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Parameters of the Complex of Retinal Ganglion Cells and Optic Disc During Phacoemulsification of Cataracts in the Background of Advanced Stage of Primary Glaucoma

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Abstract **Relevance.** Combined pathology such as primary glaucoma with complicated cataract is one of the leading causes of blindness in the world. **Purpose of the study.** To study the effect of ultrasound on the thickness of retinal ganglion cells and the optic disc during cataract phacoemulsification in patients with advanced (III) stage of primary glaucoma. **Material and methods.** We analyzed OCT parameters in 72 patients with advanced stage primary glaucoma before and after cataract phacoemulsification surgery. **Results and conclusion.** It was established that, after phacoemulsification of cataracts in patients with primary glaucoma, the study of the parameters of the GCC complex using optical coherence tomography showed a decrease in the average thickness of the GCC complex and the dependence of OCT parameters on the density of the cataract.

Keywords Glaucoma, Cataract, GCC, Phaco, Optical coherence tomography

1. Introduction

The prevalence of combined pathology, such as primary glaucoma and cataracts, varies from 17.0 to 38.6% of cases. The main method of treating cataracts against the background of primary glaucoma (PG) is phacoemulsification of cataracts (phaco) with low-frequency ultrasound (US) [8,10].

Studying the problem of the influence of low-frequency ultrasound on the internal structures of the eye remains one of the unsolved problems. The existing concept is based on the study of the relationship between ultrasound during phaco and changes in eye tissue, which is dose-dependent [2,6,9]. Even minimal exposure to low-frequency ultrasound has biological effects. This is explained by the fact that under the influence of low-frequency ultrasound during phaco, not only visible cavitation effects occur, described in the ophthalmological literature as causing structural morphological damage to eye tissue, but also sound-chemical reactions [1,4]. It has been experimentally proven that the threshold for the occurrence of intracellular sonochemical reactions is only 0.02-0.04 W/cm², and for the emulsification of two oil-water media at an ultrasound frequency of 40 kHz, an intensity of at least 0.3-0.4 W/cm² is required. The occurrence of sound-chemical reactions contributes to the emergence of collapsing microbands several microns in size that disrupt bimolecular bonds [3,5,7,10].

However, the research conducted on this issue is not unambiguous. In this regard, the study of the effect of phaco on the visual-nervous apparatus of the organ of vision in patients with advanced stages of PG becomes particularly relevant and requires further studies.

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There is no conflict of interest.

Purpose of the study. To study the effect of low-frequency ultrasound during phacoemulsification of cataract on the thickness of the complex of retinal ganglion cells and optic disc in patients with advanced stage of primary glaucoma.

2. Material and Methods

We analyzed data from OCT studies in 72 patients (72 eyes) with advanced stage PG in combination with cataracts of II (40 eyes) and III degree (32 eyes) density (according to L. Buratto, 1999). Of these, 40 patients (55.5%) were diagnosed with primary open-angle glaucoma (POAG) and 32 (44.5%) were diagnosed with primary angle-closure glaucoma (PCAG). Distribution by gender: women - 38 and men -34. The age of the patients was from 40 to 69 years

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(average was 63.3±4.1 years). Of these: from 40 to 49 years old - 11 patients, from 50 to 59 - 15 patients and from 60 to 69 - 19 patients. The duration of the disease (glaucoma) ranged from 3 years to 12 years, on average 8.1 ± 3.4 years. In patients with POAG, the II degree of cataract density was established in 20 eyes, the III degree of density – in 18. Accordingly, with POAG, the II degree of cataract density was established in 18 and the II degree of density – in 10 eyes. The criterion for selecting patients was an OCT signal strength index of at least 18 (with a lower signal strength, the data obtained were unreliable). The control group consisted of 30 patients (40 eyes) with cataracts of density degrees II and III, corresponding to age and gender.

Patients were examined by general ophthalmological and specific diagnostic methods: visometry, autorefractometry, non-contact tonometry, computer perimetry, ultrasound A, B - scanning, tonometry with a 5.0 g load (according to Maklakov), ultrasound biomicroscopy (UBM), biomicroscopy, optical coherence tomography (OCT) . OCT was performed using a 3D OCT-1 Maestro unit (TOPCON, Japan). The study of the optic disc area was performed using the "Optic Disc Cube 200x200" protocol with data processing using the "ONH and RNFL OU Analysis" protocol. The greatest importance was attached to the average thickness of the RNFL (Average RNFL Thickness). Scanning of the macular area was carried out according to the "Macular Cube 512x128" protocol, followed by analysis of retinal thickness "Macular Thickness Analysis". The average GCC thickness (GCC Average) is calculated, its value for the upper (GCC Superior) and lower (GCC Inferior) segments. To assess the normality of the distribution of study results, the Kolmogorov–Smirnov test was used.

The most convenient and optimal for all stages of work with the II degree of lens density were a needle with an angle of 30°, digital vacuum parameters of 350 mm Hg, ultrasound - 25-30%. With the third degree of lens density, the vacuum parameters were 350-400 mm Hg, ultrasound - 30-40%. Statistical processing was carried out using Excel (Microsoft). Differences were considered significant at $p<0.05$.

3. Results

During the initial examination of patients, regardless of the form of the disease, visual acuity with 2nd degree cataract density was at the level of 0.3 to 0.5, with 3rd degree density – 0.1-0.3. The boundaries of the visual field in 62 eyes along the nasal meridian were 10-15 degrees from the fixation point. In 8 eyes (5 eyes with PCAG and 3 eyes with POAG), the visual field was "tubular" and the boundaries ranged from 3 to 15 degrees along different meridians and on average the sum of visual field boundaries was 115.3±9.0°. In 53 patients (53 eyes), in preparation for phacoemulsification, antiglaucomatous operations were performed in advance and their IOP was at the level of 17.0-20.0 mm Hg. In 19 patients (19 eyes), IOP was normalized by one of the combined antihypertensive drugs and were at the level of 19.0 – 22.0 mm Hg. It should be noted that the above data did not differ significantly between POAG and PCAG. When performing phaco, the depth of the anterior chamber may have a certain significance, especially with PCAG. In the advanced stage of PCAG, the anterior chamber of the eye is shallow, damage to the corneal endothelium and the development of keratopathy are possible, which requires a gentle approach.

The average data on visual acuity, visual field, IOP level, and anterior chamber depth before and after surgery are shown in Table 1.

Table 1. State of visual function before and after phacoemulsification with low-frequency ultrasound

№	Name of indicators	Before surgery	After surgery
1	Visual acuity	0,2±0,06	0,6±0,03
2	Total boundaries of the field of view	204,2±92,8	245,4+91,7°
3	IOP (mmHg)	20,3±2,2	18,9±1,8
	Depth of the anterior chamber with POAG (mm)	2,8±0,1	4,3±0,2
4	Depth of the anterior chamber with PCAG (mm)	1,2±0,1	3,2±0,1

Note: * - reliability $p<0.05$

Table 2. Retinal thickness and GCC parameters before and after surgery

№	Name of indicators	before		After 1 day		After 1 month		After 3 month	
		POAG	PCAG	POAG	PCAG	POAG	PCAG	POAG	PCAG
1	Average retinal thickness (µm)	208,2±16,9	193,6±15,8 *	209,1±14,6	194,2±16,1*	207,8±14,1	193,3±15,3*	207,1±13,9	192,4±16,4*
2	Average thickness of the GCC layer (µm)	71,3±6,7*	53,5±10,3*	71,1±6,2*	53,1±9,9*	70,4±5,9*	52,9±,9,8*	69,2±5,8*	50,4±,9,2*
3	Control group Average retinal thickness (µm)	248,4±31,3*		254,7±28,9*		250,1±29,2*		249,4±30,8*	
4	Control group Average thickness of the KGC layer (µm)	100,3±5,1*		102,6±4,7*		101,8±4,9*		100,4±5,2*	

Note: * - reliability $p<0.05$

Table 3. Optic disc parameters before and after surgery

№	Name of indicators	Before		After 1 day		After 1 month		After 3 month	
		POAG	PCAG	POAG	PCAG	POAG	PCAG	POAG	PCAG
1	Optical disc area (mm²)	2,80	2,64	2,78	2,58	2,81	2,61	2,77	2,55
2	Excavation area (mm²)	1,95	1,86	1,96	1,82	1,99	1,85	2,13	1,84
3	RIM area (mm²)	0,81.	0,78	0,82	0,77	0,83	0,78	0,79	0,74
4	Optical disc volume (mm²)	0,70	0,68	0,59	0,58	0,60	0,63	0,64	0,61
5	RIM volume (mm²)	0,08	0,07	0,06	0,06	0,06	0,06	0,05	0,05

According to OCT data, a statistically significant difference in retinal thickness and ganglion cell complex (GCC) was established in POAG and PCAG. Retinal thickness and CGC in patients with advanced stage PCAG are less than in patients with the same stage of POAG. Perhaps these circumstances are related to the biometric parameters of the eyeball during PCAG.

After appropriate standard preparation, all 72 eyes underwent lens removal with implantation using PE using low-frequency ultrasound. The operation and postoperative period proceeded without complications in all patients. Only one patient with a very shallow depth of the anterior chamber during PCAG on the 1st day after surgery had slight corneal edema, which resolved on the 3rd day of surgery.

In the postoperative period on day 1, OCT data for both forms of primary glaucoma have a slight difference with preoperative data, but they are statistically unreliable. However, in 3 patients (3 eyes) (7.5%) with POAG with grade 3 cataract density and 3 patients (3 eyes) (9.3%) with PCAG, thickening of the retinal thickness was noted and averaged 206.8 for POAG ±10.3 and PCAG 194.4±9.5 degrees. 1 month after surgery, the average retinal thickness and CGC indicate a tendency toward thinning. So, in 6 (8.3%) eyes out of 72 eyes in which thickening of the retinal layers was noted, its thickness decreased to the level of the primary data. A statistically significant thinning of the average indicators of the ganglion complex was established after 3 months. At the same time, in 39 eyes (54.2%) the thickness of the retina and CGC did not change after surgery, in 25 eyes (34.7%) there was a statistically unreliable thinning of the retina, in 8 eyes (11.1%) significant changes in these indicators were established . It should be noted that in these 8 patients (8 eyes) the visual field was "tubular" before surgery. Thus, on day 1 after surgery in patients with advanced stage POAG, the retinal thickness, as well as before surgery, averaged 201.4 ± 14.2; with PAAG – 187.8±9.8 After 3 months, in 3 patients with POAG (7.5%) and 4 patients with PCAG (12.5%), the average retinal thickness thinned and the average for POAG was 193.6±11, 3 and 179.6±8.7 with PCAG. It should be noted that in these patients before surgery the visual fields were "tubular" and on average the sum of the boundaries was 115.5 ± 11.7 degrees. According to the thinning of the retina, the boundaries of the visual field narrowed and the SPV averaged 96.6 ± 5.6 in open-angle glaucoma and 85.2 ± 8.2 degrees in closed-angle glaucoma.

The average retinal thickness and CGC data before and after surgery are shown in Table 2.

On the part of the optic disc before and after surgery, we have not established any significant significant changes in such indicators as the area of the optic disc, excavation and NRP. However, in 8 patients (8 eyes) with a "tubular" field of view, the volume of the optic disc and the onset of the optic disc significantly changed towards a decrease, which may indicate the development of glaucomatous optic neuropathy (Table 3).

In the control group before and after surgery, the distinctive indicators were visual acuity and anterior chamber depth. SPZ, retinal thickness and GCG (on average from 260 to 280 μm), optic disc parameters (excavation 0.2) in 28 patients (28 eyes) remained virtually unchanged. In 2 eyes (6.7%), the next day after surgery, retinal thickening and retinal thickness were noted, which amounted to 283 μm (before surgery 245 μm) and CGC 130 μm (before surgery 108 μm), which indicates swelling of these structures. A month later, these indicators returned to the original figure. Visual acuity after surgery improved from 0.5 to 1.0, the depth of the anterior chamber was from 3.4 to 4.1 mm.

4. Discussion

Thus, 1 month after cataract FE with low-frequency ultrasound in 11.1% of cases and after 3 months in 19% of cases, the thickness of the retina and MCG became thinner. According to a number of authors, low-frequency ultrasound during FEC in PG can contribute to the occurrence of sound-chemical reactions on retinal nerve cells, thereby causing their death. These indicators indicate the possible role of low-frequency ultrasound in the development of GON. According to Quigley H.A. et al [2006], the death of retinal ganglion cells (RGCs) in PG begins long before the first manifestations of visual functional disorders. In advanced stages of primary glaucoma, a significant part of the RGCs are already damaged [11]. Thanks to the use of the diagnostic method optical coherence tomography (OCT), it became possible to separately analyze the thickness of the three inner layers of the retina that make up the ganglion cell complex: nerve fibers, ganglion cells and the inner plexiform layer, containing, respectively, axons, cell bodies and dendrites GCC [12,14]. The information content of the results of an OCT study in a combination of primary glaucoma and cataract

can be significantly affected by the degree of opacification and density of the lens [13]. Our data on changes in retinal thickness and GCC in grade III cataract density against the background of an advanced stage of PG in patients with a "tubular" visual field indirectly confirm this opinion.

5. Conclusions

The study of the parameters of the RGC complex using optical coherence tomography showed a high diagnostic accuracy of the indices and a decrease in the average thickness of the RGC complex in primary glaucoma and the dependence of OCT indicators on the density of the cataract. Data from OCT parameters in patients with PG showed changes within 3 months, in 19% of cases, and possibly reflect damage to the GCL complex by low-frequency ultrasound during phacoemulsification.

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