

# The Role of the UBM Method in Assessing the Topographic and Anatomical Relationships of the Structures of the Iridociliary Zone of the Eyes in Glaucoma

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**Abstract** Every year, 1 in 1000 people develop glaucoma. The overall incidence of the population increases with age: among people over 40 years old it is 1.5%, and over 80 years old - 14%. More than 15% of the blind have lost their sight as a result of glaucoma. Optical research methods are based on the use of the laws of optics concerning the nature, propagation and interaction with matter of electromagnetic radiation in the optical range (visible light, ultraviolet and infrared radiation).

**Keywords** Glaucoma, Ciliary body, UBM method, Iridociliary zone

## 1. Introduction

Despite the progress made in studying the causes of glaucoma, early diagnosis and treatment, the percentage of vision loss and blindness due to this disease is still significant. About 60.5 million people in the world have glaucoma, and this figure, according to statistical calculations, will increase to 79.6 million by 2022 [14]. The key point is that among the individuals with glaucoma there is a very large proportion of people of active working age.

Every year, 1 in 1000 people develop glaucoma. The overall incidence of the population increases with age: among people over 40 years old it is 1.5%, and over 80 years old - 14%. More than 15% of the blind have lost their sight as a result of glaucoma.

Optical research methods are based on the use of the laws of optics concerning the nature, propagation and interaction with matter of electromagnetic radiation in the optical range (visible light, ultraviolet and infrared radiation).

Various optical devices are widely used in ophthalmology [18]:

- for functional diagnostics: a set of optical methods used to study the process of light perception by the human eye is traditionally singled out as an independent section of optics - physiological optics; they serve to study visual acuity, absolute sensitivity, the critical frequency of fusion of light flickers, etc.; to implement

these methods, optical devices such as ophthalmoscopes, ophthalmometers, eye refractometers, adaptometers, etc. are used. [8,17].

- for therapeutic purposes: in particular, methods of laser- pleoptic treatment of various types of amblyopia (the use of laser systems for the treatment of disorders of the sensory and accommodative apparatus of the eye), methods of treating metabolic eye diseases using a low-intensity infrared laser, photodynamic therapy and a number of other methods [14,25,39].
- for visualization: this group consists of both well-known methods of traditional diagnostics used in the daily practice of an ophthalmologist, and more rarely used diagnostic aids.

Biomicroscopy (microscopy of the eye) is a detailed and accurate method for studying the anterior segment of the eye using a slit lamp, which is a combination of a binocular microscope with a device for illuminating the examined part of the eye with a slit-like beam of light [10,36].

The study covers not only the areas of the eye that are directly accessible to inspection, but can also be used to study those departments (anterior chamber angle, vitreous body, retina), which are visible only when using special devices [27].

The main content of biomicroscopy is to assess the degree of optical inhomogeneity of eye tissues. This becomes possible, first of all, by limiting the area of illumination of the eyeball and a sharp increase in the brightness of the light source. For biomicroscopy, 4 types of illumination are used: direct focal, indirect focal, direct diaphanoscopy and indirect diaphanoscopy, as well as techniques such as

examination “in a grazing beam”, “in a luminous zone” [25]. Variations are achieved as a result of changing the parameters of the light beam (shape and cross-sectional area, angle of incidence of light on the object, brightness, color).

With biomicroscopy, the most peripheral parts of the anterior chamber remain inaccessible to the eye of the researcher - the iridocorneal angle of the anterior chamber of the eye (ACC), the anatomical structures that make up the posterior chamber of the eye, and the ciliary body.

The biomicroscopic picture of the anterior segment can be captured by photography using white light or light with different spectral wavelengths. Photo registration of the anterior segment of the eye contributes to the objectification of dynamic monitoring of patients with various pathological changes.

In 1904, Theodor Scheimpflug (Theodore Scheimpflug) - the captain of the Austrian army, who systematized various optical effects, received a British patent for the focusing method he discovered. The Scheimpflug principle allows you to find such a plane of rotation of the lens or film cassette (a line perpendicular to the optical axis, called the Scheimpflug line) with respect to the plane of the object, at which the object in the frame will be shown completely sharp. Scheimpflug's rule allows you to get a sharp image of the entire object at an angle to the photographer. The Scheimpflug principle has found application not only in photography, but also in medicine, in particular, in ophthalmologists [12].

Today, this rather complicated method for quantitative assessment of the transparency of media, based on the Scheimpflug principle, is implemented in commercially available computer-analytical systems of the anterior segment of the eye. The method of computer densitometry (quantitative determination of optical density) of the cornea and lens makes it possible to objectively determine the transparency of these structures in numerical values (linear densitometry) [18,25].

Some devices make it possible to determine the angle and volume of the anterior chamber of the eye and calculate the curvature of the cornea and lens [15,23]. Since the possibilities of analysis from a photographic image depend on the degree of transparency of the structures under study, Scheimpflug photography does not solve the problem of visualizing anatomical units covered by the iris.

Gonioscopy (or biomicrogonioscopy) - the study of the angle of the anterior chamber of the eye using a gonioscope (various modifications) and a slit lamp - is used to determine the shape of the angle of the anterior chamber of the eye, visualize the root of the iris, the anterior part of the ciliary body, the trabecular apparatus and identify pathological changes in this area [25,28,38]. The transparency of the cornea is a prerequisite for performing gonioscopy. The shape of the angle (width and profile) is evaluated by the degree of closure of the identification zones of the angle by the iris and by the distance of the root of the iris from the notch. With a wide and medium angle, the gonioscopy method significantly expands the possibilities of

visualization, however, in the eyes with a narrow or closed angle, the assessment of the APC parameters remains difficult.

Goniolenses in combination with a slit lamp are also used for microcycloscopy (examination of the area of the ciliary body), microsinoscopy (examination of the region of the ciliary girdle of the eye (zinn ligaments) and ophthalmoscopy of the periphery of the retina (or posterior microcycloscopy) [25,31,38,39]. However, often the implementation of these studies is difficult, which is associated with a strong decrease in illumination at the periphery of the fundus, in the area of the ciliary body and zinn ligaments under conventional methods of illumination, as well as with a large angle at which the rays exit the studied areas of the eye. completely rule out the possibility of a diagnosis.

## 2. Materials and Methods

Diaphanoscopy of the eye, transillumination (transillumination) of the walls of the eyeball through the cornea or sclera with the study of the resulting diaphanoscopic tissue patterns to detect an intraocular tumor, was first used in ophthalmology from the end of the 19th century. It makes it possible to identify areas that transmit visible light worse or better than usual [25,31].

Transcorneal transillumination allows you to clearly see the "girdle" of the ciliary body, post-concussion ruptures of the sclera. When the eye is translucent through the sclera, the luminescence of the pupil (diaphanopupilloscopy) and its contralateral area (diaphanoscleroscopy) are evaluated. Since translucence can only be performed through the anterior hemisphere of the eye, the method allows to identify and roughly estimate the size of tumors of the ciliary body, choroid and retina in the case of their preequatorial location. The criterion is the disappearance of the usual glow of the membranes of the eyeball at the site of the tumor. The transparency of the optical media of the eye is a prerequisite for conducting diaphanoscopy. There is also a method of transpalpebral transillumination to detect pathological changes in the eyelids (for example, fragments of foreign bodies) [25].

Despite a large selection of different designs of diaphanoscopes and various methods (including invasive ones) of survey and clarifying diaphanoscopy, transillumination of the eyeball does not always give satisfactory results. For example, a very small tumor may not be visible, and a large intraocular hemorrhage may obscure the illuminated fundus and give the impression of a growing neoplasm. In addition, with diaphanoscopy, the shadows of the tumor and the bands of the ciliary body may merge. Due to the impossibility in all cases to correctly interpret the data, studies, the results of diaphanoscopy can be regarded as a guide for further clinical research using more reliable and reliable methods.

Keratotopography is a method of measuring the curvature of the cornea, which can be conditionally classified as

imaging. It is based on the fact that the front surface of the cornea, acting as a convex glass, reflects a small part of the light incident on it (Placido's disk) and forms the first Purkinje image, which gives a map of the isopter surface. Topographic printouts of the anterior surface of the cornea (map of the anterior surface) are color-coded, reflecting the quantitative characteristics of its curvature at any point [32]. New generation keratotopographs have advanced diagnostic capabilities and provide complete information about the state of not only the anterior but also the posterior surface of the cornea [17,19].

The principle of photoregistration is the basis of the method of mirror endothelial microscopy, due to which visualization of the posterior corneal epithelium is achieved with its subsequent qualitative and quantitative assessment.

Confocal microscopy is one of the most modern methods that allows obtaining information about the morphology, anatomy and physiology of the cornea with visualization of tissues on cellular and microstructural level. The video image capture system makes it possible to obtain hundreds of ultrathin optical sections of all layers of the cornea in the central and paracentral zones, store them for subsequent analysis in digital format in the form of images or video sequences [5,6,21].

A living organism generates natural radiations (surface electrical potentials, infrared radiation, etc.), which are also used in diagnostics, i.e. the subject's body is an active component of the imaging process [22]. So, in ophthalmology (mainly in ophthalmology -oncology), thermography has found application - a method of registering a visible image of the infrared radiation of the human body surface with the help of special devices [20,33]. The physiological basis of thermography is an increase in the intensity of infrared radiation over pathological foci (due to increased blood supply and metabolic processes in them) or a decrease in its intensity in areas with reduced regional blood flow and concomitant changes in tissues and organs. A detailed study of the thermographic image of the face on a color monitor screen allows you to determine the distribution of "hot" and "cold" areas, in comparison with their localization with the location of the tumor, the nature of the contours of the focus, its structure and area of distribution, as well as determine the indicators of the temperature difference (gradients) of the area under study compared to the symmetrical zone.

Thermography is a physiological, harmless, non-invasive diagnostic method with visualization elements that complement the understanding of the clinical picture.

Optical coherence tomography (OCT) of the anterior segment of the eye belongs to a new generation of non-invasive diagnostic methods; it appeared due to the introduction of high-tech technologies into clinical practice.

technologies and provided ophthalmologists with new visualization possibilities [12,19,32].

physical principle of low-coherence interferometry, which forms the basis of OCT, is similar to ultrasound, with the difference that in optical coherence tomography,

not acoustic (sound) waves, but optical radiation in the near infrared range are used to probe biological tissue. A superluminescent diode (SLD, SLED) with a wavelength of 1310 nm is used as a light source. At this wavelength, the depth of penetration into the eye is negligible.

The basics of interferometry were described by I. Newton. An optical beam from a laser or light source is directed to a translucent mirror, which divides it into two beams - measuring and control.

The data obtained through computer analysis is converted into a picture of light-scattering and reflective ability tissues and are used for imaging (high-resolution tomograms of the eye section) and measuring the size of anatomical structures in the scanned area.

Optical coherence tomography makes it possible to estimate with a high degree of accuracy the diameter and depth of the anterior chamber, the thickness of the cornea, the radius of curvature and the thickness of the lens in the central zone, the state (value) of the anterior chamber angle [28,31]. However, the possibilities of this technology are limited by the anterior chamber. Since the pigment sheet is a barrier to infrared rays, the light diagnostic signal is completely absorbed by the iris pigment and does not penetrate deep, which does not allow direct visualization and description of the structures of the posterior chamber of the eye [20,31]. For this reason, the possibilities of studying the lens located behind the iris are limited to a certain extent by the size of the pupil. To visualize the posterior chamber, this method can only be used in albinos [10].

In addition to non-invasive methods of optical research, invasive methods are also used in ophthalmology, for example, fluorescein angiography. Initially, it was used only to study the blood vessels of the fundus, and now it is also used to study blood circulation in the vessels of the iris, cornea, and sclera.

The essence of the method of fluorescein angiography is that the patient is injected intravenously with a dye solution - fluorescein and then a series of photographs is taken. This requires certain conditions. A dark blue lighting filter should be installed on the light source, passing only blue, violet and part of ultraviolet rays with a wavelength of more than 350 nm. Under the influence of such illumination, fluorescein, passing along with the blood through the vessels, emits a yellow-green light. In order to prevent this relatively weak glow from being suppressed by the blue-violet light reflected from the object, a so-called blocking filter is installed in front of the camera lens, which almost completely absorbs the reflected blue-violet light, but freely transmits yellow-green fluorescence. Thus, fluorescent blood vessels turn out to be light against a darker background [3,11,16].

Fluorescein angiography of the anterior segment of the eye is mainly used to differentiate tumors localized in the anterior segment of the eye. A symptom complex of angiographic signs, including early fluorescence of pathologically altered tumor vessels, intense filtration of the dye into the extravascular space, and late confluent fluorescence of the tumor with spread to the surrounding iris tissue, is

characteristic of malignant tumors [21].

Direct visualization of the "silent" zone of the eye is possible using the endoscopy method. Endoscopic systems are widely used for vitreoretinal operations, and can also help with cataract phacoemulsification in conditions of impaired corneal transparency [13,18,24]. For intervention, endoscopes are used, which include a fiber optic tip less than 1 mm thick (which expands the viewing angle due to elasticity), a xenon light source and a camera. The surgeon observes the picture on a nearby monitor of the endoscopic system. The equipment allows not only to receive an image in real time, but also to perform endolaser coagulation. It is clear that the use of an invasive endoscopic method in clinical practice is rather a rare phenomenon, not always feasible due to well-known reasons, and it is difficult to classify it as a purely diagnostic one.

Modern studies point to the leading role of the lens in the etiopathogenesis of relative pupillary block in patients with primary angle-closure glaucoma (PACG). Anatomical prerequisites for closing the angle of the anterior chamber (ACC) of the eye are: short axial size of the eye, shallow anterior chamber and thickening of the lens. These anatomical features, together with the growth of the lens, lead to the development of a relative pupillary block [1].

A number of authors noted that the removal of the lens contributes to the opening of the angle of the anterior chamber and the normalization of intraocular pressure (IOP) [2-5]. With the advent of ultrasonic biomicroscopy (UBM), interest in studying the topography of the anterior segment of the eye with an intravital assessment of its structures has increased.

Using UBM, K. Hayashi et al. [6] showed that in eyes with chronic PACG after cataract extraction, the anterior chamber significantly deepens and the angle of the anterior chamber widens. Y. Kurimoto et al. [7] also analyzed changes in the anterior segment of the eye after US phacoemulsification with implantation of a flexible intraocular lens (IOL) in 20 patients with age-related cataract.

The results of their studies showed that after the removal of the lens there is a statistically significant deepening of the anterior chamber and expansion of the trabecular-iridescent angle. A.S.F. Pereira and S. Cronemberger [8] performed UBM of the anterior segment of 21 eyes with PACG after US phacoemulsification.

The authors found that after this surgical intervention in patients with PACG there is a deepening of the anterior chamber by approximately 30%, an expansion of the angle by 50%, and the appearance of space between the posterior surface of the iris and the anterior surface of the lens.

There are many works in the literature devoted to the study of the spatial structures of the anterior segment of the eye in patients with PACG using UBM [9,11], and few studies [12] performed by optical coherence tomography (OCT). OCT of the anterior segment of the eye is a new method that allows you to get a detailed image of the anterior segment of the eye in 2 projections.

This method also has the ability to image the APC in 3

dimensions. OCT is of greater practical interest, as it is a non-invasive non-contact method of examination, it offers a quick and simple analysis of the structures of the anterior segment.

It provides high resolution scanning of the cornea and PDA and a pachymetry map at a rate of 4000 axial scans per second.

The development of any medical discipline from the past to the present day is inextricably linked with progress in the development of medical technology. Improving diagnostic methods that allow adequate and complete examination of the anatomical and functional state of the organ of vision is a necessary condition for the development of ophthalmology. Existing diagnostic studies can be divided into 2 groups: imaging and functional diagnostic methods. As is known, due to its anatomical and topographic advantages, the eye is one of the most visualized organs. Imaging is facilitated by routine and special diagnostic methods that are being developed and continuously improved.

Breakthrough powerful impulses that contributed to progress in ophthalmology were, for example, the invention of an ophthalmoscope by G. Helmholtz in 1851, which made it possible to examine the fundus of the eye, as well as the development of a slit lamp in 1911 by Gulstrand, which made it possible to study in detail the anterior segment of the eye. There are well-visualized and difficult-to-visualize structures in the eye. All structures located in front of the iris are "easy" for examination in the anterior segment, in the posterior segment - the optic disc and retina, and the structures that form the posterior chamber of the eye, the so-called "silent" zones, are inaccessible. In ophthalmic practice, it often becomes necessary to study the structures of the anterior segment covered by the iris (the posterior surface of the iris itself, elements of the posterior chamber, the ciliary body, up to the extreme periphery of the retina). In addition, in cases of reduced transparency of the cornea, it becomes impossible even to examine the elements of the anterior chamber. The use of existing imaging methods in such cases is ineffective.

In medicine, visualization is usually understood as methods for converting a radiation field invisible to the human eye (infrared, ultraviolet, x-ray, ultrasound, etc.) into a visible (black and white or color) image of a radiating object. In ophthalmology, optical (based on the use of electromagnetic radiation in the optical range) and beam (using ionizing radiation, magnetic resonance, ultrasonic radiation) diagnostic methods are used for visualization.

The technological breakthrough of the late 20th century contributed to the emergence of many special diagnostic methods "microimaging", i.e. obtaining images with a very high degree of detail of anatomical structures, bringing methods of in vivo diagnostics closer to morphological studies. Thus, confocal microscopy of the cornea allows for intravital visualization of all layers of the cornea at the cellular level. Progress in the development of methods for visualizing the posterior segment is more obvious and in demand. Among such studies are optical coherence

tomography of the retina, laser confocal scanning tomography of the optic nerve head and others. Thanks to this, the possibilities of diagnosing pathological conditions in the fundus have significantly expanded. At the same time, as regards the structures of the anterior segment covered by the iris and the adnexal apparatus of the eye, the possibilities of diagnostics remain at the same level. There are objective prerequisites for this, namely: the posterior segment is accessible to direct visualization, and the anterior segment is not even visible to the eye, so the problems of diagnostic difficulties in the "silent zone" of the eye remain unresolved.

Traditionally, in ophthalmology, the eyelids and the anterior part of the eyeball from the cornea to the irido-lens diaphragm are referred to the anterior segment of the eye, everything that is located behind it is commonly called the posterior segment. In this paper, the term "anterior segment of the eye" denotes the anterior pre-equatorial segment of the eyeball, the eyelids will be considered separately.

Until recently, to assess the condition of the anterior segment of the eye, as a rule, only traditional research methods were used. An indirect method for assessing impairments is based on the use of routine visometry (specifically, on determining the maximum visual acuity with correction). For direct assessment of the anterior segment of the eye, as a rule, the biomicroscopy method is used, in particular, using an optical section and diffuse coaxial illumination.

To "objectify" the results of biomicroscopy, a photographic technique was used, which was proposed by Allenprin ^ and then modified by other researchers, thanks to which it is possible to obtain a photographic image of the structures of the anterior segment of the eye along the axis of the slit-like beam and to measure some parameters of interest with varying degrees of accuracy.

This rather complicated method of quantitative assessment of the transparency of media, based on the Scheimpflug principle, is implemented in modern, commercially available devices by registering optical sections of the lens in various meridians, followed by densitometry. However, the possibilities of analysis based on measurements from a photographic image depend on the degree of transparency of the structures under study.

Gonioscopy is used to study the angle of the anterior chamber of the eye, namely to determine its shape and identify pathological changes in this area. The shape of the angle (width and profile) is evaluated by the degree of closure of the identification zones of the angle by the iris and by the distance of the root of the iris from the notch. If at a wide and medium angle all or almost all the structures of the angle are visible, then at a narrow or closed angle, most or all of the trabecular zone is covered by the iris root, and it becomes difficult to assess the APC parameters.

Goniolenses are also used for microcycloscopy, microsonulocopy and ophthalmoscopy of the periphery of the retina. However, the implementation of these studies is often difficult, which is associated with a strong decrease in illumination at the periphery of the fundus, in the area of the

ciliary body and zinn ligaments under conventional illumination methods, as well as with a large angle at which the rays exit the studied areas of the eye. Insufficient mydriasis or a violation of the transparency of optical media completely exclude the possibility of diagnostics.

Another direction of investigation of the anterior segment is based on the transmission of ultrasound. Keratopachymetry provides isolated information about the thickness of the cornea. To characterize linear parameters (corneal thickness, anterior chamber depth, lens thickness), ultrasound in A-mode is used (F.E. Fridman *et al.*, 1989). Linear values only indirectly reflect the state of the anterior segment as a whole, which is often far from sufficient.

Direct visualization of the "silent" zone of the eye is possible using the endoscopy method. Endoscopic systems are widely used for vitreoretinal operations, and can also help with cataract phacoemulsification in conditions of impaired corneal transparency (Neroev V.V., 1998; Andronov A.G., 1999; BaM K.A1. & a1, 2009). It is clear that the use of an invasive endoscopic method in clinical practice is rather a rare phenomenon, not always feasible due to well-known reasons, and it is difficult to classify it as a purely diagnostic one.

The introduction of high technologies into clinical practice has contributed to the emergence of a new generation of diagnostic equipment. Thus, a method of optical coherence tomography of the anterior segment of the eye appeared, based on the use of infrared rays with a wavelength of 1310 nm. Optical coherence tomography makes it possible to estimate the diameter and depth of the anterior chamber, the thickness of the cornea, the radius of curvature and the thickness of the lens in the central zone, the condition (value) of the anterior chamber angle. The visualization area using this technology is limited to the anterior chamber, since the pigment sheet of the iris is a barrier to infrared rays: being absorbed by the pigment, they do not penetrate deep into. The capabilities of optical coherence tomographs are to a certain extent limited by the size of the pupil, and therefore do not provide a full study of the structures located behind the iris. To visualize the posterior chamber, this method can only be applied to albinos.

A detailed study of the anterior segment of the eye from a clinical point of view is primarily important for the timely and adequate diagnosis of various pathological conditions accompanied by violations of anatomical structures, including inflammatory, tumor, traumatic, proliferative, degenerative, etc. In addition, it often becomes necessary to evaluate the results of various surgical interventions performed in the anterior segment of the eye.

With all the variety of diagnostic methods for examining and examining the anterior segment of the eye, which help in assessing individual parameters of isolated anatomical structures, the problem of adequate visualization and analysis of the spatial relationships of all elements of the anterior segment remains unresolved.

Despite the high information content of the above methods, some parts of the anterior segment of the eye, namely, the

posterior surface of the iris, the ciliary body, in practice often remain inaccessible to inspection. In addition, a lifetime study of the anatomical relationships of the structures of the entire anterior segment cannot be carried out by any of these diagnostic methods.

An analysis of world clinical experience and literature data indicates that at present, among the existing variety of optical and radiation methods used in ophthalmology, the only method for visualizing all elements of the anterior segment, including the "silent" zone of the eye (and with microscopic resolution), is ultrasonic biomicroscopy, developed and introduced into clinical practice in 1990 by SL. RauNp et al.

Despite the fact that the UBM method has been known for a long time, and, accordingly, a lot of experience in its use should be accumulated, there are few publications on clinical application, the possibilities have not been fully studied, there are no clear recommendations on the parameters of the study, there is not enough material on the results of diagnosing pathological conditions affecting individual structures of the anterior segment of the eye.

There are no large-scale studies on the use of the UBM method in ophthalmology in the domestic special literature. Reports on the use of UBM in the diagnosis of ophthalmopathy are rare, more often they affect a specific particular pathology, or are descriptive, which is not enough to introduce the method into wide clinical practice.

The interpretation of ultrasound results, which is often the basis for an accurate diagnosis, is highly dependent on the knowledge and skill of the operator. Perhaps lacking a base to provide training for specialist ultrasonic biomicroscope operators, medical institutions refrain from acquiring expensive ultrasound equipment, assuming that its use is unlikely to be cost-effective.

The developers of diagnostic equipment today have armed ophthalmologists with high-tech new equipment, the possibilities and advantages of which are fully revealed in the course of practical application. The diagnostic potential of the method of ultrasonic biomicroscopy can be revealed and used to the full if the interpretation of scans is carried out. clinical assessment. Perhaps the scope of UBM is even wider than it was envisaged by the developers of the device.

In 1990, Charles Pavlin et al reported the development of an ultrasonic biomicroscopy method for microvisualization of the anterior segment of the eye [20]. The term "ultrasonic biomicroscopy" was proposed by the authors of the method due to the fact that, like optical biomicroscopy, the new technology they developed provided lifetime (in vivo) visualization of eye tissues with very high (microscopic) resolution (acoustic microscopy). This level of detail of structures with micron precision was previously available only when studying preparations (in vitro). According to the authors of the method, due to the anatomical and topographic features that require shallow penetration of high-frequency ultrasonic waves for visualization, the eye is an ideal organ for the use of ultrasonic biomicroscopy.

High-frequency scanning in the range from 35 to 100

MHz, which is the basis of ultrasonic biomicroscopy, makes it possible to visualize a much smaller area in comparison with traditional B-scanning - only the anterior preequatorial segment of the eye - scanning depth from 15 to 2 mm. This is due to the wave nature of ultrasound and the peculiarities of its propagation in living tissues according to the laws of physics, as described above.

The most important parameters for ultrasound imaging in UBM (as well as for scanning using traditional methods) are attenuation (attenuation), reflectivity and propagation velocity of ultrasonic waves. Mathematical calculations carried out by C. Pavlin et al., taking into account that the propagation of ultrasound obeys the fundamental laws of refraction and reflection, and in accordance with the classical diffraction theory, showed that with radiation in the frequency range from 40 to 80 MHz, a resolution within 20-80 microns. This is at least 10 times the resolution of the traditional B-scan method. Since the loss associated with the attenuation (attenuation) of the waves increases almost linearly as the scanning frequency increases, the imaging area decreases significantly - from 5-15 to 2-4 mm.

The first commercial version of an ultrasonic biomicroscope (manufactured by Zeiss-Humphrey Inc, San Leandro, CA) was equipped with a 50 MHz transducer. The authors of the UBM method reflected the results of their clinical studies in a number of articles in various foreign sources [14,19], as well as in an atlas published in 1995 [21]. C. Pavlin and co-authors in their publications tried to demonstrate to the maximum extent the range of possibilities they discovered for visualizing eye structures using the UBM method. Most of the available articles published in the first years after the appearance of the method present the results of a rather limited number of studies on specific nosologies.

A more detailed in-depth analysis based on the accumulated experience was carried out by the authors of the method in subsequent years to identify US criteria and study the parameters of eye structures in assessing hydrodynamics, both in normal conditions and in glaucoma. C. Pavlin et al. proposed a method for assessing the "degree of openness" of the anterior chamber angle in linear terms, as well as an algorithm for measuring some parameters of the anterior segment of the eye, characterizing both individual anatomical structures and their relative position (trabeculo-ciliary distance, iridociliary distance, sclero-iris angle, sclero-ciliary angle, iris root thickness, etc.).

The research results are reflected in a number of publications 201 2-20 14. [14,19,40]. In addition to studies on various aspects of glaucoma diagnosis, C.Pavlin et al. applied UBM: to assess changes in the configuration of the iris during accommodation, inducing the development of pigment dispersion syndrome due to iridosonular friction [18]; to assess changes in the cornea after excimer laser photokeratectomy (in 12 patients) [16]; to determine the position of the supporting elements of intraocular lenses after suture transscleral fixation (in 17 eyes) [10]; to assess the degree of thinning of the sclera in a patient as a result of combined excision of conjunctival melanoma with

cryotherapy of the scleral bed [14,28]; to detect ultrasound signs of ligamentous apparatus disorders in 18 patients with clinically obvious subluxation of the lens due to pseudoexfoliation syndrome, spherophakia, Marfan's syndrome, as well as trauma, including surgical [8,13].

The UBM method gradually began to be introduced into the clinical practice of foreign ophthalmologists on different continents, as evidenced by the publications of ophthalmologists who have become familiar with the use of UBM. The authors analyzed the results of studies using ultrasonic biomicroscopy for various purposes. For example, studies by M. Marraffa *et al.* aimed at assessing the impact of laser interventions on the eye showed that the loss of the average density of endothelial cells is inversely proportional to the distance from iridotomy to the endothelium and scleral spur [11]. G. Mannino *et al.* used UBM to evaluate the results of fistulizing BUT: YAG laser interventions *ab externo* (namely, sclerostomy formation) in 10 eyes of patients with glaucoma [31,38].

Similar studies were carried out by other authors: P. Jacobi *et al.*, G. Haring *et al.* and others [13,17].

J. McWhae *et al.* studied the features of the ultrasound picture during the formation of a functional and non-functional filtration cushion in 46 patients after trabeculectomy [24].

D. Kazakova *et al.* used UBM to study surgically formed fluid outflow tracts in the long-term period after deep sclerectomy, when resorption of the implanted collagen drainage took place (43 eyes of 32 patients).

The authors revealed the relationship between the type of filtration cushion and the degree of intraocular pressure compensation [22]. In available sources, there are publications of other researchers on the results of ultrasound evaluation of surgical treatment of glaucoma (A. Chiou *et al.*, G. Marchini *et al.*, F. Aptel *et al.*, L. Cabrejas *et al.* and others) [11,19,23].

S. Matsumura *et al.* published the results of studying the ultrasound picture of changes in the eyes with anterior hyaloid fibrovascular proliferation that developed in 5 eyes of patients after vitrectomy for proliferative diabetic retinopathy [24,40]. Similar studies to visualize changes in eye structures around sclerotomy zones were carried out by M. Bhende *et al.*, K. Hotta *et al.*, V. Hershberger *et al.* and others [5,9,18].

D. Doro *et al.* a combined diagnosis of intermediate uveitis was performed using UBM scanning at an emitter frequency of 20 and 50 MHz [30]. Research conducted by K. Greiner *et al.* in 15 patients with pars planitis showed that UBM makes it possible to assess the structural changes that occur in pars planitis, and therefore can be used in the diagnosis and monitoring of treatment outcomes, especially in patients with a decrease in the transparency of optical media [23,27].

N. Mungan *et al.* examined the eyes of 6 patients with nephropathic cystinosis to detect ultrasound signs of pathological changes in the structures of the eye observed in this disease. According to the authors, a change (decrease) in the depth of the anterior chamber and the configuration of the

ciliary body (as in the "flat iris syndrome"), as well as the presence of crystals in the trabecular meshwork detected during gonioscopy, are prerequisites for the development of glaucoma in this group of patients [1,4,20,21,22].

J. Ma *et al.* UBM was used to assess dynamic changes in the configuration and size of the ciliary body of 68 eyes in normal conditions under close accommodation conditions. A statistically significant change in a number of parameters was revealed, including an increase in the thickness of the anterior part of the ciliary body and the length of the ciliary processes, as well as a decrease in the width of the ciliary processes, the distance between the ciliary processes and the trabecula, iris, scleral spur, and a decrease in the linear width of the anterior chamber angle [18,19,24,25,26].

The UBM method appeared in the "armament" of domestic ophthalmology after 1994. Opportunity to use an ultrasonic biomicroscope for the first time was given to specialists from the IRTC Eye Microsurgery in Moscow. The sphere of scientific interests, including the problems of diagnosing glaucoma and analyzing the results of its surgical treatment, is reflected in the works of D.G. Uzunyan and H.P. Takhchidi *et al.* [15,16,17,27,29]. In their work, the authors used UBM to identify the symptoms of pseudoexfoliative syndrome. When evaluating the results of surgical treatment of glaucoma, the acoustic criteria of the fibroplastic process in patients in the area of antiglaucoma operations were determined, on the basis of which the stability of the results obtained was predicted. D.G. Uzunyan and his colleagues described in detail the possibilities of UBM for assessing the parameters of a surgically formed drainage path.

### 3. Result and Discussion

The studies of A.A. Sarukhanyan, devoted to the study of the anatomical and topographic features of the anterior segment of the eye using the UBM method in cataracts in combination with glaucoma and pseudoexfoliative syndrome, showed that an increase in the thickness of the lens with the progression of cataract opacities leads to a reduction in linear and angular parameters determined during the UBM study and thus creates favorable conditions for the occurrence of intraocular blocks [12,13,14,38,40].

In studies by U.S. Faizieva *et al.*, UBM was used to study the anatomical structure of the anterior segment of the eye in Uzbeks, as well as to assess the clinical significance of the identified distinctive features in the conditions of angle-closure glaucoma [4,6,10,11,36,37].

In domestic sources, there are single publications of other authors. Thus, V.V. Strakhov, M.A. Buzykin, L.A. Mineeva, using UBM, assessed the accommodative apparatus of the eye in young people and involutional changes in patients with presbyopia [7,8,30,31,32]. The authors reported on the detection, according to UBM data, of a significant decrease in the orbicular space of the posterior chamber of the eye, up to its transformation into a slit-like space in presbyopes; about various changes in the topography of the middle and posterior portions of the ligaments and the direction of their

course in the orbicular space of the posterior chamber of the eye in young and elderly people. The involuntional decrease in the volume of accommodation, according to studies, is associated with the constant growth of the lens and the resulting decrease in the main working distance of accommodation between the lens equator and the dentate line of the retina.

V.V. Strakhov et al. made an interesting attempt to study in a group of volunteers aged 20-25 years the functional state of the accommodation apparatus and the hydrodynamics of the eye at rest of accommodation and on drug models of accommodation tension near and the state of disaccommodation [5,34,35,36]. The totality of the data obtained as a result of ultrasound and biomicroscopic studies of the anterior segment of the eye allowed the authors to conclude that with accommodation tension near, the outflow of aqueous humor through the trabecula and Schlemm's canal increases and the outflow along the uveoscleral pathway decreases, and with deaccommodation, on the contrary, a decrease in outflow fluid through the drainage system is compensated by an increase in outflow along the uveoscleral pathway.

G.V. Shkrebet et al. used UBM to evaluate the features of the anterior and posterior chambers of the eye in patients with primary open-angle glaucoma and high myopia [3,8,9,33]. The study showed that one of the pathogenetic factors in the development of primary open-angle glaucoma with high myopia is a change in the anatomical and topographic relationships of the structures of the anterior and posterior chambers of the eye of a congenital and acquired nature.

A.G. Shchuko reported on the structural features of the anterior segment of the eye revealed by UBM in patients with pigment dispersion syndrome, patterns of changes in the volume and configuration of the posterior chamber of the eye in these patients after laser iridectomy [2,28]. According to the author, after iridectomy, the position of the iris changes, the depth of the anterior chamber remains stable, but the configuration and area of the posterior chamber of the eye change significantly. This leads to the fact that the iris takes on a normal configuration, friction in the iridosonular zone stops and the reverse pupillary block is eliminated.

E.E. Nesterova proposed to make an individual choice of the method of surgical intervention in patients with primary open-angle glaucoma, based on the clinical and anatomical classification of the structure of the iridociliary zone, developed on the basis of the study of the anatomical and topographic parameters of the eyes using ultrasound biomicroscopy [1,39].

Thus, the above results, obtained by both foreign and domestic ophthalmologists, convincingly testify to the obvious advantages of the method of ultrasonic biomicroscopy over all existing methods, which consist in the possibility of intravital visualization of all anatomical structures of the anterior segment (conjunctiva, cornea, anterior chamber, sclera, iris, lens, ligamentous apparatus, ciliary body, anterior vitreous body), including in conditions

of reduced transparency of optical media.

Along with this, both in the domestic and in the available foreign literature there are no sources that adequately reflect the information content and capabilities of UBM for diagnosing various pathologies affecting the structures of the anterior segment of the eye, there are no clear recommendations on the research algorithm. Reports on the use of the method are rare, often descriptive, affecting a limited private pathology (mainly devoted to the analysis of the parameters of the structures of the eye in glaucoma or the assessment of the results of its surgical treatment), which is not enough for the active introduction of the method into wide clinical practice. In our opinion, the unique possibilities of UBM and the scope of this method in the diagnosis of various pathologies, in the choice of indications and technology of surgical interventions, in predicting the effectiveness and evaluating the results of medical and surgical treatment of various diseases have not been fully disclosed. All this necessitated the present work.

Ultrasonic biomicroscopy (UBM) of the anterior segment uses high-frequency probes (50 MHz) to produce a high-resolution image (approximately 50  $\mu\text{m}$ ) to allow viewing *in vivo* anterior segment of the eye (penetrating depth - 5 mm). In addition, the anatomic relationships of structures surrounding the posterior chamber that are obscured by clinical examination can be visualized and assessed.

Ultrasound biomicroscopy is used to study the normal structures of the eye and the pathophysiology of eye diseases, including the cornea, lens, glaucoma, congenital anomalies, the effects and complications of anterior segment surgery, trauma, cysts and tumors, and uveitis. The method is important for understanding the developmental mechanisms and pathophysiology of angle closure, malignant glaucoma, pigmentary dispersion syndrome, and filter pads. Studies using ultrasonic biomicroscopy are qualitative. Quantitative and three-dimensional image analysis of ultrasonic biomicroscopy is still at an early stage of development.

Ultrasound biomicroscopy is ideal for examining angle closure as it can simultaneously image the ciliary body, posterior chamber, iridolenticular relationship, and angle structures.

It is important in the clinical assessment of possible occlusion of the narrow angle of the eye to perform gonioscopy in a completely darkened room using a very small light source for the slit lamp beam to avoid pupillary light reflex. The effect of external light on the shape of the angle is well shown when performing ultrasonic biomicroscopy under illumination and dark conditions.

Trabecular meshwork is not visible with ultrasound biomicroscopy, but during the study, a scleral spur located posteriorly is determined. On the ultrasound biomicroscopy image, the scleral spur is visible as the deepest point on the line separating the ciliary body and the sclera at their point of contact with the anterior chamber. The trabecular meshwork is anterior to this structure and posterior to the Schwalbe line.

Angle -closure glaucomas are classified based on the

placement of anatomical structures or forces that cause the iris to close the trabecular meshwork. They are defined as a block originating at the level of the iris (pupillary block), the ciliary body (flat iris), the lens (phacomorphic glaucoma), and forces posterior to the lens (malignant glaucoma).

Swelling of the lens causes a marked decrease in the depth of the anterior chamber and leads to the development of acute angle-closure glaucoma due to the pressure of the lens on the iris and ciliary body and their displacement anteriorly. During treatment with miotics, the axial length of the lens increases, inducing an anterior displacement of the lens with a subsequent reduction in the anterior chamber, which paradoxically worsens the situation as a result.

Malignant glaucoma (ciliary block) is a multifactorial disease in which the following components play a different role: previous acute or chronic angle -closure glaucoma, shallow anterior chamber, anterior displacement of the lens, pupillary block of the lens or vitreous body, weakness of the zinn ligaments, rotation of the ciliary body anteriorly and / or its edema, thickening of the anterior hyaloid membrane, an increase in the volume of the vitreous body and the movement of intraocular fluid into the vitreous body or posteriorly from it. Ultrasound biomicroscopy reveals a small supraciliary detachment not seen on routine B -scan or clinical examination. This detachment appears to be the cause of anterior rotation of the ciliary body.

The intraocular fluid secreted behind the lens (during the posterior displacement of aqueous humor) increases the pressure of the vitreous body, which shifts the iridolenticular diaphragm forward, causing the angle to close and the anterior chamber to shrink.

Ultrasonic biomicroscopy determines the wide open angle. The mid- peripheral portion of the iris has a convex shape (reverse pupillary block) presumably creating contact between the iris and the anterior ligaments of Zinn, with greater contact between the iris and the lens than in the healthy eye. It is believed that this contact prevents even distribution of intraocular fluid between the two chambers, leading to an increase in pressure in the anterior chamber. With accommodation, the convexity of the iris increases.

When blinking is suppressed, the iris takes on a convex shape, which returns to its original state when blinking, which indicates the participation of the act of blinking as a mechanical pump for pushing intraocular fluid from the posterior chamber to the anterior one.

After laser iridotomy, the pressure difference between the posterior and anterior chambers disappears, reducing the bulge of the iris. The iris takes on a flat or flattened shape.

## 4. Conclusions

A deep chamber in the center and shallow on the periphery may be a sign of pupillary block due to posterior synechia. It is also necessary to conduct a comparative assessment of the depth of the chamber in both eyes.

An indirect assessment of the width of the angle of the

anterior chamber is carried out according to the Van Herick method: behind a slit lamp, a narrow light slit illuminates the periphery of the cornea at an angle of 60° as close as possible to the limbus. As a rule, the study begins with illumination of the opaque area of the limbus, smoothly moving the light gap to the cornea until a strip of light appears on the periphery of the iris. The light band of the optical section of the cornea, the band of light on the surface of the iris, and the distance from the inner surface of the cornea to the iris are visualized.

The width of the angle of the anterior chamber is judged by the ratio of the thickness of the optical section of the cornea (OSR) to the distance "cornea-iris" (RRR). This test allows an indirect evaluation of the CAA and cannot serve as an alternative to gonioscopy.

The use of the UBM method significantly expands the possibilities of qualitative and quantitative assessment of the topographic and anatomical relationships of the structures of the irido- ciliary zone of the eyes in glaucoma.

Patients with advanced and terminal primary and secondary glaucoma have narrower trabeculo-iris (TAR), sclero - iris and sclerociliary angles than in healthy individuals, as well as a smaller angle opening distance.

A decrease in the APC value in the advanced and terminal stages of glaucoma can be considered as a feature of the late stages of the glaucomatous process.

The progressive increase in the volume of the lens in the compared groups of eyes was accompanied by a significant progression of the APC blockade, both in profile and in length.

In glaucoma, the depth of the anterior chamber is assessed. Normally, in the pupil area, it is 2.75-3.5 mm. Depending on the depth, a deep chamber is distinguished (with pseudophakia, high myopia), medium depth and shallow or slit-like with angle-closure glaucoma; the anterior chamber may also be absent.

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