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Scientific article

The method of the exophthalmos value predicted calculation when planning the orbital decompression procedure in patients with endocrine ophthalmopathy

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BACKGROUND: The most effective method of surgical treatment of lipogenic and mixed forms of edematous exophthalmos is currently the internal orbital decompression. During this surgical procedure, the excessive pathologically altered adipose tissue is removed from the external and the internal surgical spaces of the orbit. Many scientists are developing methods for calculating the volume of orbital fat, but the question on developing a method for predicted exophthalmos after internal orbital decompression, which could be used without attracting additional equipment and software, is easy to learn and does not require a long calculation time, remains actual. This method has to take into account the individual features of the patient's orbital structure and be used for calculations in the bilateral proptosis correction.

AIM: To develop and evaluate the effectiveness of a new method for calculating the eyeball position after orbital decompression.

MATERIALS AND METHODS: 64 patients (126 orbits) with lipogenic and mixed forms of endocrine ophthalmopathy were examined. All patients underwent internal orbital decompression, during which the orbital fat was removed, the volume of which was calculated according to the developed original method. Patients underwent ophthalmological examination and MSCT before surgery and 6 months after it. .

RESULTS: As a result of orbital decompression in the examined group, a decrease in proptosis was observed in all patients, and the exophthalmos calculated by the method corresponded to the eyeball position in patients in 6 months after surgery. The level of statistical significance of the planned postoperative eyeball position in relation to the actual postoperative exophthalmos calculated according to the Student's t-test was 0.98 ($p > 0.05$), that is, it can be argued that the groups do not differ, and no statistically significant differences were found.

CONCLUSIONS: The developed method for calculating the estimated postoperative exophthalmos is effective without using additional software. This technique allows you to achieve a symmetrical eyeball position in the postoperative period and to reduce the risk of complications.

Keywords: endocrine ophthalmopathy; internal orbital decompression; lipogenic and mixed forms of edematous exophthalmos.

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Научная статья

Методика прогнозируемого расчёта величины выстояния глазных яблок при планировании операции декомпрессии орбиты у больных эндокринной офтальмопатией

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Введение. Наиболее эффективным методом хирургического лечения липогенной и смешанной формы отёчного экзофтальма в настоящий момент является внутренняя декомпрессия орбиты. В ходе данного оперативного вмешательства выполняется удаление избыточной патологически изменённой жировой клетчатки из наружного и внутреннего хирургических пространств орбиты. Многими учёными разрабатываются методики расчёта объёма орбитальной клетчатки, но остаётся актуальным вопрос разработки методики прогнозируемого выстояния глазного яблока после выполнения внутренней декомпрессии орбиты, которая может быть использована без применения дополнительного оборудования и программного обеспечения, проста в освоении и не требует длительного времени для расчёта. Эта методика должна учитывать индивидуальные особенности строения орбит пациента и применяться для расчётов при коррекции двустороннего экзофтальма.

Цель — разработать и оценить эффективность новой методики расчёта положения глазных яблок у пациентов после выполненной операции декомпрессии орбит.

Материалы и методы. Обследовали 64 больных (126 орбит) липогенной и смешанной формами эндокринной офтальмопатии. Всем пациентам была выполнена внутренняя декомпрессия орбиты, с удалением орбитальной клетчатки, объём которой рассчитывали по разработанной авторами оригинальной методике. Пациентам проводили офтальмологическое обследование и выполняли мультиспиральную компьютерную томографию до оперативного лечения и через 6 мес. после операции.

Результаты. В результате декомпрессии орбиты у всех пациентов обследуемой группы отмечалось уменьшение степени экзофтальма, а рассчитанные по методике величины выстояния глазных яблок соответствовали положению глазных яблок у пациентов после оперативных вмешательств через 6 мес. Уровень статистической значимости, рассчитанный согласно t-критерию Стьюдента, планируемого послеоперационного положения глазного яблока по отношению к фактическому послеоперационному экзофтальму составил 0,98 ($p > 0{,}05$), то есть можно утверждать, что группы не отличаются и статистически значимых различий не выявлено.

Выводы. Разработанная методика расчёта предполагаемого послеоперационного выстояния глазного яблока работает без помощи дополнительного программного обеспечения. Данная методика позволяет рассчитать эффект симметричного положения глазных яблок в послеоперационном периоде и снизить риск развития осложнений.

Ключевые слова: эндокринная офтальмопатия; внутренняя декомпрессия орбиты; липогенная и смешанная форма отёчного экзофтальма.

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BACKGROUND

Endocrine ophthalmopathy (EOP) is an independent progressive autoimmune disease with a primary lesion of the adipose tissue of the orbit and oculomotor muscles and of the lacrimal gland with secondary involvement of the eye (i.e., optic neuropathy, corneal damage, and increased intraocular pressure) [1].

According to the classification of the Academician of the Russian Academy of Sciences (RAS) A.F. Brovkina, one of the manifestations of EOP is edematous exophthalmos, which has three course variants, namely, muscular, mixed, and lipogenic [2]. Currently, the most effective surgical treatment of the lipogenic and mixed forms of edematous exophthalmos is internal decompression of the orbit [3]. For this surgical procedure, excess pathologically damaged adipose tissues were removed from the external and internal surgical spaces of the orbit [4]. To date, various surgical options have been proposed and described [5, 6].

To determine the volume of the orbital tissue, various programs have been developed based on the examination results such as magnetic resonance imaging [7–11] and multispiral computed tomography (MSCT) [12–15]. However, all the proposed methods for calculating the soft tissue volume are not adapted to the calculations of predicting the postoperative protrusion of the eyeball, as they are quite time consuming and dependent on the operator [3].

The literature provides single publications describing the calculation methods used when planning internal orbital decompression in patients with EOP. Thus, in 2009, the Academician of RAS A.F. Brovkina et al. [16] proposed an equation for calculating the excess orbital tissue volume to be removed during decompression. However, they only used this equation for unilateral exophthalmos; as the calculation method is laborious, they recommended the use of a special computer program.

In 2021, Li et al. [17] proposed a new radiological method for evaluating the plastic effect of modified transconjunctival orbital fat decompression surgery in patients with inactive EOP. The authors measured the degree of eyeball protrusion according to the findings of spiral computed tomography 6 months before and after surgery on the Infiniti workstation. Based on the results obtained using the Philips IntelliSpace Portal, elliptical area and linear segment measurement tools, the standard elliptical cone volume equation was used to calculate the internal volume of the muscle cone. Changes in eyeball protrusion and the internal volume of the muscle cone before and after surgery were assessed [17]. Moreover, this technique is intended to assess the efficiency of the surgery and has not been evaluated in terms of prognosis.

Thus, the need to develop a method for predicting eyeball protrusion after internal decompression of the orbit, which can be used without additional equipment and software, is easy to learn, and does take a long calculation time, remains relevant. The technique should consider individual characteristics of the structure of the orbits and be used for calculations in the correction of bilateral exophthalmos.

This study aimed to develop and evaluate the efficiency of a new method for calculating the position of the eyeballs after orbital decompression.

MATERIALS AND METHODS

Sixty-six patients (128 orbits) with endocrine ophthalmopathy, including 54 women and 12 men aged 28–62 (mean age, 41 ± 8) years, were examined. A lipogenic EOP was identified in 45 patients and a mixed variant in 21 patients. In all patients, EOP was in remission. We used a different algorithm of actions to detect the myogenic form, so this group of patients was not included in the present study. Simultaneous (bilateral) internal decompression of the orbit was performed in 62 patients, and four patients underwent surgery of one orbit (unilateral). Preoperatively, a standard ophthalmological examination was performed to determine visual acuity, intraocular pressure, and status of the eyelids and periorbital region (Table 1).

All patients underwent MSCT of the orbits using various devices Philips Brilliance 64, Somatom Sensation 40, and Aquilion ONE640 (Table 2).

The MSCT study was conducted according to the following methods in the middle zone of the face. Before the study, the patient's head was freed from all removable elements. With the patient in the supine position, the head was placed exactly in the standard headrest, and positioning was

Table 1. Clinical signs of patients depending on the course of endocrine oftalmopathy

Таблица 1. Клинические признаки у пациентов с эндокринной офтальмопатией в зависимости от варианта заболевания

Clinical signs	Mixed variant (42 orbits)	Lipogenic variant (84 orbits)
Visual acuity, average	0.81 ± 0.3	0.99 ± 0.04
Intraocular pressure, mm Hg	22 ± 1.0	21 ± 1.2
Degree of eye protrusion, mm	27.6 ± 2.0	23.6 ± 1.7
Lagophthalmos	8	–
Restrictions in eye movement	27	1
Conjunctival chemosis	3	–
Characteristics of the borders and the presence of edema of the optic nerve head	24	–

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Table 2. The parameters of the MDCT analysis of the orbit

Таблица 2. Параметры мультиспиральной компьютерной томографии исследования глазниц

Parameter	Apparatus type		
	Somatom Sensation 40	Aquilion One 640	Philips Brilliance 64
Imaging mode	Spiral	Volumetric	Spiral
Slice thickness, mm	1	0.5	0.9
Gantry angle	0	0	0
Field of study, cm	20–30	16	20
Voltage, kV	100	100	120
Current, mA	60	60	100
Time of one revolution of the tube, s	0.37	up to 0.275	0.5
Study duration, s	4–5	1–2	3–4
Type of reconstruction	Bone, soft tissue	Bone, soft tissue	Bone, soft tissue

Table 3. Analysis of the results of preoperative and postoperative measurements of orbital structures

Таблица 3. Анализ результатов предоперационных и послеоперационных измерений структур орбит

Parameters	Values
Exophthalmos before surgery, mm	24.94 ± 2.5
Removable volume calculated using the method, mL	3.323 ± 0.9
Volume of adipose tissue removed during surgery, mL	3.319 ± 0.9
Postoperative exophthalmos assumed according to the method, mm	21.63 ± 2.2
Result of surgical treatment of eyeball protrusion after 6 months, mm	21.65 ± 2.2
Significance level	0.98

performed according to the laser marks in three mutually perpendicular projections. The patient's eyes were open at the time of scanning, and the gaze was fixed centrally. To mark the study area, a topogram was obtained in a lateral projection, and the scanning area included the skull (from the upper border of the soft tissues of the cranial vault to the lower contour of the upper jaw teeth), with the jaws in habitual occlusion. Tomography was performed in the axial plane in the spiral or volumetric scanning modes (depending on the apparatus type) with a slice thickness of 0.5–1.0 mm, depending on the apparatus capabilities, using reconstruction in bone and soft tissue modes. Multiplanar reconstructions in the coronal and sagittal planes were added to the MSCT data obtained in the axial plane. Virtual three-dimensional (3D) models were constructed using the standard software of each tomograph.

Calculation method

Based on the data obtained as a result of the MSCT study, 3D reconstruction was performed in the bone mode in the axial plane. A mark was placed on the zygomaticoorbital suture (Fig. 1), through which the frontal plane was constructed (Fig. 2), and the entire array of data located behind this plane was eliminated from further analysis. Then, the orbital entry was contoured, and the entire data array located outside the resulting circle was also excluded from further calculations (Fig. 3). In the axial plane, a perpendicular line was drawn from the top of the cornea to the frontal plane. The resulting segment is the size of the exophthalmos (AB, before surgery). From the same point (from the corneal apex), a parallel segment AC was made, which was the estimated size of the exophthalmos after surgery (Fig. 4). Another frontal plane was drawn through point C, and the fragment of the image that included point A was removed. The volume of the resulting disk-shaped fragment was calculated (Fig. 5), and data obtained were entered into the table (Table 3).

RESULTS AND DISCUSSION

From 2014 to 2020, we examined and analyzed 128 orbits in 66 patients with exophthalmos in EOP, who underwent surgical internal decompression of the orbit. Our findings revealed that preoperative exophthalmos varies from 18.6 to 33.0 mm (average 24.94 ± 2.5 mm).

Yatsenko et al. [12] presented a technique and based on which published calculations for the volumes of the bone orbit, adipose tissues, and other soft tissue structures. However, this method is time consuming and requires additional equipment, so the authors did not use this method for simultaneous bilateral decompression or an anophthalmic syndrome on the contralateral side [12]. When planning the volume for removal (mean value, 3.319 ± 0.9 ml), we consider the EOP variant, initial size of eyeball protrusion, and statistical data of patients who underwent surgery. The adipose tissue volume removed during surgery coincided completely with

Fig. 1. MSCT. 3D reconstruction in the bone mode. Placing a mark on the orbital seam of one of the orbits (arrow)
Рис. 1. Мультиспиральная компьютерная томограмма. Костный режим. 3D-реконструкция. Вид спереди. Метка на скулоорбитальном шве (стрелка)

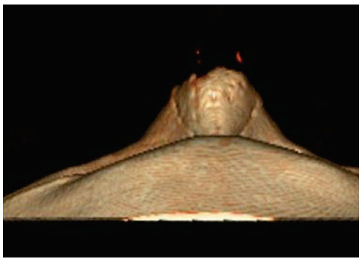

Fig. 2. MSCT. 3D reconstruction in the bone mode. Alignment of the frontal plane and removal of the data array located behind this plane
Рис. 2. Мультиспиральная компьютерная томограмма. Костный режим. 3D-реконструкция. Вид сверху. Создание фронтальной плоскости

Fig. 3. MSCT. 3D reconstruction in soft tissue mode. Noted the zone of entry into the orbit along the bone edge, images outside the circle were excluded from the analysis
Рис. 3. Мультиспиральная компьютерная томограмма. Мягкотканный режим. 3D-реконструкция. Метка установлена на костном крае, изображения за окружностью исключены

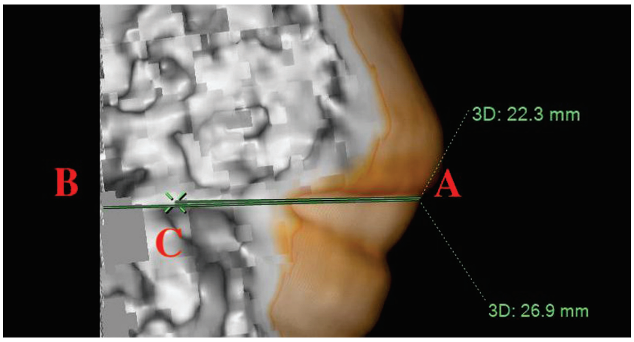

Fig. 4. MSCT. 3D reconstruction in soft tissue mode. Measurement of the magnitude of the exophthalmos of the right orbit (AB segment) before surgery and the estimated exophthalmos (AC segment) after surgery
Рис. 4. Мультиспиральная компьютерная томограмма. Мягкотканный режим. 3D-реконструкция. Величина экзофтальма правой орбиты (отрезок AB) до операции и планируемое положение после операции (отрезок AC)

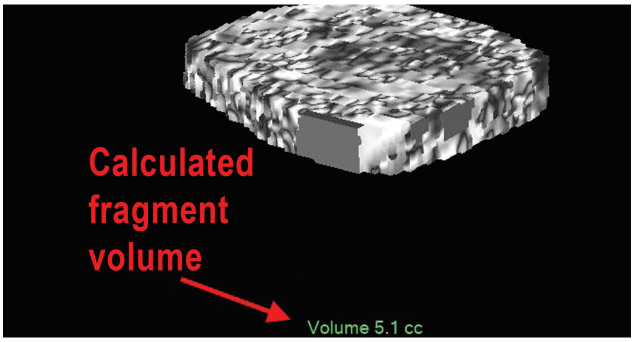

Fig. 5. MSCT. 3D reconstruction in soft tissue mode. The amount of fatty tissue calculated using standard programs MSCT, which must be removed during surgery
Рис. 5. Мультиспиральная компьютерная томограмма. Мягкотканный режим. 3D-реконструкция. Необходимый к удалению объём жировой орбитальной клетчатки. Стандартная программа томографа

the volume planned for the MSCT study. The estimated postoperative position of the eyeball (mean value, 21.63 ± 2.2 mm), which we obtained during planning, was not significantly different from the actual measurement (mean value, 21.65 ± 2.2 mm) at the control MSCT study after 6 months. The significance level of the planned postoperative position of the eyeball relative to the horizontal plane in relation to the actual eye position was 0.98 (i.e., $p > 0.05$); thus, it can be argued that the study groups were not significantly different, and no significant differences were revealed. The average calculation error was 0.1 ± 0.1 mm. The surgical interventions led to a decrease in exophthalmos by 3.3 ± 0.9 mm. The correlation coefficient between the removed volumes of the adipose tissue and values by which the exophthalmos has changed was (ρ) 0.44; this means that these values are related (moderate constraint force).

CONCLUSIONS

The proposed method for calculating the estimated postoperative eyeball protrusion enables to preoperatively determine the amount of adipose tissue to be removed to achieve the desired outcomes without using time consuming calculations and additional software. This technique made it possible to calculate the planned amount of adipose tissue to be removed from each orbit for symmetrical eyeball position postoperatively based on the MSCT data. The technique will help reducing the risk of postoperative complications, such as diplopia.

ADDITIONAL INFORMATION

Author contributions. All authors confirm that their authorship complies with the international ICMJE criteria (all authors have made a significant contribution to the development of the concept, research and preparation of the article, and read and approved the final version before its publication). D.V. Davydov performed scientific editing and surgical interventions. D.A. Lezhnev contributed to scientific editing and prepared the illustrations. K.A. Konovalov wrote the text, formatted the references, and prepared the illustrations.

Conflict of interest. The authors declare no conflict of interest.

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