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MODELLING THE INFLUENCE OF CONJUNCTIVATHICKNESS ON TENSION DISTRIBUTION AND DEVELOPMENT OF CHILDHOOD GLAUCOMA

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Introduction. *Glaucoma is an ophthalmological disease that is detected at birth or during life, where its development without treatment leads to severe consequences - blindness. Cases of partial or complete loss of visual functions in children due to increased intraocular pressure (IOP) are increasingly being detected, and this figure is constantly increasing in Eastern European countries (1-2 cases per 2500 newborns are registered). The appearance of this disease, its course and complications depend on the intraocular pressure, which at birth is 9-12 mm Hg. st., and later increases, reaching a maximum of 22-45 mm Hg. st. already in adulthood. Therefore, it is necessary to monitor IOP even in the early stages of development of the child's body.*

Main purpose of this study *Timely detection of the disease in the early stages of is an extremely important problem in glaucoma and allows you to use drug treatment with a positive effect. In childhood, during growth, the parameters of the eye change, including the thickness of the eye membrane, its elasticity, which have a significant impact on the pressure distribution and the possibility of glaucoma. The authors conducted a simulation of the impact of changes in the thickness of the eye membrane on the distribution of stresses, which can lead to the occurrence of glaucoma..*

Conclusions *During the modeling process, it was determined that within the thickness of the eye membrane of 0.1-0.3 mm and the pressure of 9-14 mm Hg. optimal tension of less than 100 kPa is provided. Raising IOP values more than 21 mm Hg. leads to a sharp increase in tension (>150 kPa) and the progressive development of glaucoma. Recommendations include preventive examination, IOP control when the thickness of the eye membrane changes, possible stages of drug and surgical treatment.*

Keywords: *childhood glaucoma; intraocular pressure; eye tension; drainage devices.*

Introduction

In children's ophthalmology, there are some cases of partial or complete loss of visual functions in children, which is characterized by an increase in intraocular pressure (IOP) and due to changes in the conditions of exposure to eye diseases, this figure is constantly increasing in European countries [1, 2]. In glaucoma, visual impairment significantly reduces the level of information perception and aggravates the pathological condition with progressive death of ganglion cell axons, which causes complete loss of the visual field. Some well-known modern methods of treating glaucoma are the following: drug therapy, laser therapy and surgical implantation of drainage devices, which provide the necessary rate of the intraocular fluid removal (normally it is 2-2.5 μl/min) almost stably.It is known that the implantation of drainage devices in glaucoma is performed after unsuccessful previous attempts at conservative treatment and due to a decrease in the speed of movement and insufficient outflow of intraocular fluid through the trabecular meshwork of the eye [3-5]. Normal IOP values for children are lower than for adults: the norm for newborns is approximately 9-11 mm Hg, and by the age of 4-5 this figure increases to 14 mm Hg. Therefore, with a constant increase in IOP, which can often occur, before a planned surgery, it is necessary to carry out an individual selection of implants with reasonable parameters for an individual patient.

The main clinical sign of glaucoma in children is a significant increase in IOP (more than 22 mm Hg and above), and in some cases even low pressure in this range may be considered unacceptable. The detection of IOP leads to the action of high pressure on the conjunctivaand, accordingly, on the optic nerve [4-6]. This creates a force that changes the shape and stretches the thin conjunctiva. In these conditions, tension is defined as the ratio of pressure to the actual size of the conjunctivaon which it acts.

It should be noted that performing surgery and installing a regulating valve, for example, of the Ahmed type, is a complex process that can be used if the use of drug therapy has not achieved results and further deterioration of the child's vision is noted. Making a decision to perform surgery as the only option to prevent vision loss in a child depends on many factors: the choice of the valve and the use of high-quality material elements, checking the modes of its timely operation (the magnitude of the pressures of its opening and closing), the mandatory technological inspection on special stands, etc. [7, 8]. It is also important to correctly assess the state of the eye during its functioning and the magnitude of the tension level in it. The purpose of this study is to conduct modelling of the child's conjunctivatension at different pressure parameters and sizes of the eye conjunctivathickness in order to further take it into account in the period before surgery, which will further increase the effectiveness of surgical intervention.

Modelling the influence of conjunctiva thikness on tension distribution

It is known that the size of a child's eye at birth is on average 16.2 mm. By the 1st year of life it increases to 19.2 mm, and at the age of 15 it is equal to 23 mm, which is already practically approaching the average size of an adult's eye, namely 24 mm. Since the shape of the child'sconjunctivais not perfectly spherical (Fig. 1), its radius of curvature is variable: it increases from the front to the back and in the central part of the cornea its radius of curvature is approximately 7 mm, on the periphery of the cornea it is already 9 mm, in the anterior part of the sclera - 11 mm, and in its posterior part - 12 mm.

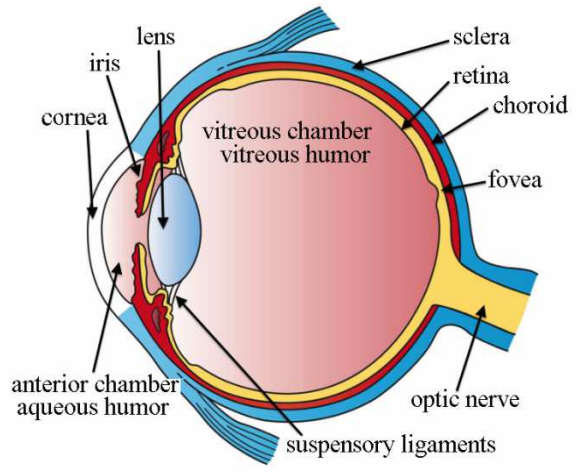

Fig. 1 Human eye anatomy

Also, the thickness of the sclera is not the same in different areas: in the posterior pole of the eye it is almost 1 mm, near the edge of the cornea - 0.6 mm [5].

Considering the above parameters of the eye, we can proceed to the modelling of tensions.

Since the wall thickness of the spherical conjunctiva of the eye (Fig. 2) is much smaller than the radius of its curvature, to calculate the tension per unit area of the cross-sectional area of the TS eye conjunctiva, it is advisable to use the Young-Laplace formula [9], where all the necessary values can be taken into account - the parameters of the intraocular pressure, the parameters of the conjunctiva and the cornea:

$$T_s = \frac{\mathrm{Pr}_k}{2d}, \qquad (1)$$

where, P is intraocular pressure (IOP); r_k – radius of curvature of the cornea of the eye; d – thickness of the eye conjunctiva.

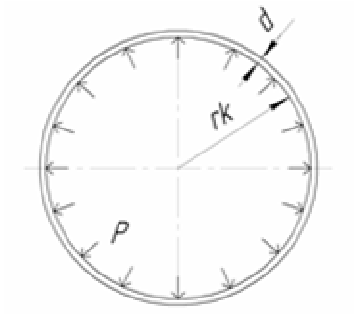

Fig. 2. Image of tension action in the spherical conjunctiva

Since the shape of a child's eye is elliptical, to calculate the tension per unit of the cross-sectional area $T\varphi$ it is necessary to apply a more accurate formula (2) that uses clarifying coefficients, which provides more accurate results:

$$T_\varphi = \frac{P}{2bd}\sqrt{r^2(b^2-a^2)+a^4}, \qquad (2)$$

where: P is intraocular pressure (IOP); a – larger diameter of the conjunctiva; b – smaller diameter of the conjunctiva; r – coefficient determined from the ratio:

$$r = \sqrt{\frac{a^4}{2(b^2-a^2)}}, \text{ at } (a>b). \qquad (3)$$

Based on the above ratios (1) – (3), the authors have constructed graphs of the dependence of tensions on different conjunctiva thicknesses, taking into account the parameters of the child's eye at different IOPs. The distribution of tensions in the posterior segment of the conjunctiva on the conjunctiva thickness is given below (Fig. 3).

In the process of modelling, based on the calculations and results obtained, it can be stated that with IOP in the range of 9 mm Hg - 14 mm Hg (normal in children) [10], optimal tension of less than 100 kPa is ensured. An increase in IOP values significantly more than 21 mm Hg leads to a rapid increase in tension (>150 kPa) and the creation of conditions for the development of glaucoma.

So, in IOP from 21 mm Hg up to 40 mm Hg, the tension increases almost 2 times or more, especially with a conjunctiva thickness of less than 0.6 mm. In this mode, the process of glaucoma is diagnosed, which ultimately leads to damage to the optic nerve and, as a result, to the child's vision loss.

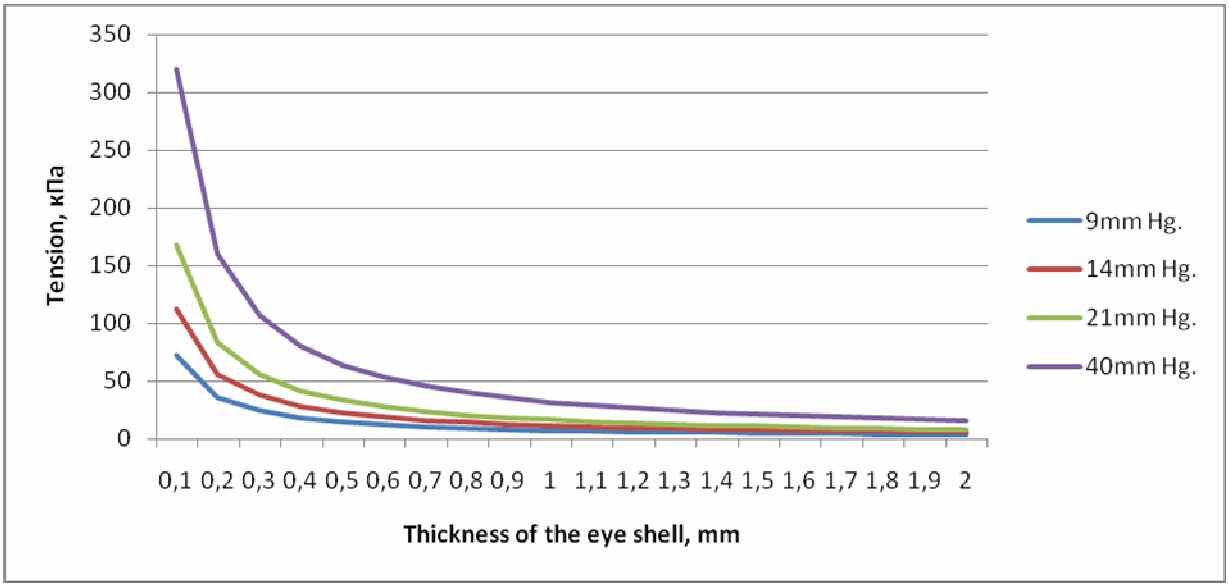

Fig. 3. Dependence of the posterior conjunctiva tensions on its thickness, with a curvature radius of 12 mm for different IOP levels: 9 mm Hg; 14 mm Hg; 21 mm Hg; 40 mm Hg

Conclusions

1. Preventive control of intraocular pressure in childhood can prevent glaucoma with vision loss.

2. An increase in IOP to 11-14 mm Hg creates tension in the conjunctivawithin values up to 100 kPa, which becomes a signal for the use of more effective treatment methods.

3. Further increase in IOP (>14-21 mm Hg) with ineffective treatment and reaching tensions of more than 100 kPa is stopped by performing surgical intervention with the installation of a valve.

4. So, an increase in IOP above the norm in the treatment of glaucoma in childhood requires enhanced treatment or effective surgical intervention, as evidenced by publications of domestic and foreign authors and the results of calculations with graphical representations presented above.

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МОДЕЛЮВАННЯ ВПЛИВУ ТОВЩИНИ КОН'ЮНКТИВИ НА РОЗПОДІЛ НАПРУЖЕННЯ ТА РОЗВИТОК ДИТЯЧОЇ ГЛАУКОМИ

Анотація Глаукома є офтальмологічним захворюванням, яке виявляють при народженні дитини чи протягом життя, де її розвиток без лікування призводить до важких наслідків - сліпоти. Все частіше виявляють випадки часткової або повної втрати зорових функцій у дітей, внаслідок підвищення внутрішньоочного тиску (ВОТ), і ця цифра у країнах Східної Європи постійно зростає (реєструється 1-2 випадки на 2500 новонароджених). Поява цього захворювання його протікання і ускладнення залежать від внутріочного тиску, який при народженні складає 9-12 мм рт. ст., а пізніше зростає, досягаючи максимуму 22-45 мм. рт. ст вже у дорослому віці. Тому необхідно проводити контроль внутрішньоочного тиску навіть на ранніх етапах розвитку дитячого організму.

Вчасне виявлення хвороби на ранніх стадіях захворювання ока є надзвичайно важливою проблемою при глаукомі і дозволяє скористатись медикаментозним лікуванням з позитивним ефектом. У дитячому віці під час росту змінюються параметри ока, в тому числі товщина оболонки ока, її пружність, які мають суттєвий вплив на розподіл тиску та можливість появи глаукоми.

Автори провели моделювання впливу зміни товщини оболонки ока на розподіл напружень, який може призводити до появи глаукоми. В процесі моделювання визначено, що в межах товщини оболонки ока 0.1 - 0.3мм та тиску 9-14 мм рт. ст. забезпечується оптимальне напруження менше 100 кПа.

Підняття значень внутрішньоочного тиску більше 21 мм рт. ст. призводить до різкого збільшення напруження (>150 кПа) та прогресуючий розвиток глаукоми. До рекомендацій слід віднести профілактичний огляд, контроль внутрішньоочного тиску при зміні товщини оболонки ока, можливі етапи медикаментозного і хірургічного лікування.

Ключові слова: дитяча глаукома; внутрішньоочний тиск; напруження ока; дренажні пристрої.

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