acuity

Table 6. Distribution of dominant and non-dominant (fellow) eyes of patients with both hyperopic astigmatism and amblyopia among two best-corrected visual acuity categories before and after a course of complex treatment

Best-corrected acuity category	Statistical characteristics	Visual acuity before treatment		Visual acuity after treatment	
		Dominant eye	Non-dominant (fellow) eye	Dominant eye	Non-dominant (fellow) eye
0.75-0.9	M±m	0.91±0.03	0.87±0.04	0.94±0.02	0.91±0.03
	Number (percentage) of eyes	11 (22.92%)	9 (18.75%)	15 (31.25%)	11 (22.92%)
0.3-0.7	M±m	0.40±0.05	0.47±0.04	0.57±0.05	0.54±0.05
	Number (percentage) of eyes	11 (22.92%)	17 (35.41%)	7 (14.58%)	15 (31.25%)
Total eyes		n = 48 (100%)		n = 48 (100%)	

Note: p, significance of difference >0.05; n, number of eyes

Table 8 shows the distribution of astigmats with amblyopia among categories where separable visual acuity in the vertical meridian in dominant and non-dominant (fellow) eyes is equal to, greater or smaller than that in the horizontal meridian before treatment. Table 8 demonstrates that the study sample was heterogeneous regarding asymmetries in separable visual acuity. No MA was found in 25% of study patients. Asymmetries in separable visual acuity that may be considered MA we found in 75% of eyes with both astigmatism and amblyopia.

Table 7. Meridional separable visual acuity values for eyes of patients with both hyperopic astigmatism and amblyopia before complex treatment

Eye under examination	Direction of the meridian under investigation	Separable visual acuity (arc second)			p
		M±SD	Min	Max	
Dominant eye n = 24	Vertical	9'36"±1'04"	5'41"	16'46"	0,668773
	Horizontal	10'39"±1'01"	6'21"	14'47"	
Non-dominant (fellow) eye, n = 24	Vertical	9'17"±1'27"	6'30"	14'43"	0,817699
	Horizontal	9'30"±1'16"	5'35"	12'56"	
Total, 48 eyes					

Note: p, significance of difference; N, number of eyes; M, mean value; SD, standard deviation; Min, minimum value; Max, maximum value

Table 8. Distribution of patients with both hyperopic astigmatism and amblyopia among the categories related to the features of the direction of separable visual acuity asymmetry between the vertical and horizontal meridians in dominant and non-dominant (fellow) eyes before complex treatment

Distribution of eyes of patients among the categories related to the features of the direction of SVA asymmetry between the orthogonal meridians before complex treatment					
SVA in the horizontal meridian is equal in magnitude to that in the vertical meridian		SVA in the horizontal meridian is larger than that in the vertical meridian		SVA in the horizontal meridian is smaller than that in the vertical meridian	
Dominant eye	Non-dominant (fellow) eye	Dominant eye	Non-dominant (fellow) eye	Dominant eye	Non-dominant (fellow) eye
n = 6 (12.5%)	n = 6 (12.5%)	n = 12 (25%)	n = 12 (25%)	n = 4 (8.33%)	n = 8 (16.67 %)
n = 12 (25 %)		n = 24 (50 %)		n = 12 (25 %)	
Total eyes, n = 48 (100%)					

Note: n, number of eyes; SVA, meridional separable visual acuity

Our analysis of asymmetry directions in these subgroups revealed that the group with asymmetry in visual acuity between the meridians may be split into two different clusters. Separable visual acuity in the horizontal meridian was higher than that in the vertical meridian in 50% of eyes in cluster 1, and lower than that in the vertical meridian in 25% of eyes in cluster 2. Of note that separable visual acuity asymmetry between orthogonal meridians was noted not only in non-dominant eyes, but also in dominant eyes.

Table 9 shows data on the effect of complex treatment on separable visual acuity in meridians in patients with with-the-rule hyperopic astigmatism and amblyopia. Complex treatment demonstrated a positive impact on separable visual acuity in meridians in dominant and non-dominant (fellow) eyes in astigmats with amblyopia.

While assessing the efficacy of treatment for amblyopia in astigmats, we need to pay attention to changes in the magnitude and direction of separable visual acuity asymmetry between meridians. Table 10 shows data on changes in the type of asymmetry in separable visual acuity in meridians. After treatment the percentage of eyes without asymmetry in separable visual acuity between orthogonal meridians significantly increased from 25% to 43.75% ($\chi2 = 3.74$, $p = 0.05$).

The use of complex treatment had a positive impact on meridional characteristics of visual acuity, with a decrease in asymmetry in separable visual acuity between orthogonal meridians in dominant and non-dominant (fellow) eyes in all subgroups of patients. In addition, after complex treatment, a more apparent increase in MSVA was noted in non-dominant (fellow) eyes, whereas after accommodative facility training, a more apparent increase in MSVA was noted in dominant eyes.

Discussion

We proposed to use a new visual acuity assessing algorithm for assessing the results of treatment for amblyopia in astigmats, with this algorithm allowing the evaluation of integrative and selective MSVA indices. This approach allowed us to reveal that the group of patients with the same type of astigmatism was heterogeneous regarding the magnitude and direction of separable visual acuity asymmetries in orthogonal retinal meridians with respect to the direction of refractive asymmetries [21, 25]. This is confirmed by the fact that asymmetries in separable visual acuity that may be considered MA were found in dominant and non-dominant eyes of 83.35% astigmats. In addition, our analysis of asymmetry directions in these groups revealed that each group may be split into two

Table 9. Changes in separable visual acuity in vertical and horizontal meridians in dominant and non-dominant (fellow) eyes of patients with both hyperopic astigmatism and amblyopia after complex treatment

Eye under investigation	Direction of the meridian under investigation	Separable visual acuity before and after treatment (arc second)			
		M+SD		Δ	p
Dominant eye, n = 24	Vertical	Before	9'29"±1'04"	3'03"	0.020208
		After	6'26"±1'04"		
	Horizontal	Before	8'19"±1'02"	1'81"	0.046941
		After	6'38"±0'34"		
Non-dominant (fellow) eye, n = 24	Vertical	Before	8'31"±1'28"	2'08"	0.021537
		After	6'23"±0'55"		
	Horizontal	Before	9'20"±1'15"	2'37"	0.025339
		After	6'41"±0'35"		
Total eyes, n=48					

Note: p, significance of difference <0.05; n, number of eyes; Δ, difference between post-treatment and pre-treatment visual acuity values (arc second)

Table 10. Distribution of eyes with both hyperopic astigmatism and amblyopia among categories related to types of asymmetry in separable visual acuity between orthogonal meridians before and after complex treatment

Type of asymmetry in SVA between orthogonal meridians of the retina	Distribution of eyes among categories related to types of asymmetry in SVA between orthogonal meridians before and after treatment (number and percentage of eyes)			
	Before treatment		After treatment	
	абс	%	абс	%
Horizontal = Vertical	12	25	21	43.75
Horizontal > Vertical	24	50	20	41.67
Horizontal < Vertical	12	25	7	14.58
Total eyes	48 (100%)		48 (100%)	

different clusters. SVA in the horizontal meridian was higher than that in the vertical meridian in 35.45% of eyes in cluster 1, and lower than that in the vertical meridian in 47.85% of eyes in cluster 2. This indicates that, for a detailed assessment of the efficacy of pleoptic methods, MA characteristics in orthogonal meridians should be considered as vector quantities.

The number of eyes with no difference in the magnitude of MSVA between orthogonal meridians increased by 10.41% after treatment for MA with accommodative facility training only versus 18.75% after complex treatment. Not only the meridional acuity improved, but also integrative VA improved after treatment. The number of eyes with a visual acuity of 0.7 to 0.9 increased by 8.33% after MA treatment with accommodative facility training versus 12.5% after complex treatment.

Therefore, we propose to use the following criteria for assessing the efficacy of treatment for MA: a decrease in the magnitude of VA asymmetry between retinal orthogonal meridians due to an increase in meridional acuity in one or two meridians; a change in the direction of VA asymmetry in retinal orthogonal meridians, and/or a removal of asymmetry in VA between retinal orthogonal meridians.

Conclusion

The optimization of the algorithm for assessing the efficacy of treatment for amlyopia in astigmats through the determination of the features of changes in visual acuities in orthogonal retinal meridians as vector quantities enables obtaining principally new information on the performance of sensory functions in patients with amblyopia, and to determine the most effective stand-alone and complex methods of treatment for meridional amblyopia.

References

1. Dobson V, Miller JM, Harvey EM, Mohan KM, et al. Amblyopia in astigmatic preschool children. Vision Res. 2003;43:1081–90. doi: 10.1016/s0042-6989(03)00014-2.
2. Gwiazda J, Bauer J, Thorn F, Held R. Meridional amblyopia does result from astigmatism in early childhood. Clin Vis Sci. 1986;1:145–52.
3. Hubel D H. Eye, brain, and vision. New York: Scientific American Library, 1988.

4. Freeman RD, Mitchell DE, Millodot M. A neural effect of partial visual deprivation in humans. Science. 1972;175(4028):1384–6. doi: 10.1126/science.175.4028.1384.
5. Mitchell DE, Freeman RD, Millodot M. Meridional amblyopia: evidence for modification of the human visual system by early visual experience. Vision Res. 1973;13 (3): 535–58. doi: 10.1016/0042-6989(73)90023-0.
6. Vit VV. [Structure of the human visual system]. Odesa: Astroprint; 2003. Russian.
7. Polat U, Bonneh Y, Ma-Naim T, Belkin MD. Spatial interactions in amblyopia: Effects of stimulus parameters and amblyopia type. Sagi Vision Research. 2005;45: 1471-9. doi: 10.1016/j.visres.2004.12.014.
8. Shamshinova AM, Volkov VV. [Functional methods of research in ophthalmology]. Moscow: Meditsina; 1999. Russian.
9. Lavrent'ev BF, Rozhentsov VV. [Instrumental treatment of amblyopia]. Ophthalmology in Russia. 2016;13(3):144–50. doi: 10.18008/1816–5095–2016–3–144–150. Russian.
10. Botabekova TK, Kurgambekova NS. [A comparative analysis of the efficiency of different methods in the treatment of amblyopia]. Vestn Oftalmol. 2004 Sep-Oct;120(5):40-1. Russian.
11. Abrahamsson M, Sjöstrand J. Astigmatic axis and amblyopia in childhood. Acta Ophthalmol Scand. 2003 Feb;81(1):33–7. doi: 10.1034/j.1600-0420.2003.00022.x.
12. Harvey EM, Dobson V, Miller JM, Clifford-Donaldson CE. Amblyopia in astigmatic children: patterns of deficits. Vision Res. 2007; 47: 315–26. doi: 10.1016/j.visres.2006.11.008.
13. Harvey EM. Development and Treatment of Astigmatism-Related Amblyopia. Optom Vis Sci. 2009 Jun;86(6):634-9. doi: 10.1097/OPX.0b013e3181a6165f..
14. Harvey EM, Dobson V, Clifford-Donaldson CE, Miller JM.Optical treatment of amblyopia in astigmatic children: the sensitive period for successful treatment. Ophthalmology. 2007 Dec;114(12):2293-301.
15. Flynn JT. Amblyopia: its treatment today and its portent for the future. Binocul Vis Strabismus Q. 2000;15(2):109.
16. Flynn JT, Cassady JC. Current trends in amblyopia therapy. Ophthalmology. 1978;85:428-50.
17. Kämpf U, Mascolus W, Muchamedjarow F, et al. Coherence induction via phase conjugate adaptive resonance coupling: Computer-generated sinusoidal grating patterns as a background stimulus in amblyopia treatment. J Psychophysiology. 2006; 20(2):149.
18. Kampf U, Shamshinova A, Kaschtschenko T, et al. Long-term application of computer-based pleoptics in home therapy: selected results of a prospective multicenter study. Strabismus. 2008;16(4):149-58. doi: 10.1080/09273970802451125.
19. Kempf W, Rychkova SI, Haim E, Mukhamedyarov F. [Comparative results of the application of moving and fixed sinusoidal framework in functional treatment of amblyopia]. Tochka zreniia. Vostok-Zapad. 2016;3:140-43. Russian.
20. Deshpande PG, Bhalchandra PC, Nalgirkar AR, Tathe SR. Improvement of visual acuity in residual meridional amblyopia by astigmatic axis video games. Indian J Ophthalmol. 2018 Aug; 66(8): 1156–60. doi: 10.4103/ijo.IJO_1096_17.
21. Aznaurjan IE, Gorlacheva LI. LASIK in complex treatment of meridional form of refractive amblyopia in children with astigmatism. Refractive Surgery Updates. Italy, Venice, June 2002. p.112-3.
22. Boubaker Hafedh BA. [Significance of accommodation therapy in complex treatment of children with different kinds of hypermetropic amblyopia]. [Abstract of a Thesis for the Degree of Cand Sc (Med)]. Filatov Institute of Eye Diseases and Tissue Therapy. Odesa, Ukraine; 1998. Russian.
23. Serdiuchenko VI, Kuzhda IM. [Features of accommodation and their relationship with the state of visual acuity in children and adolescents with mixed and hyperopic astigmatism]. Oftalmol Zh. 2005;6 (407):35–9. Ukrainian.
24. Strogal AS. [Influence of chromatic light irritation on the reserves of accommodation in children with amblyopia]. Oftalmol Zh. 2002;3:96-8. Russian.
25. Serdiuchenko VI. [Accommodative facility training as an alternative or adjunct to spectacle]. Oftalmol Zh. 2000;2:30-33.Russian.
26. Kuzhda IM, Serdiuchenko VI. [Efficacy of accommodative facility training in the treatment of accommodative disorders in chidren with hyperopic astigmatism]. In: [Proceedings of the 3rd Conference on the Current Issues of Medical and Social Rehabilitation of Children with a Disabling Eye Condition]. 4-6 October, 2006, Evpatoriia, Ukraine. Kyiv: MAKROS; 2006; p. 118-22. Ukrainian.
27. Kuzhda IM, Serdiuchenko VI. [Treatment of accommodative disorders in chidren with mixed astigmatism]. In: [Proceedings of the Conference on the Surgical Treatment and Rehabilitation of Children with an Eye Condition]. 7-8 October, 2004. Kyiv: Schupik Medical Academy of Postgraduate Education; 2004. p. 154-6. Ukrainian.
28. Kolomiyets V, Bandura M, Kolomiyets N. [Meridional vernier visual acuity in children and adults with hypermetropic astigmatism]. Oftalmologiia. Vostochania Evropa. 2015; 3(26):27-34. Russian.
29. Kolomiyets V, Bandura M, Kolomiyets N. [Peculiarities of vernier monocular and binocular visual acuity in the retinal orthogonal meridians in patients with hypermetropic astigmatism]. Science Rise. 2015; 6/4(11):38-44. Russian. DOI: 10.15587/2313-8416.2015.45310
30. Goncharova SA, Panteleiev GV, Tyrlova EI. [Amblyopia. A Guide for a Practicing Physician]. Lugansk; 2006. Russian.

Disclosures

Received 25.08.2023
Accepted 14.11.2023

Corresponding Author: *Kolomiets Volodymyr Oleksandrovych, Email: kolomiets.wa@gmail.com*

Author Contribution: *Kolomiyets V.O. - conceptualization; design methodology; analysis; review and revision; Kachan O.V. - data collection; analysis; manuscript preparation; review and revision. All authors analyzed the results and approved the final version of the manuscript.*

Disclaimer: *The opinions expressed in this article are those of the authors and do not represent the official position of the institution.*

Sources of support: *None.*

Conflicts of interest: *The authors declare that they have no conflicts of interest that could influence their opinions regarding the subject matter or materials described and discussed in this manuscript.*