DIAGNOSTIC AND TREATMENT METHODS

S.E. Avetisov, Z.V. Surnina, K.S. Avetisov, M. Ndari, S. Georgiev, I.P. Lutskan

THE CONDITION OF THE CORNEAL NERVE FIBERS AFTER EXTRACAPSULAR CATARACT EXTRACTION

DOI 10.25789/YMJ.2022.80.08

УДК 617.736 (571.56)

The term "phacosurgery" combines various surgical technologies for the complete or partial removal of the lens. The last decades are characterized by an almost complete transition from extracapsular cataract extraction to the so-called. microinvasive phacosurgery, in particular, standard ultrasound and hybrid (femtolaser) phacoemulsification. Nevertheless, in a number of cases (for example, when the so-called brown cataract is combined with severe dystrophic changes in the cornea), extracapsular extraction, which involves the removal of the “whole” nucleus through a wide surgical incision in the limbal zone of the cornea, is still the method of choice for phacosurgery. The condition of the cornea after phacosurgery remains one of the criteria for the success of the intervention. In this case, as a rule, attention is focused on the "loss" of cells of the posterior epithelium and violations of the optical regularity of the cornea. Changes in corneal nerve fibers (CNF) have been studied to a lesser extent.

The aim of the study was to study the structural changes in CNF after extracapsular cataract extraction based on laser confocal microscopy.

The studies were conducted on the clinical material of 20 operations of extracapsular cataract extraction, which were performed on 20 patients aged 52 to 74 years. The condition of CNF was assessed before and after 7-10 days, 2-2.5 and 6 months after surgery, using the length and density of the main branches of CNF (in mm/mm2 and units/mm2, respectively) in the central zone of the cornea.

Regardless of the timing of follow-up, a decrease in the length and density of CNF was revealed with a moderate tendency to recovery by the 6th month after the intervention. Despite this, a statistically significant decrease in the average length of the main CNFs persisted during all periods of observation, and in density - for 2-2.5 months.

Factors that induce changes in CNF after various phacosurgery techniques include their intersection during the surgical incision and the energy impact on the cornea. When using microinvasive techniques, taking into account the minimization of the length of the incision, ultrasound and/or laser radiation may be the dominant factor, and when using the extracapsular technique, the directly extended corneal incision, accompanied by the intersection of the CNF. In clinical practice, potential disturbances in the CNF structure after phacosurgery should be taken into account in situations accompanied by pronounced initial changes in CNF (condition after keratoplasty and excimer laser keratorefractive surgery, various types of systemic polyneuropathy).

Keywords: corneal nerve fibers, extracapsular cataract extraction, laser confocal microscopy of the cornea.

Introduction. The term "phacosurgery" combines various surgical technologies for the complete or partial removal of the lens. The last decades are characterized by an almost complete transition from extracapsular cataract extraction to the so-called. microinvasive phacosurgery, in particular standard ultrasound and hybrid (femtolaser) phacoemulsification [6, 4]. Possible limitations of the use of microinvasive phacosurgery techniques are associated with such technical elements of the intervention as energy fragmentation and emulsification of the nucleus, which are potential sources of complications caused by damage to the ligamentous-capsular apparatus of the lens and posterior corneal epithelium. The probability of these violations increases in a number of complicated situations, for example, with a combination of the so-called. brown cataract with severe dystrophic changes in the cornea. In these cases, the method of choice for phacosurgery is still extracapsular cataract extraction, which involves the removal of the “whole” nucleus through a wide surgical incision in the limbal zone of the cornea.

The condition of the cornea after phacosurgery remains one of the criteria for the success of the intervention. In this case, as a rule, attention is focused on the "loss" of cells of the posterior epithelium and violations of the optical regularity of the cornea. To a lesser extent, changes in the nerve corneal nerve fibers (CNF), an important structural component that provides the function of its sensitivity, have been studied. To date, a detailed study of the state of CNF is one of the directions for assessing the structural and functional state of the cornea. Structural analysis is based on various technologies of confocal microscopy, a method that allows, at a level close to morphological, to analyze the state of various anatomical layers and components of the cornea. According to the literature data based on confocal microscopy, the diameter [11, 10], the density and length of the fibers and their branches [17], the coefficients of anisometropia and directional symmetry [7] are used for the structural characteristics of CNF.

In a number of previous studies, changes in CNF have been studied in such systemic diseases as diabetes mellitus, amyloidosis, Parkinson's disease, past coronavirus infection, and other pathologies accompanied by the development of polyneuropathy [2,3,8,13,14]. The need to study CNF after various methods of phacosurgery is dictated by a number of circumstances: the presence of corneal incisions of various localization and length, the energy effect on the posterior layers of the cornea when performing microinvasive technologies, and, finally, the possibility of preoperative changes in the cornea of various origins, as well as a combination of pathological changes in the lens with various endocrinological and neurological diseases affecting the initial state of CNF. Taking into account the anatomical features of the CNF (“penetration” into the cornea in the limbus zone), the main cause of their

FBSSE Scientific Institute of Eye Diseases: **AVETISOV Sergey E.** – Prof. Acad. RAS, Scientific Director. Head. Department of I.M. Sechenov First Moscow State University, orcid.org/000-0001-7115-4275; **SURNINA Zoya V.** – PhD in Medical Sciences, senior researcher, MEDZOE@yandex.ru, orcid.org/0000-0001-5692-1800; **AVETISOV Konstantin M.** – Head of Department, orcid.org/000-0001-9195-8908; **GEORGIEV Stefan** – postgraduate student; ophthalmologist of the Yakutsk Republican Ophthalmologic Clinical Hospital, orcid.org/0000-0002-5201-299X; **NDARI Mohamed** – graduate student of I.M. Sechenov First Moscow State University, orcid.org/000-0002-09182635; **LUTSKAN Ivan P.** – PhD, Doctor of the Yakutsk Republican Ophthalmologic Clinical Hospital, Associate Professor of the Medical Institute of M.K. Ammosov SVFU, orcid.org/0000-0003-3440-1534.

damage during extracapsular cataract extraction can be the so-called. the corneal incision is rather long.

In previous studies, a decrease in the sensitivity of the cornea in the incision zone, a decrease in the density and thickening of the CNF after microinvasive ultrasonic phacoemulsification was noted [9,12,16]. When assessing the state of CNF after standard ultrasound and hybrid phacoemulsification, changes were revealed that, according to the authors, are comparable to age-related changes - a decrease in the anisotropy coefficient of directivity and an increase in the symmetry coefficient of directivity of CNF [5].

The aim of this study was to study the structural changes in CNF after extracapsular cataract extraction based on confocal microscopy.

Materials and methods. The studies were conducted on the clinical material of 20 operations of extracapsular cataract extraction, which were performed on 20 patients aged 52 to 74 years. Criteria for exclusion from the observation group: pathological changes in the cornea of any origin and systemic polyneuropathy of various etiologies. All patients gave informed consent to participate in the study.

In the process of extracapsular extraction at a distance of 0.5 mm from the limbus, a corneal incision was performed from 10:00 to 02:00 hours of the dial scale, tangential capsulotomy in the upper third of the anterior capsule, nuclear expression, lens sac lavage, intercapsular implantation of an intraocular lens, and removal of the central part of the anterior capsule. The incision was sealed with a continuous X-shaped nylon suture with a dipping knot.

The condition of CNF was assessed before and after 7–10 days, 2–2.5 and 6 months after the operation. When choosing the maximum period of postoperative follow-up (6 months), we took into account the known and noted in previous studies time period of reinnervation processes in case of CNF damage [15].

The previously developed algorithm for assessing the state of CNF is based on the analysis of images obtained using a laser confocal microscope (HRT III device with a corneal attachment Rostock Cornea, Germany) using the original Liner 1.2S software [1, 7]. As the main criteria for assessing the structure of the CNF, we used the length and density of the main branches of the CNF (in mm/mm2 and U/mm2, respectively) in the central zone of the cornea.

Statistical analysis and assessment of the reliability of the results obtained were carried out using Microsoft Excel 2010 and Statistica 8.0 software.

Average length and density of the main CNF (M ± d)

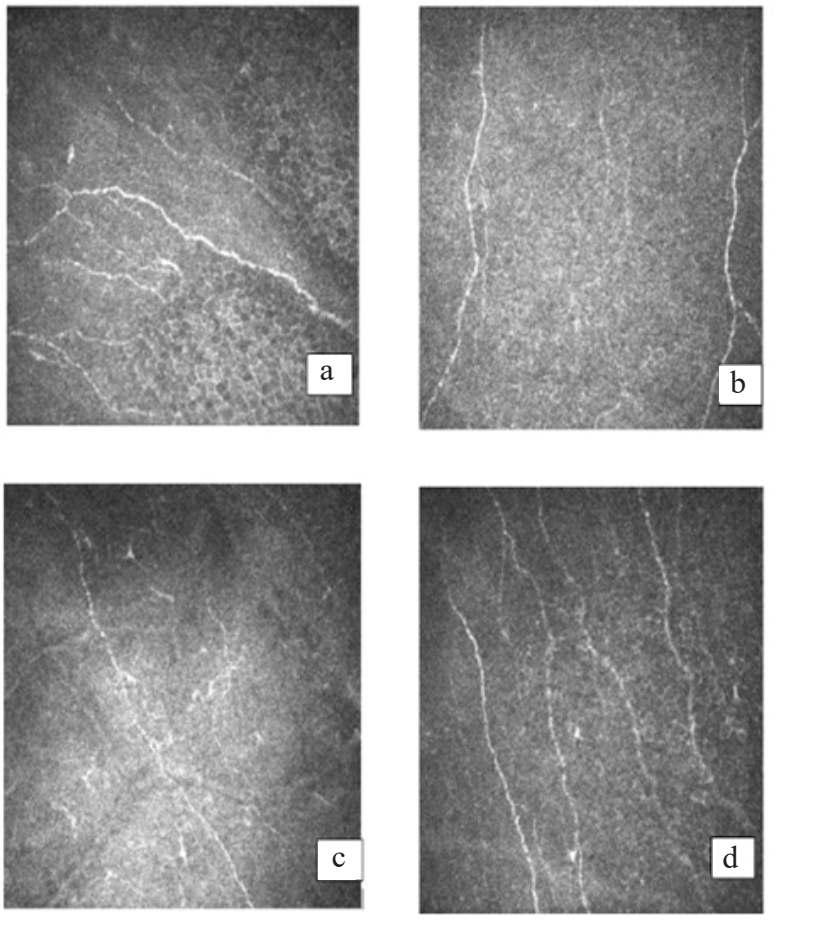
Index	Examination terms			
	1	2	3	4
Main CNF length (mm/mm$^{2)}$	34.4 ± 5.1	19.1 ± 3.9*	21.3 ± 4.3*	26.8 ± 3.4*
Density of main CNF (units/mm^2)	5.2 ±1.7	2.2 ±0.9*	3.4 ±1.3*	3.9 ±1.6

* differences compared to baseline are statistically significant ($p \leq 0.05$)

Results and discussion. Differences in the initial parameters were within the limits of age fluctuations, the average values of the length and density of the main branches of the CNF were 34.4 ± 5.1 mm/mm2 and 5.2 ± 1.7 units/mm2, respectively. The table shows the average values of the indicated indicators of the state of CNF at different periods of observation. Designations 1, 2, 3 and 4 in the table correspond to the terms of the examination (before and after 7–10 days, 2–2.5 and 6 months after the operation, respectively).

Regardless of the timing of follow-up, a decrease in the length and density of the main CNFs was revealed with a moderate tendency to recovery by the 6th month after the intervention. Despite this, a statistically significant decrease in the average length of the main CNFs persisted throughout the entire observation period, and the density of the main CNFs persisted for 2–2.5 months. As a clinical example, Figure 1 shows the results of confocal microscopy before and after extracapsular cataract extraction.

In a previous study, changes in the CNF structure after standard ultrasonic and hybrid phacoemulsification were



The results of laser confocal microscopy and the length (mm/mm2) and density (un/mm2) indices of the main CNFs, respectively, before (a) and at different times (b, c, d) after extracapsular cataract extraction: a) before surgery - 54.91 / 7, b) after 10 days - 18.69 / 3, c) in. after 2 months - 41.04 / 5, d) after 6 months - 54.10 / 6

analyzed using the directional anisotropy and directional symmetry coefficients characterizing the state of the CNF based on the analysis of their tortuosity and directionality [5]. Regardless of the operation technique, there was a tendency to a decrease in the directional anisotropy coefficient and an increase in the directional symmetry coefficient, which indicates an increase in the crimp of the fibers and a violation of their orientation. After hybrid phacoemulsification, the decrease in the directional anisotropy coefficient 2-2.5 months after the intervention turned out to be statistically less significant compared to the standard ultrasound technique, which may be due to a lower energy “load” on the cornea in the process of fragmentation and emulsification of the lens nucleus.

The factors that induce changes in CNF after various phacosurgery techniques include the intersection of fibers during the surgical incision and the energy impact on the cornea. When using microinvasive techniques, taking into account the minimization of the length of the incision, ultrasound and/or laser radiation may be the dominant factor, and when using the extracapsular technique, the directly extended corneal incision, accompanied by the intersection of the CNF.

Conclusion. With the obvious conditionality of comparing the results of assessing the state of CNF after extracapsular cataract extraction and microinvasive phacosurgery, it should be noted that in the first case there are more pronounced changes that persist even in the long term after surgery. In clinical practice, potential disturbances in the CNF structure after phacosurgery should be taken into account in situations accompanied by pronounced initial changes in CNF (condition after keratoplasty and excimer laser keratorefractive surgery, various types of systemic polyneuropathy).

Reference

1. Avetisov C.E., Chernenkova N.A., Surnina Z.V. Anatomo-funkcional'nye osobennosti i metody issledovaniya nervnyh volokon rogovicy [Anatomical and functional features of corneal nerve fibers and methods of their evaluation]. Vestnik oftal'mologii [Journal of Ophthalmology. 2018;134(6):102 106 (In Russ.).] https://doi.org/10.17116/oftalma2018134061102

2. Avetisov S.E., Surnina Z.V., Novikov I.A. [et al.]. Vliyanie sleznoj plenki na rezul'taty pryamoj ocenki chuvstvitel'nosti rogovicy [The effect of the tear film on the results of a direct assessment of the sensitivity of the cornea]. Ibid. 2020; 136(2): 81 85 (In Russ.).] https://doi.org/10.17116/oftalma202013602181.

3. Avetisov SE, Chernenkova NA, Surnina ZV, [et all.] Vozmozhnosti rannej diagnostiki diabeticheskoj polinejropatii na osnove issledovaniya nervnyh volokon rogovicy [Early diagnosis of diabetic polyneuropathy based on the results of corneal nerve fibers examination]. Ibid. 2020; 136 (5):155 162 (In Russ.).] https://doi.org/10.17116/oftalma2020136052155

4. Avetisov SÉ, Mamikonian VR, Iusef IuN, [et all.] Gibridnaya fakoemul'sifikaciya: novyj etap v sovershenstvovanii hirurgii katarakty [Hybrid phacoemulsification: a new stage in the improvement of cataract surgery. Ibid. 2014;130 (2):4 7 (In Russ.).]

5. Avetisov KS, Iusef NIu, Surnina ZV. [et all.] Izmeneniya nervnyh volokon rogovicy posle mikroinvazivnoj fakohirurgii (predvaritel'noe soobshchenie) [Changes in corneal nerve fibers after microinvasive cataract surgery (a preliminary report). Ibid. 2020;136 (2):6 12 (In Russ.).] https://doi.org/10.17116/oftalma20201360216

6. Malyugin B.E. Hirurgiya katarakty i intraokulyarnaya korrekciya na sovremennom etape razvitiya oftal'mohirurgii [Cataract surgery and intraocular correction at the present stage of development of ophthalmic surgery. Ibid. 2014;130 (6):80- 88 (In Russ.).]

7. Avetisov SE, Surnina ZV, Novikov IA, Mahotin SS. Novyj princip morfometricheskogo issledovaniya nervnyh volokon na osnove konfokal'noj biomikroskopii pri saharnom diabete [The new principle of morphometric research of nerve fibers based on confocal biomicroscopy in diabetes mellitus. Ibid. 2015;4:5-11 (In Russ.).] https://doi.org /10.17116/oftalma201513145-11

8. Avetisov SE, Surnina ZV, Akhmedzhanova LT, Georgiev S. Pervye rezul'taty kliniko-diagnosticheskogo analiza postkovidnoj perifericheskoj nevropatii [First results of clinical diagnostic analysis of post-COVID peripheral neuropathy. Ibid. 2021;137(4):58 64 (In Russ.).] https://doi.org/10.17116/oftalma202113704158

9. Smetankin IG, Agarkova DI. Sravnitel'naya ocenka nekotoryh morfologicheskih izmenenij rogovicy posle fakoemul'sifikacii katarakty metodami konfokal'noj mikroskopii i opticheskoj kogerentnoj tomografii [Comparative evaluation of some morphological changes in the cornea after cataract phacoemulsification by confocal microscopy and optical coherence tomography. Ibid. 2012;6:30-32 (In Russ.).]

10. Niederer R, Perumal D, Sherwin T. [et al.] Age-related differences in the normal human cornea: a laser scanning in vivo confocal microscopy study. Br J Ophthalmol. 2007;91:1165-1169. https://doi.org/10.1136/bjo.2006.112656

11. Grupcheva CN, Wong T, Riley AF. [et al.] Assessing of sub-basal nerve plexus of the living healthy human cornea by in vivo confocal microscopy. Clin Exp Ophthalmol. 2002;45:3030-3035. https://doi.org/10.1046/j.1442-9071.2002.00507.x

12. Kim H, Chung J, Kang S, [et al.] Change in corneal sensitivity and cornealnerve after cataract surgery. Cornea. 2009;28 (11):20-25. https://doi.org/ 10.1097/ico.0b013e3181aea0e3

13. Papanas N., Ziegler D. New vistas in the diagnosis of diabetic polyneuropathy. Journal of Diabetes Investigation. 2014; 47(3): 690-698. doi:10.1007/s12020-014-0285-z

14. Papanas N, Ziegler D. New diagnostic tests for diabetic distal symmetric polyneuropathy. J Diabetes Complications. 2011 Jan-Feb;25(1):44-51. doi: 10.1016/j.jdiacomp.2009.09.006. Epub 2009 Nov 6. PMID: 19896871.

15. Labetoulle M, Baudouin C, Calonge M, [et all.] Role of corneal nerves in ocular surface homeostasis and disease. J.Acta Ophthalmol. 2019 Mar;97(2):137-145. doi: 10.1111/aos.13844.

16. Sitompiu R, Sancoyo GS, Hutauruc JA, [et al]. Sensitivity change in cornea and tear layer due to incision difference on cataract surgery with either manual small-incision cataract surgery or phacoemulsification. Cornea. 2008;27:13-18. https://doi.org/10.1097/ico.0b013e31817f29d8

17. Sivaskandarajah GA, Halpern EM, Lovblom LE.[et al]. Structure-function relationship between corneal nerves and conventional small-fiber tests in type 1 diabetes. Diabetes Care. 2013; 36(9):2748-2755. https://doi.org/10.2337/dc12-2075