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OPTIMIZATION OF ANTERIOR CHAMBER ANGLE IMAGING APPROACH USING ANTERIOR OPTICAL COHERENCE TOMOGRAPHY IN GLAUCOMA (REVIEW ARTICLE)

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Introduction. Glaucoma remains one of the leading causes of irreversible blindness worldwide, posing a significant threat to eye health. The most important aspect in managing glaucoma is early diagnosis and monitoring of the disease to prevent disease progression and vision loss. In recent years, significant advances in diagnostics have been made with the introduction of anterior optical coherence tomography (AOCT), which provides highly accurate visual representation of the anterior chamber angle and structures of the anterior segment of the eye. This method has become an important tool in the evaluation of patients with glaucoma, allowing the degree of angle closure to be determined and timely measures to be taken to prevent progression of the disease.

Optimizing the approach to visualizing the anterior chamber angle using AOCT requires constant development and improvement of technologies, as well as a deep understanding of the mechanisms of glaucoma development. The development of data processing algorithms and angle assessment criteria, along with other research, may offer new opportunities for early diagnosis and individualized treatment of patients with glaucoma.

Thus, optimizing the use of AOCT in the diagnosis and monitoring of glaucoma is a promising direction in ophthalmology, which can significantly improve the prognosis and quality of life of patients with this pathology. A key aspect of success is interdisciplinary collaboration between researchers, clinicians and technology developers to create improved research methods.

When performing anterior optical coherence tomography (OCT) of the anterior segment, an infrared laser is used and no contact is required during the examination, which allows you to examine the structure of the anterior chamber of the eye in the dark. This makes it possible to obtain valuable quantitative and spatial information about changes in the angle of the anterior

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chamber, which cannot be obtained by standard gonioscopy. Thus, AOCT is an informative method for assessing and analyzing the anterior segment in glaucoma [1, 2, 12].

The purpose of the ongoing research is a comprehensive analysis of modern methods for optimizing visualization of the anterior chamber angle using AOCT for the purpose of diagnosing and managing patients with glaucoma. The article aims to assess the potential of AOCT as an advanced technology that promotes early detection and more accurate prediction of the progression of the glaucomatous process.

The diagnostic value of OCT in ophthalmology continues to grow, especially in the detection of glaucoma. OCT provides important information about the structures of the anterior eye, which facilitates early detection and monitoring of disease progression. In this section, we review some of the key studies and findings regarding the use of OCT for the diagnosis of angle-closure glaucoma.

OCT makes it possible to evaluate structural changes in the anterior segment of the eye, as well as in the area of the anterior chamber angle and the optic nerve. Monitoring changes using OCT allows doctors to timely adjust treatment and prevent disease progression.

Anterior segment OCT allows visualization of the anterior chamber angle and provides quantitative assessment of its parameters, such as the opening angle and depth of the anterior chamber, which is key in the diagnosis of glaucoma. Studies show that OCT can detect various changes in the anterior chamber angle, whereas traditional methods such as gonioscopy may not detect these abnormalities [6]. All this makes it possible to detect the disease early and begin adequate treatment before damage to the optic nerve develops.

AOCT allows high-resolution, non-invasive visualization of structures in the anterior part of the eye, including the anterior chamber angle. This is especially important for assessing the anterior chamber angle, which plays a key role in the development of glaucoma. AOCT of the anterior segment provides highly accurate images of the structures of the anterior chamber of the eye, allowing one to assess the angle, depth of the anterior chamber, the state of the iridocorneal angle, the presence or absence of angle block, as well as measure the thickness of the cornea and the volume of the anterior chamber [16].

In addition, the use of this information is especially important for choosing the most appropriate treatment method, such as laser iridotomy or deep sclerectomy.

Authors such as Wagner I.V. and colleagues (2022), emphasize the importance of innovative methods of diagnosis and patient management, including the use of AOCT to more accurately assess the anterior chamber angle [13]. These studies confirm that AOCT is capable of detecting angular changes that may not be visible with traditional gonioscopy, thereby providing an opportunity for early diagnosis and prevention of disease progression.

In turn, researchers such as Lin S.C. and colleagues (2007), discuss the benefits of AOCT in identifying patients at high risk of developing glaucoma and in monitoring the effectiveness of treatment. They note that AOCT provides important data on the morphology of the anterior chamber angle, which makes it possible to more accurately assess the condition of the angle and select the most effective treatment methods [8].

Mansouri K. and colleagues (2013) studied the impact of innovative technologies, including AOCT, on the management of patients with glaucoma. They emphasized that the use of AOCT data with other diagnostic methods, such as intraocular pressure measurement and retinal analysis, can significantly improve the diagnostic accuracy and effectiveness of glaucoma treatment [9].

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In a study conducted by Xu et al. (2019) [15], classifiers were developed and tested that examine the state of the anterior chamber angle based on a fully automated analysis of AOCT results. This study showed that classifiers can effectively detect anterior chamber angle closure, facilitate automated clinical assessment of anterior chamber angle status, and improve ophthalmologist surveillance and monitoring in a population at increased risk of developing complications.

Yang et al. (2023) in their study [16] developed a new method based on an automatic study of the state of the iris and scleral spur on AOCT images, with which it is possible to calculate the parameters of the anterior chamber angle of the eye. This method showed the most accurate information content compared to existing methods of AOCT analysis.

OCT of the optic nerve allows you to assess the thickness of the nerve fibers, the shape and size of the optic disc, as well as the presence of cavities or other structural changes indicating the progression of glaucoma. These parameters are crucial for monitoring the effectiveness of treatment and adjusting therapeutic treatment [15].

Systematic monitoring using OCT allows not only to assess the current condition of the eye, but also to predict the risk of disease progression. Changes in parameters measured by OCT may indicate the need for treatment adjustments even before the onset of clinical symptoms, deterioration of vision, or significant increases in intraocular pressure.

Laser peripheral iridotomy, often used to treat glaucoma, is aimed at restoring the natural outflow of fluid from the anterior chamber of the eye. OCT allows you to evaluate the results of this procedure by measuring the anterior chamber angle in order to prevent possible complications [10].

A study by Xie Q. et al (2022) shows that OCT plays a key role in studying and comparing anterior segment structures in patients with primary glaucoma and control subjects with similar anterior chamber depth but without anterior chamber angle closure.

The study demonstrates the value of AOCT for assessing anterior chamber angle parameters such as open angle area and trabecular-iris space area at different distances (250 μm, 500 μm, and 750 μm) from the scleral spur. These parameters revealed significant differences between the narrow-angle glaucoma (NAG) group and the control group, indicating a narrower iris root angle in NAG patients, especially in the oblique and vertical axes.

The role of AOCT in this study is that while identifying structural differences, AOCT can accurately measure and compare the structural parameters of the anterior segment of the eye in patients with CAG (closed-angle glaucoma) and in the control group, even if their anterior chamber depth is the same. The method helps to evaluate the structural features of the anterior chamber, which may contribute to the development of glaucoma.

Research by Raluca M. (2015) is notable for its detailed analysis and presentation of specific data on various methods of imaging the anterior segment of the eye for the diagnosis of glaucoma. The findings illustrate the contributions and benefits of modern imaging techniques in diagnosing glaucoma, providing a more accurate and less invasive alternative to traditional methods such as gonioscopy.

In the studies of Raluca M. et al (2015) [12], high frequency UBM (50-80 MHz) allows visualization of anterior segment structures with a lateral resolution of 50 microns and an axial resolution of 20 microns. The new generation of linear UBM (ultrasound biomicroscopy) probes simplifies the procedure by minimizing lateral distortion and eliminating the need for a special eye bath during image acquisition.

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In turn, AOCT offers a transversal resolution of 60 microns and an axial resolution of 10-20 microns, which allows one to obtain high-quality images of the anterior segment of the eye. However, it is important to note that certain structures, such as the ciliary body, may be invisible due to light absorption by the sclera and iris. The authors, using rotating Scheimpflug imaging technology in Pentacam OCT, studied that the technique was able to measure anterior chamber depth (ACD) and anterior chamber volume (ACV) with high accuracy. For example, studies have shown that the use of a 2% pilocarpine solution reduces the central ACD by 97 microns and the ACV by 5.7 mm^3, which is not statistically significant, but has an angle opening effect. In a study, Pentacam was proven to have a sensitivity of 88.37% and a specificity of 90.62% when using ACD as a criterion for diagnosing narrow angles, highlighting the effectiveness of Pentacam as a screening method for detecting glaucoma [12].
The study by Ni Ni S. et al (2014) makes a significant contribution to the diagnosis of glaucoma using AOCT. The novelty of the work lies in the development of a method that uses analysis of the shape of the iridocorneal angle to determine the type of glaucoma. For the first time, a comprehensive analysis is proposed based on six parameters, including the average angle opening distance, the area of the angle's trapezoidal profile, the average iris curvature, the fractal dimension for assessing angle closure, and the angle in degrees. Using the developed classifier, the researchers achieved data accuracy of up to 99.11% ± 0.76% and an angle area index of up to 0.98 ± 0.012. This indicates the high efficiency of the proposed method in identifying the type of glaucoma. The analysis was carried out on 264 AOCT images of 148 patients, which emphasizes the scale and reliability of the study. The proposed analysis of the shape of the iridocorneal angle using fractal dimension and other morphological parameters is an effective approach in assessing the risk of developing glaucoma.
The above data highlight the potential of AOCT as an effective method for the early diagnosis of glaucoma. The study demonstrates the integration of several parameters using modern research methods, which can significantly improve the diagnosis of complex ophthalmic diseases, in particular glaucoma [10].
The development of a method for automatically measuring the anterior chamber angle parameters obtained using anterior segment optical coherence tomography has significantly increased the possibilities of diagnosing and treating primary glaucoma. A study by Yang G. et al (2023) demonstrates the prognostic value of AOCT in several aspects. The study covered 3305 AOCT results of patients with glaucoma, according to which the high effectiveness of this method was proven.
The algorithm demonstrated significant efficiency compared to existing methods for analyzing AOCT results, the accuracy of which was 0.941, sensitivity 0.914, F1-score 0.927, and the average absolute error of 37.1 ± 25.3 μm for the iris root, for the scleral spur, respectively, 0.805, 0.847, 0.826 and 41.4 ± 29.4 microns.
The method allows us to evaluate the effectiveness of surgical treatment of cataracts with IOL implantation in patients with glaucoma and high myopia who have a potential risk of developing glaucoma.
Thus, the proposed method has high potential for use in clinical practice for screening, treatment and prevention of glaucoma due to an automated and accurate method for measuring anterior chamber angle parameters based on AOCT indicators [16].
AOCT also plays an important role in monitoring the effectiveness of glaucoma treatment. After laser peripheral iridotomy or iridoplasty. AOCT can be used to assess changes in the

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anterior chamber angle and monitor the course of the postoperative period [7]. This allows doctors to tailor the treatment plan according to the individual patient.

In addition, AOCT can serve as a prognostic method to assess the risk of glaucoma progression. Measurements performed with AOCT, such as iris thickness and anterior chamber depth, can predict the risk of developing the disease in patients with suspected glaucoma [5]. This facilitates the early identification of patients at high risk of developing the disease and requiring urgent intervention.

For many years, the main method for studying the anterior chamber angle (ACC) has been gonioscopy using a slit lamp. Although clinically effective, this method has low reproducibility for patient follow-up and clinical research. The development of several imaging technologies in recent years has aimed to improve the assessment of ACC and overcome the limitations of gonioscopy. Recent advances include three-dimensional and 360-degree analysis using SS-OCT. Unlike gonioscopy, it was the first to allow circumferential assessment of the degree of angle closure from moderate to severe. Research algorithms show encouraging results from automated image analysis, which can potentially save clinicians time when interpreting results [11].

Yoshihara N. et al. (2022) in their research discovered new practical value of AOCT. They propose a new method for quantitatively assessing the presence of fine particles of epithelium and pigment in the anterior chamber of the eye, which in turn serves as an important criterion for the subjective assessment of the inflammatory process. This study demonstrates the effectiveness of AOCT to detect structural and inflammatory changes in the anterior chamber of the eye [17].

Conclusion. When confirming the diagnosis of glaucoma, although gonioscopy is the gold standard for diagnosing the condition of the anterior chamber angle, AOCT allows for additional assessment of the structure of the anterior chamber angle, which is an important criterion in confirming the diagnosis and assessing the stages of the disease. Most importantly, by comparing the structural parameters of the anterior segment in patients with glaucoma, it is possible to determine the cause of the development of the disease. Parameters measured by OCT, such as angle area and trabecular-iris space area, can be useful in assessing the risk of developing glaucoma in people with a narrow anterior chamber angle (NACA), which is important for early detection and prevention of disease progression [14]. .

Anterior optical coherence tomography (AOCT) is used as a highly accurate, non-invasive diagnostic method that allows one to obtain detailed images of the structures of the anterior segment of the eye, which is important for diagnosing and studying the pathogenesis of the glaucomatous process.

AOCT is a modern technique in the diagnosis and monitoring of glaucoma, which is confirmed by numerous studies. This technique allows non-invasive and high-precision visualization of the anterior chamber angle and structures of the anterior segment of the eye, providing valuable quantitative and spatial information about dynamic changes in angle configuration.

The use of AOCT in ophthalmological practice significantly improves the possibilities of early diagnosis of glaucoma, provides accurate prediction of disease progression and allows the development of individual treatment regimens for patients.

Systematic monitoring using AOCT makes it possible to evaluate the effectiveness of treatment, prevent the risk of disease progression and adjust the therapeutic treatment of the disease before the appearance of clinical symptoms, deterioration of vision or increased

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intraocular pressure. Thus, AOCT plays a key role in optimizing approaches to the treatment of glaucoma: from the use of antihypertensive therapy to more complex surgical interventions. Overall, the prognostic value of AOCT in the context of glaucoma is undeniable. This method not only ensures correct diagnosis, but also expands the ability to determine the pathogenetic aspects of the development of the disease, contributing to the development of new approaches to the treatment and prevention of glaucoma.

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