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FLUID CHANNELS OF CORNEA AND CONJUNCTIVA

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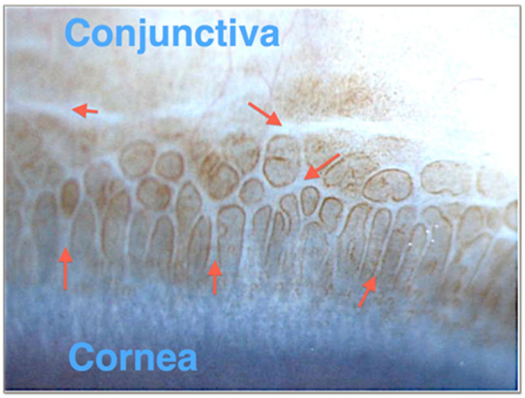


Fig 1. A picture of the limbus showing the lymphatics entering the cornea as single channels. Proximally they join each other and then merge with wider conjunctival lymphatics coursing parallel to the limbus.

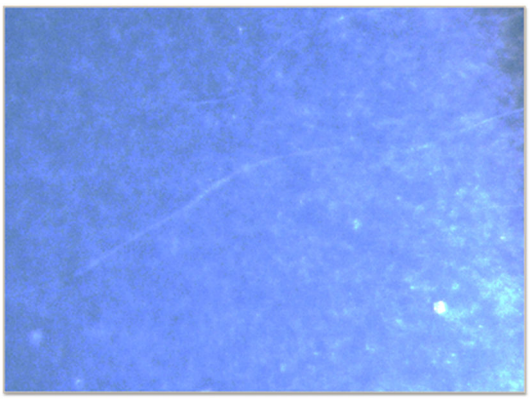


Fig.2. The low power magnification showing the translucency of the cornea. It also gives a slight hint of structure and non-structure i.e channels. High magnification makes the difference very obvious. A nerve fibre is also visible.

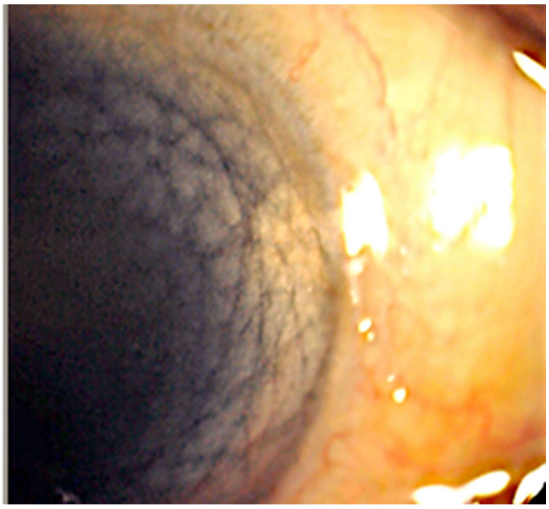


Fig. 3. A 3D picture of a prominent arcus senilis, in which there is a network of prominent corneal "channels" that join the circular "lucid interval" in the periphery of the cornea.

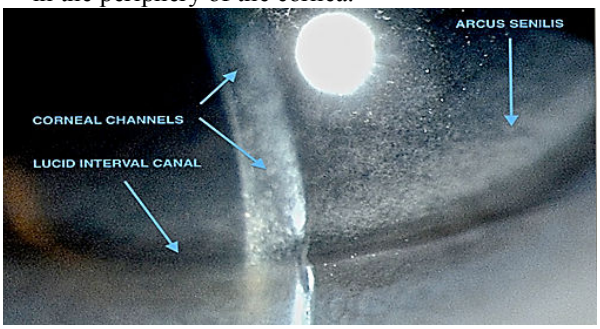
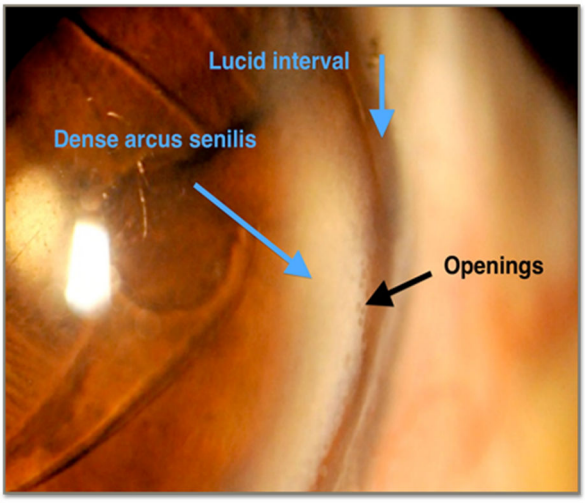
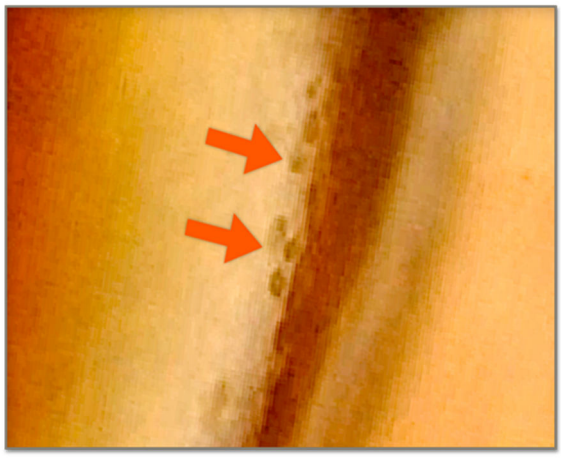


Fig.4 showing a very prominent lucid interval, giving the appearance of a gutter. However the appearance was created by the transparency of the anterior wall of the lucid interval. Optical section also shows communication between the lucid interval and the corneal channels.



a)



b)

Fig.5 (a, b). Shows very prominent arcus senilis as well as the lucid interval. The outer edge of lucid interval shows fine pores/openings, which are confirmed on magnifying the picture.

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Fig.6. Histology of the cornea showing a large number of slit like spaces throughout the depth of the cornea. They could very well represent the sinusoidal/lymphatic channels.

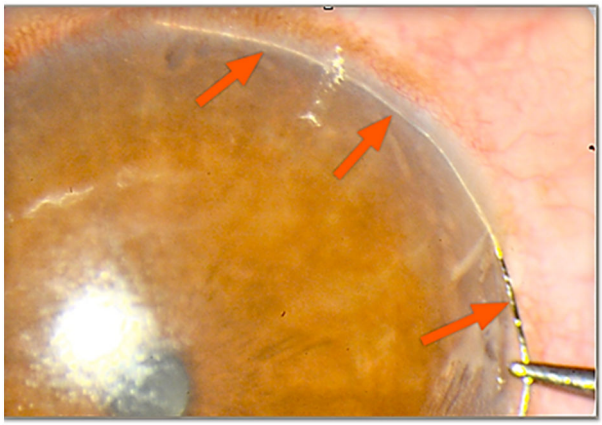

Fig.7.
A 100 micron blunt wire has been passed in to the lucid interval channel.

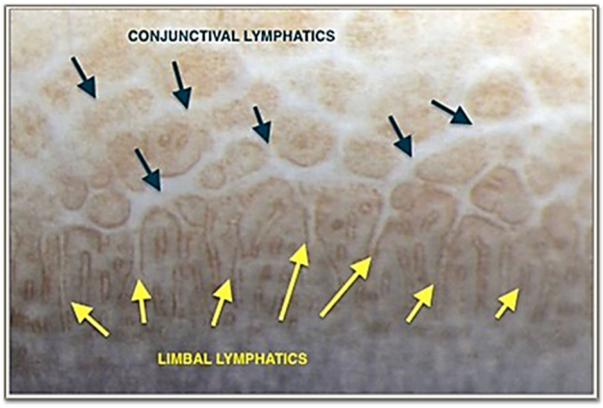

Fig.8. The oneness of the limbal lymphatics and the conjunctival lymphatics is well demonstrated in this picture.

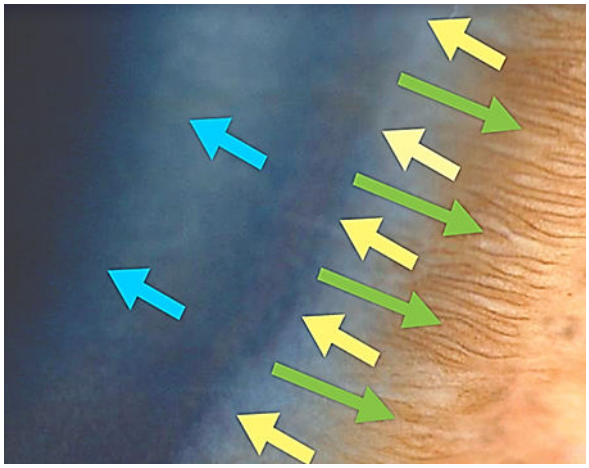

Fig.10. Diagrammatic representation of the possible mechanism of fluid movement in the area of the angle of anterior chamber. The Schlemm canal is hidden under the sclera. Yellow arrows represent aqueducts connecting to lucid interval/Singh canal. Blue arrows show connection between lucid interval and the cornea. Green arrows represent connection between lucid interval and the conjunctival lymphatics.

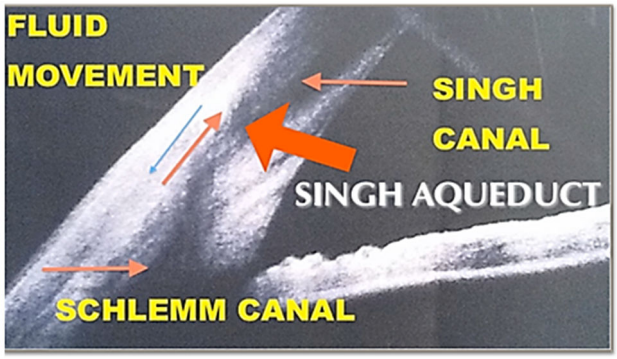

Fig.9. OCT of the angle area showing Lucid interval/canal of Singh and Schlemm canal. The two are connected through Singh aqueduct.

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Summary. For long it has been taught that there are no lymphatics in the eye. However, we have observed that lymphatics do exist, not only in the conjunctiva, but also in the cornea. A network of corneal channels is connected to a triangular sinusoidal channel in the corneal periphery, in the area that appears as "lucid interval" in cases of arcus senilis. This lucid interval channel/Singh canal has connection with the canal of Schlemm through slit like aqueduct. Thus Singh canal has triple connections – corneal channel network, Schlemm canal and conjunctival lymphatics. Every structure has been minutely photographed. The presence of channel network shall help us to study the corneal and glaucoma problems better than before.

Keywords: lucid interval channel/Singh canal, corneal and conjunctival lymphatics

INTRODUCTION: Data regarding fluid and blood system of the anterior segment of the human eye are presented in literature. Ascher detected aqueous veins in 1941 [1]. According to him, the aqueous seeps through the trabecular meshwork, in to the canal of Schlemm, thence through the scleral venous network, and, finally into conjunctival and episcleral veins. Norman Ashton in 1951 made a significant contribution to the understanding of drainage channels, by the study of neoperene casts [4]. He concluded that some aqueous veins arise directly from Schlemm canal, while some other were connected to Schlemm canal indirectly through superficial and deep scleral plexus. He further observed that all aqueous veins were of striated or laminated variety. What is noteworthy is that the author talked only about "veins". However the way the study was conducted, he could not find anything finer than veins. He also made a remark that "Nor it can be said that our results dispose of the possibility that certain aqueous veins may not derive their aqueous from Schlemm's canal." Whatever it meant, but lymphatics were not in his mind, when he wrote this.

The current understanding about aqueous movement is summed up in 2011 edition of Shields Text book of Glaucoma as,"The Schlemm canal is connected by intrascleral channels to the episcleral veins [7]. The trabecular meshwork, Schlemm canal and the intrascleral channels make up the main route of aqueous humor outflow. " Nowhere in this 610 pages long book, is there any mention of lymphatics.

Singh et al in 2003 presented their study of conjunctival lymphatics [6]. It was suggested that lymphatics play an important role for aqueous drainage, normally and especially after a filtration surgery. Our work continued. We could demonstrate conjunctival lymphatics by a variety of ways [5].The conjunctival lymphatics enter the cornea at the limbus, in great numbers, as single channels. Proximally they join each other and merge with the wide conjunctival network. A question arose, where do they disappear in to the cornea? What is happening in the cornea?

The current paper is a continuation of the same work in greater depth. The lymphatic network has been traced in the cornea. They exist as a network of sinusoidal channels that are connected to a large circular sinusoidal channel in the periphery of the cornea. The location of this channel corresponds to the "lucid interval" that is often seen in cases of arcus senilis. The Lucid interval /channel of Singh is situated not far from canal of Schlemm. The two are connected through "Aqueducts of Singh". The Lucid interval channel has multilayered lymphatic connections both on the corneal as well as on the conjunctival side. These are described as follows.

For the cornea to maintain its hydration, transparency and metabolism, it must have certain kind of fluid movement from the endothelial and epithelial side as well as from the limbus. Does the fluid movement occur by a process of diffusion only between the stroma and the limiting membranes on the two sides, or there is a more efficient system of fluid movement through the cornea?

The cornea is transparent for all practical purposes. Hence it is difficult to visualise any kind of non-vascular sinusoidal/lymphatic channels coursing through it. The vascular channels remain visible, because of the vessel walls, even if there is no blood in them. A purpose of this study is to demonstrate an existence of the lymphatic channels of the cornea.

METHODS. Normal and eyes with corneal diseases were examined using slit-lamp equipped with a camera. One picture was borrowed from other scientific sources. The human eyes were used to investigate channels in the corneal stroma.

RESULTS AND DISCUSSION. Cornea is not as transparent as glass. It is translucent. When light is passed through it, it is not reflected uniformly, because of "structures". The nearest reflection shows optically light and dark areas.

The structures reflect, while non-structures (sinusoidal fluid channels) do not. This is what we actually find under high magnification. If the corneal tissue is "inflamed" or less transparent for some reason, the difference becomes exaggerated. Any kind of corneal channels, if present in the cornea, are expected to be transparent, hence invisible. But suppose there is a corneal pathology renders the corneal tissue translucent or semi-opaque. That is what we found in a variety of cases (Fig.1). Here are a few samples.

1. A case of megalocornea with a central opacity. He was a 7 year old child suffering from megalocornea and congenital cataract. An iris claw lens was implanted. A faint opacity was noticed in the centre of the cornea. On closer look, it showed the presence of a network of dark lines in between the semiopaque corneal areas. On optical section, these lines/channels were seen to be located in the corneal stroma (Fig.2). He has been observed for 13 years. The appearance has remained the same.

2. Cases of arcus senilis. Arcus senilis is an interesting condition in which the cornea becomes semi-opaque and wherein it is possible to observe channels. The following picture (Fig. 3) in 3 D shows wide arcus senilis with a network of channels. In the periphery, the network merges with the "lucid interval". In every case of arcus senilis, the "lucid interval" on optical section, appears as roughly triangular, irregularly edged, optically empty space, the apex of the triangle being directed towards the centre. There is an anterior and a posterior wall. Towards the apex/corneal side, it appears to be continuous with the corneal channels. Rarely one might come across an extremely prominent lucid interval as in the following case (Fig.4). At first look it appeared to be a deep gutter in the periphery of the cornea that also showed arcus senilis. Optical section showed that it was lucid interval that had an opaque posterior and a transparent anterior wall. The optical section also showed intimate connection between the lucid interval and corneal channels towards the centre of the cornea. This case leaves no doubt that "lucid interval" is indeed a sinusoidal canal that serves to move fluid in the cornea. The optical section also shows a conjunctival lymphatic channel joining the lucid interval. In a short segment, the outer edge of the arcus senilis showed roughness due to the possible presence of holes of the corneal channels opening in to lucid interval. It is not a figment of imagination, as the appearances of the next case shall show. This patient had a very prominent nearly opaque arcus senilis and an equally sharp and prominent transparent lucid interval (Fig.5). A large number of openings in multiple layers were seen to come from the arcus senilis towards the lucid interval. If we consider whole of the corneal circumference, the number of these openings will run into many thousands. And these openings must be connected to thousands of channels in the cornea.

Histology of the cornea shows a huge number of large and small slits in the stroma (Fig.6). These slits are either ignored or they are labelled as artifacts. It is because of lack of awareness about the lymphatics in the cornea. The huge number of slits seen in cornea histology pictures seem to match the large number of big and small corneal lymphatics that we have been able to see and photograph through the slit lamp microscope. It must be emphasised that the clinically visible channels are only a fraction of the real number, since they are being visualized in one plane only.

The next question was if lucid interval is channel, can we pass a wire in to it ? We tried and found that a 100 micron blunt steel wire could be easily pushed for considerable distance. We could also pass a straight 240 micron blunt cannula for a shorter distance (Fig.7).

Let us now look at the relationship between the corneal channels, lucid interval and the conjunctival lymphatics. Figs.8 shows that these channels/lymphatics are connected to each other.

Most of the pictures that give us information from the surface/one plane only. Sometimes we see the corneal channels entering lucid interval at multiple planes. Similarly we come across cases, in which lymphatics are seen connected to the limbus not in one but in multiple levels. There is great probability that they are mostly connected to the lucid interval channel of Singh, it being so wide. There is a reasonable chance that some of them are directly connected to canal of Schlemm or to intra-scleral lymphatics. It may be mentioned that the literature talks of intra-scleral venous plexus and not of intra-scleral lymphatic plexus. If there is network of lymphatics in the cornea, why not the same in the sclera? The lymphatic system of the cornea, sclera and conjunctiva has to be one interconnected.

The source of fluid in the corneal and conjunctival lymphatics. The channel/lymphatic system discussed thus far helps us to understand, that there is a high probability of free movement of fluids. These fluids should hydrate the cornea and aid in the metabolism. But we have yet to find out where the circulating fluid comes from. The only

available fluid source in this anatomical area is the aqueous in the anterior chamber. The classical teaching would lead us to believe that the nutrition flows through the corneal endothelium and the the form of a “lucid interval channel”, that we have demonstrated. The lucid interval channel is situated in the peripheral most part of the clear cornea. It lies superficial to the anterior part of corneo-scleral trabeculae. That means it is very close to the canal of Schlemm, which overlies the posterior part of trabecular meshwork (Fig.9).

The clinical concept of corneal channels is new. The anterior segment OCT has existed for over a decade. The OCT images often show lucid interval channel connected to Schlemm canal via aqueduct connect. We have studied hundreds of OCTs of our patients. We frequently come across images that clearly show the triple relationship of lucid interval channel, aqueduct and Schlemm canal. This relationship is uneven/unequal around the circumference. Much more amazing has been the fact that sometimes the OCT image showing the triple connection might change appearance after local medication with pilocarpine.

Once the link between the lucid interval and canal of Schlemm is understood, the dynamic nature of fluid movement become clear (fig. 10). What happens with every pulse beat? This is how I visualize. With every pulse beat, aqueous gets pushed from the ciliary body in to the posterior chamber, from where it is pushed towards the anterior chamber and further towards the angle of the anterior chamber. There is a positive phase when the heart is beating and there is a negative phase when it is relaxing. The aqueous is pushed through trabecular meshwork in to the canal of Schlemm. A little less goes back than gets in, since the fluid has to move on. From the Schlemm canal it pulses through the aqueduct of Singh in to the lucid interval/ Singh canal. From Singh canal the fluid pulses in to and out of the corneal lymphatic network. The to and fro movement is equal in volume. However with every pulse beat, some fluid escapes from Singh canal to conjunctival lymphatics, through limbal connections, from where it gets in to general circulation. The formation of topography waves is explained by to and fro limbal capillaries. But these sources do not relate to the presence of a huge network of channels in the cornea and conjunctiva and the presence of a junction between the two in pulsatile movement of fluid between canal of Singh and corneal channels. Similar fluid movement is also occurring on the uveo-scleral side. The fluid ultimately passes through the scleral network and episcleral network in to the conjunctival network. The lymphatic network exists as a three dimensional network. Limbal lymphatics vs Vogt limbal palisades. Lagali [3] has studied palisades of Vogt in cases of aniridia, by confocal microscopy. He has observed “limbal palisade ridges” and “focal stromal projections”. Vertical appearances of the tubes are seen as ring shapes, or “Focal stromal projection”. We have observed these very appearances through slit lamp microscopy. According to Lagali (personal communication), the function of the palisades is not known. According to Goldberg too the functions of the palisades of Vogt are not known with certainty, but their inter-palisadal epithelial rete ridges may serve as a repository for corneal epithelial cells [2]. They may thus be important in both aging and diseases of the cornea.

For nearly a century, a part of the corneal-conjunctival lymphatic system has got studied in isolation, as Vogt palisades. However the lymphatic origin of the palisades has been totally missed. We described conjunctival lymphatic system in 2003 [6].

CONCLUSION. On the basis of our slit lamp microscopy studies we strongly believe that the parallel formations as seen at the limbus that are actually a part of the lymphatic system. These lymphatics can join the cornea in only one pattern - the palisade. Once away from the limbus they join each other and merge in to the conjunctival lymphatic system. The ‘lymphatic palisades’ have important function to perform, i.e. they are a conduit for the movement of the aqueous. The corneal, limbal and conjunctival network is one system. It explains their functions of providing nutrition to the cornea. It serves as a fast channel for the movement of inflammatory cells in cases of corneal infections. It explains the movement of the aqueous to drain the aqueous normally and after filtration surgery.

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Далжит Сингх
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Лімфатичні канали рогівки і кон'юнктиви

Резюме. Довгий час вважалося, що в оці відсутня лімфатична система. Автором показана наявність лімфатичних каналів в кон'юнктиві і рогівці. Мережа каналів рогівок з'єднується з трикутним синусоїдальним каналом Сингха, розташованим на периферії рогівки. Канал Сингха сполучається із склеральним синусом за допомогою акведуків Сингха. Трикутний синусоїдальний канал рогівки має сполучення також з кон'юнктивальною і рогівкою лімфатичною системою. Кожна описувана анатомічна структура представлена на фотографіях. Показана наявність лімфатичних каналів в кон'юнктиві і рогівці істотно допоможе у вивченні питань лікування глаукоми і патології рогівки.

Ключові слова: канал Сингха, лімфатичні канали рогівки і кон'юнктиви

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Лимфатические каналы роговицы и конъюнктивы

Резюме. Долгое время считалось, что в глазу отсутствует лимфатическая система. Автором показано наличие лимфатических каналов в конъюнктиве и роговице. Сеть роговичных каналов соединяется с треугольным синусоидальным каналом Сингха, расположенным на периферии роговицы. Канал Сингха сообщается со склеральным синусом посредством акведуков Сингха. Треугольный синусоидальный канал роговицы имеет сообщение также с конъюнктивальной и роговичной лимфатической системой. Каждая описываемая анатомическая структура представлена на фотографиях. Показанное наличие лимфатических каналов в конъюнктиве и роговице существенно поможет в изучении вопросов лечения глаукомы и патологии роговицы.

Ключевые слова: канал Сингха, роговичные и конъюнктивальные лимфатические каналы

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ДОСЛІДЖЕННЯ СТАНУ ДИСКА ЗОРОВОГО НЕРВА ПІСЛЯ ДВОЕТАПНОГО ХІРУРГІЧНОГО ЛІКУВАННЯ ПЕРВИННОЇ ВІДКРИТОКУТОВОЇ ГЛАУКОМИ ЗА РЕЗУЛЬТАТАМИ СКАНУЮЧИХ ЛАЗЕРНИХ МЕТОДІВ ДІАГНОСТИКИ

Національна медична академія післядипломної освіти
імені П. Л. Шупика, Київ, Україна

Резюме. Проведено аналіз даних обстеження 338 очей пацієнтів із первинною відкритокутовою глаукомою у післяопераційний період двоетапних антиглаукомних операцій впродовж 12 міс, розподілених на три групи за типом хірургічного лікування. Визначено та проаналізовано розподіл частоти змін стереометричних параметрів диска зорового нерва відносно вихідного стану щодо стабілізації, негативізації та позитивної динаміки за результатами скануючих лазерних методів діагностики первинної відкритокутової глаукоми. Показники середньої товщини шару нервових волокон і площі нейроретинального пояска, які демонструють зміни з 3-го місяця спостереження, доцільно виокремити як найбільш чутливі і ранні, і це треба врахувати у післяопераційному спостереженні за динамікою глаукомної оптичної нейропатії.

Ключові слова: глаукома, стереометричні параметри, HRT, GDxVCC, глибока неперфоруюча склеректомія, лазерна трабекулотомія

Первинна відкритокутова глаукома (ПВКГ) посідає одне з перших місць серед причин незворотної сліпоти, слабкозорості та первинної інвалідності, залишаючись важливою медико-соціальною проблемою сучасної