Original article

Reprint

Comparison of sensory fusion recovery with different types of liquid crystal glasses programming

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Abstract:
Objective: to compare the effectiveness of a new method for restoring sensory fusion in patients with personalized selection of the alternating frequency of liquid crystal glasses (LCG) vs. empirical selection of the alternating frequency.
Materials and methods. The study included 39 patients with concomitant convergent strabismus in a state of orthotropy with no sensory fusion after strabismus surgery, who were prescribed LCG. Glasses were empirically programmed at 2 Hz in 21 patients (empirical group), while in 18 patients, glasses were programmed using the developed formula for calculating the alternating frequency of LCG via determining the duration of the eyeball alignment movement (calculation-based group). The comparison groups were similar in gender, age, visual acuity, and other characteristics.
Results. Restoration of sensory fusion was significantly more common in the calculation-based group (16 patients, 88.9%) than in the empirical group (9 patients, 42.9%) and the difference was highly significant (p=0.001).
Conclusion. A new method for personalized programming of the alternating frequency of LCG using video-oculography is more effective than empirical modeling in terms of sensory fusion restoration in children after concomitant convergent strabismus surgery.

Keywords: convergent strabismus, sensory fusion, liquid crystal glasses, alternating frequency

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Introduction

Rehabilitation of children with strabismus is a crucial problem in pediatric ophthalmology. This condition occurs in 3% of the child population [1] and in 15% of ocular pathology cases [2]. Most patients with strabismus are prescribed surgical treatment, which should be followed by rehabilitation of functional connections in the brain visual centers and restoration of binocular vision. Failure to properly recover can lead to functional complications such as loss of binocular and stereoscopic vision, as well as amblyopia.

Sensory fusion is the most important function to be restored in patients after surgical treatment of congenital and early-onset strabismus. Its recovery is the key to the further development of binocular and stereoscopic vision.

The primary method of sensory fusion recovery in vision care offices for children and adolescents is treatment with a synoptophore. Furthermore, this technique is a short procedure (just 15 minutes), and it is performed using a rigid haploscope.

Liquid crystal glasses (LCG) are widely used in ophthalmology since early 1990s [3-5]. Studies using LCG in children for the treatment of amblyopia [6] demonstrated superior treatment results compared to a conventional occluder.

To improve the effectiveness of treatment in patients with strabismus, a special LCG design was developed by orthoptist P. Chaumont [7], supplemented with software that created conditions not only for monocular image presentation to one eye and then to the other, but also for binocular image presentation.

In Russia, LCG for the treatment of patients with strabismus were used in the Kapbis-1 computer appliance. This system consists of LCG connected to an electrical pulse generator and contains diskettes with a program for a standard IBM-compatible personal computer. Due to the complexity of the appliance, which is stationary and requires treatment only in outpatient settings, such glasses did not gain widespread acceptance [8].

The use of LCG for the treatment of strabismus was further investigated with the advent of stand-alone LCG, which allowed for longer treatment periods during the day in home conditions [9, 10]. These studies examined the effectiveness of empirically adjusted alternating frequency of LCG for sensory fusion recovery.

The objective of this study was to compare the effectiveness of a new method for sensory fusion recovery in patients with personalized alternating frequency selection of LCG compared with empirically adjusted alternating frequency selection.

Materials and Methods

To calculate the required personalized alternating frequency, we conducted a study of the eyeball alignment movement using a GazeLab video-oculography system. As a result, we estimated the duration of the alignment movement (including its latency period, required for the eye to acknowledge the need to perform the latter). This measurement was then incorporated into the formula developed by the authors (Patent RU 2721881). The collected data were entered into the software and transmitted via Bluetooth to the LCG.

Our study included patients who underwent surgery for concomitant convergent strabismus (persistent accommodative or nonaccommodative) at the Yasnyi Vzor Pediatric Eye Clinic. Depending on the angle of strabismus, medial rectus muscle recession, lateral rectus muscle plication, or deep medial rectus muscle recession was performed on the more commonly squinting eye using a minimally invasive technique and the StraboSoft software for the calculation of the strabismus surgery dosage. We observed no cases of hypersensitivity. All patients were orthotropic with no sensory fusion on the synoptophore.

Twenty-one For our study, using a continuous sampling method, we retrospectively selected 21 patients for whom glasses were empirically programmed at 2 Hz. They constituted the empirical group.

Continuous sampling procedure was also employed to select 18 patients for whom glasses were programmed using the original formula for calculating the alternating frequency of LCG (the calculation-based group).

Inclusion criteria were a horizontal strabismus angle of 0–10° degrees (measured on the synoptophore), age from 2 to 7 years, and the presence of congenital or early-onset strabismus.

Exclusion criteria were nystagmus, paralytic strabismus, moderate to severe amblyopia, myopia, hyperopia greater than 5.0 D, astigmatism greater than 3 D, the presence of organic ophthalmic diseases, and severe concomitant neurological and somatic disorders.

Patients underwent a standard ophthalmological examination (refractometry, biomicroscopy, binocular function testing, and visual acuity test). Also, an oculomotor function test was conducted via nystagmography using a GazeLab video-oculography system (BCN Innova, Spain) that records eye movements with two infrared cameras. The device includes a laptop with the appropriate software. Eye movement recordings are presented as a graph.

Statistical analysis of the collected data was performed using Excel (Microsoft, USA) and Statistica 13.0 (TIBCO Software, Inc., USA). The Kolmogorov-Smirnov test was employed for assessing normality of the data distribution. We established that all quantitative parameters were normally distributed; hence, they were presented as M±σ. Comparisons between the two groups were made using the Student's t-test for independent samples. Qualitative parameters were compared using Fisher's exact test. Results were considered significant at p<0.05.

Results

All patients in both groups were characterized by the congenital or early-onset strabismus. Strabismus was initially detected in all patients from birth to the age of 3.5 years. The clinical and demographic parameters of the patients in the comparison groups are presented in *Table 1*.

The comparison groups did not differ in gender, age, visual acuity, or other characteristics (*Table 1*). All patients demonstrated no sensory fusion when tested on the synoptophore and no binocular vision based on the results of the Worth four-dot test. Therefore, patients in both groups were in equal conditions for sensory fusion restoration.

Treatment outcomes are presented in *Table 2*. By sensory fusion recovery, we defined the development of stable and unstable fusion of test objects on the synoptophore, as both conditions create the conditions for subsequent binocular vision restoration. Sensory fusion recovery occurred more frequently with the LCG programming based on the calculation formula than with empirical modeling (p=0.001). In the empirical group, sensory fusion restoration occurred in just 9 patients (42.9%). In the calculation-based group, sensory fusion recovery occurred in 16 patients (88.9%). This subsequently became the basis for the personalized programming of LCG oscillation parameters for all orthotropic patients with no sensory fusion.

Table 1. Clinical and demographic parameters of patients in the comparison groups before treatment, M±σ (min-max)

Parameter	Group	
	Empirical (*n*=21)	Calculation-based (*n*=18)
Age, years	5.3±1.7 (2-7)	5.5±1.9 (2-7)
Gender, male/female	10/11	9/9
Presence of strabismus before surgery, months	35.7±12.1 (15.0-63.0)	39.3±28.3 (14.0-102.0)
Visual acuity of the better-seeing eye with correction	0.93±0.02 (0.8-1.0)	0.94±0.01 (0.8-1.0)
Visual acuity of the worse-seeing eye with correction	0.81±0.09 (0.7-1.0)	0.77±0.1 (0.7-1.0)
Spherical equivalent of the better-seeing eye, diopters	2.0±1.3 (0.25-5.5)	2.65±1.4 (0.38-5.75)
Spherical equivalent of the worse-seeing eye, diopters	2.25±1.34 (0.25-5.75)	2.83±1.4 (0.50-5.5)
Optical amount of anisometropia, diopters	0.55±0.12 (0.0-1.5)	0.45±0.16 (0.0-1.0)
Angle of strabismus, °	4.2±1.1 (2-6)	5.0±1.6 (1-8)

Groups are similar in terms of all parameters (*p*>0.05).

Table 2. Recovery of sensory fusion and binocular vision after treatment, n (%)

Sensory fusion after treatment	Group	
	Empirical (*n*=21)	Calculation-based (*n*=18)
Present	9 (42.9%)	16 (88.9%)
Absent	12 (57.1%)	2 (11.1%)

The difference between the groups is statistically significant (*p*=0.001). In some patients (4 in the empirical group and 3 in the calculation-based group), sensory fusion was unstable.

Discussion

The use of LCG in pediatric ophthalmology has been relevant for the past few decades. For instance, they were used to treat amblyopia in pediatric patients [6]. The availability of LCG allowed doctors to achieve greater compliance in patients and their parents than with an occluder.

A similar LCG design was proposed by the author of this article, I.E. Aznauryan, to restore sensory fusion in patients with congenital and early-onset strabismus [9, 10]. The glasses were programmed to an empirical alternating frequency of the liquid crystal lenses. We achieved significantly higher rates of recovery of both sensory fusion and binocular vision in patients wearing LCG vs. patients undergoing traditional orthoptic treatment with a synoptophore.

However, the lack of a personalized approach limited the potential of this method, which inspired us to conduct this study.

Our results demonstrate that the proposed method for personalized programming of the LCG alternating frequency, based on determining the duration of the eyeball alignment movement using video-oculography, improves the effectiveness of this technique.

In Russia, there were previous attempts to use LCG for patients with strabismus: e.g., S.I. Rychkova, A.G. Shchuko, and V.V. Malyshev used LCG for the rehabilitation of patients with concomitant convergent strabismus [5]. They compared the recovery of binocular vision in patients with concomitant convergent strabismus using the LCG-PC computer appliance vs. using the binarimetry. The authors observed a higher rate of binocular vision recovery in patients with binarimetry, while stereoscopic vision was restored more frequently when using the LCG-PC computer appliance. However, this method did not address the issue of sensory fusion recovery in patients with strabismus.

The availability of various modifications of devices using LCG in ophthalmology practice did not resolve the issue of a personalized approach to fitting these glasses for each individual patient, nor has it ensured the flexibility and ease of these procedures. All devices require the patient's presence in the treatment facility and do not take into account individual parameters of their eyes, such as eye movements (which, as our study has shown, affect the effectiveness of sensory fusion recovery).

Our data highlight the potential for the consistent use of these techniques in the postoperative period: during the rehabilitation of patients with concomitant strabismus. In this study, we did not examine the restoration of sensory fusion in patients with divergent strabismus or moderate to severe amblyopia. We plan to continue this research and examine the impact of personalized programming of LCG alternating frequency on the recovery of binocular vision, stereoscopic vision, as well as strabismic unilateral and bilateral amblyopia.

Conclusion

We conclude that the method of programming alternating frequency of the LCG based on determining the duration of the eyeball alignment movement is more effective than empirical programming. The proposed method ensures the most effective use of the LCG for sensory fusion recovery in children after surgery for concomitant convergent strabismus.

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Conflicts of interest: No conflicts of interest are declared by the authors.

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