Indications for repositioning of blow-out fractures of the orbital floor based on new objective criteria - tissue protrusion volumometry

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Background and Aim. The otolaryngologist often meets with fractures of the orbital floor. The most serious complication is diplopia, arising as a result of herniation of the orbital contents, with or without fixation of the inferior rectus muscle. The aim of our work was to create a mathematical model to calculate the volume of prolapsed soft tissue of the orbit in blow-out fractures, as a factor in deciding on the need for surgical treatment.
Patients and Methods. In a retrospective study (2007-2013), we evaluated 80 patients with blow-out fractures, divided into two equal groups: 40 conservatively treated and 40 surgically treated patients. We created the model by measuring the fracture lines and herniation of the orbital soft tissues in the coronal and sagittal sections from CT images, equivalent to half the volume of a rotating ellipsoid.
Results. According to the proposed model, posterior and anterior fractures with a prolapse volume above 500 mm^3, and anteroposterior fractures with a volume over 1400 mm^3, are indicated for surgery.
Conclusion. The volume of prolapsed soft tissue relative to the location of the fracture is the main indicator for selecting the best treatment procedure immediately after injury.

Key words: blow-out fractures, volumometry, diplopia, CT-assisted surgery

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INTRODUCTION

The concept of a hydraulic, retromarginal orbital fracture (blow-out fracture) first appeared in the world literature in the work of Smith and Regan[1] in 1957. Today, the most accepted explanations for the fracture[2,3].

1. Following a blunt blow to the flexible, incompressible eyeball, transfer of pressure occurs causing a fracture of the lower and/or medial walls of the orbital floor.

2. Following force on the lower orbital edge (without causing it to fracture) a pressure wave spreads through the bone and causes it to break at the point of thinning, therefore most often in the medial part of the base of the orbit.

Orbital injuries make up about 40% of all fractures of the facial skeleton, and 67-84% of these are retromarginal orbital fractures. The locus minoris resistentiae of the orbital floor is located medially from the canalis nervus infraorbitalis and is only 0.07 to 0.2 millimeters thick[4].

Clinical manifestations of these fractures include edema, hematoma and emphysema of the eyelids and orbits, neuropathy (most commonly hypoesthesia) in the n. Infraorbitalis. Depending on the time lapse since the accident, exophthalmos, the normal positioning of the eyeball and enophthalmos can all be observed. The most important symptoms are limited motility and diplopia, most often caused by myogens and mechanical lesions. Traumatic changes affect the inferior rectus muscle, the inferior oblique muscle and the medial rectus muscle.

Symptoms may be seen in various combinations or almost without them. The presence of an orbital floor fracture, its size and weight, are determined by CT imaging (coronal and sagittal sections). If the patient is asymptomatic or the symptoms quickly disappear (with the exclusion of muscle entrapment) and late onset diplopia does not occur, we would take a conservative approach to the fracture. In other cases surgical revision would be used. Due to the possibility of direct spread of infection to the sterile environment of the orbit, the procedure is carried out under blanket antibiotic treatment (Holý, Kovář).

Surgical solutions for fractures of the orbital floor are important mainly because of persistent diplopia, which can significantly limit a patient's quality of life. Independently occurring enophthalmos and numbness in the infraorbital nerve are less important.

In our previous works, we focused on anatomical and functional results in operated patients with fractures of the orbital floor in relation to the access routes, types of fixation materials, the use of CT-guided surgery and the proper timing of surgical treatment[5,6].

In the past, the only indication for surgical treatment of these fractures was the clinical finding and its evolution over time. At the time there was no quantification of the post-traumatic state.

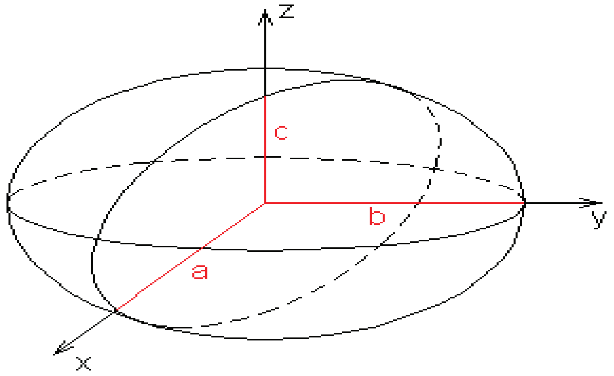

Fig. 1a. Rotating ellipsoid.

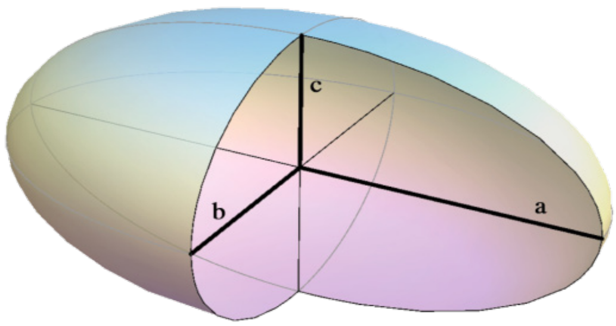

Fig. 1b. Rotating ellipsoid.

OBJECTIVES

To develop objective criteria for the indication of surgical treatment of blow-out fractures using a spheroid model.

To determine the volume of prolapsed orbital soft tissue into the maxillary sinus as a factor in predicting the necessity for surgical treatment.

To indicate patients with blow-out fractures in a correct and timely manner for surgical intervention to ensure the most effective reconstruction of the anatomical shape of the orbital floor.

PATIENTS AND METHODS

In our department from 2007 to 2013, we treated 80 patients with blow-out fractures of the orbital floor, 40 (50%) of whom were treated surgically. We confirm, that IRB was given for our study.

The ratio of males to females was 2:1, with a slight predominance of the right orbit. The average age of the patients was 40 years (16-85 years), those who were not operated were monitored until the disappearance of the diplopia, while operated patients were monitored on a regular basis: 1 week, 1 month, 3 months, 6 months and 1 year after surgery. The mechanism of injury most often involved direct blows, followed by falls, sports injuries and car accidents (Table 1).

Surgical revision of blow-out fractures was indicated in clinically significant enophthalmos associated with a defect in the orbital floor (detected by CT scan) and accompanied by diplopia, in cases of persistent double vision after recovery from edema of orbital soft tissue, in the entrapped inferior rectus muscle confirmed with CT, in cases of a positive passive duction test and even when theorbital contents were endangered by bone fragments.

Table 1. Mechanism of injury.

Mechanism of injury	Blows	Falls	Sports injuries	Car accidents
Rate (%)	60	15	15	10

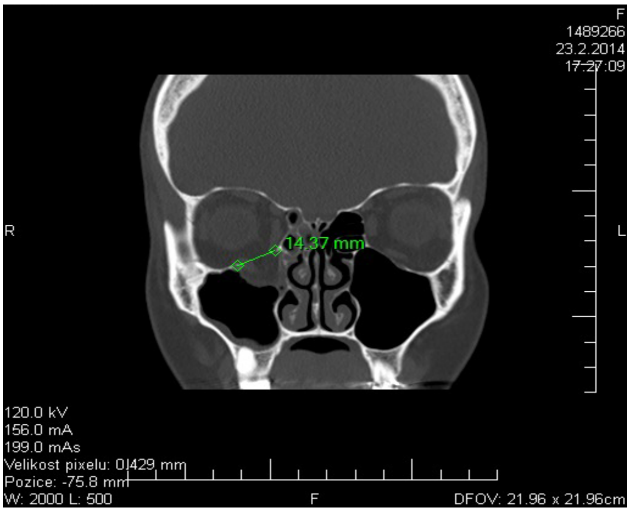

Fig. 2. Measurement through coronal

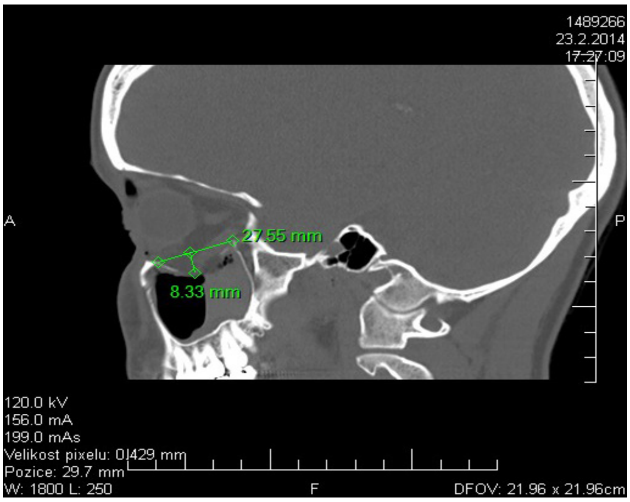

Fig. 3. Measurement through sagittal section. section.

Given our experience with the surgical and non-surgical treatment and long-term follow-up in patients recovering after fractures of the orbital floor[7], we decided, in addition to the normal clinical indication criteria for surgery of blow-out fractures, to create a mathematical model for calculating the volume of prolapsed orbital soft tissue and to determine the critical volume values, which would

Table 2. Prolapsed volumes in blow-out fractures/conservative therapy.

Conservative Approach			
Fracture location Volume (mm^3)	Anterior 90 (44 - 128)	Posterior 140 (114 - 156)	Anteroposterior 433 (345 - 474)

Table 3. Prolapsed volumes in blow-out fractures/surgical therapy.

Surgical Approach			
Fracture location Volume (mm^3)	Anterior 686 (563 - 809)	Posterior 747 (583 - 926)	Anteroposterior 1827 (1402 - 2182)

Table 4. The frequency of blow-out fractures by location and the relationship between conservative and surgical therapy.

Fracture location	Anterior (19), 24%		Posterior (28), 35%		Antero-posterior (33), 41%	
Treatment	Conserv.	Surgical	Conserv.	Surgical	Conserv.	Surgical
No. of fractures	17	2	15	13	8	25
No. of fractures (%)	89%	11%	54%	46%	24%	76%

in turn support the indication for surgical treatment in the immediate post-traumatic period.

We retrospectively evaluated the clinical findings (post-traumatic and after healing) of the groups of patients described above from 2007 - 2013, in relation to CT images and after calculating the volume of the prolapsed tissue of the orbit. The main measure of success of the treatment process was the disappearance of diplopia.

The mathematical model is equal to a half-volume rotating ellipsoid (Fig. 1a and 1b), where the the lower surface of the fractured orbital floor forms the base and the separate dimensions are obtained from coronal and sagittal sections (Fig. 2 and 3).

For each patient in the two groups, we carried out a triple measurement of individual lengths of the fracture line, calculated the arithmetic average and recorded the position of the fracture (anterior, posterior and antero-posterior).

The formula for calculating the volume of the spheroid is $V = 4/3\ \pi$ abc, ie for its half after readjustment: $V1 / 2 = 4/6\ \pi$ abc ($2/3\ \pi$ abc).

RESULTS

The resulting volumes of prolapsed orbital soft tissue in conservative and surgical methods of treatment are shown in the tables below (Table 2 and 3).

In anteroposterior fractures (76% of which required operating) we recommend surgery in prolapse greater than 1400 mm^3, and in anterior (operated only in 11% of cases) and posterior fracture types (operated in 46% of cases) in prolapse over 500 mm^3 after remission of acute swelling, if no urgent (Table 4, Fig. 4).

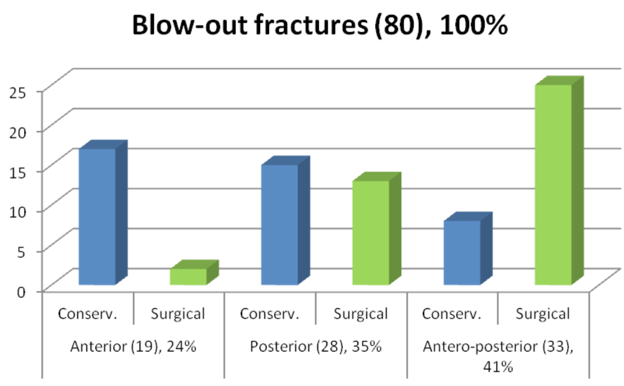

Fig. 4. Relationship between conservative and surgical therapy and fracture location.

DISCUSSION

A number of Czech and foreign authors have addressed the issues of the appropriate timing for and method of surgery in blow-out fractures. Indications for surgical treatment are currently based on clinical symptoms, ophthalmological findings and developments in the immediate post-traumatic period.

If no urgent operation is indicated, then the decision of whether to operate depends on the development of clinical symptoms and the total volume of prolapsed orbital tissue. Due to the shadow of the upper jaw, ultrasound volumometry cannot be used.

Harris, in line with most surgeons[5,7-11] recommends surgery for defects of the orbital floor where clinically significant enophthalmos can be expected or in persisting diplopia 14 days post-accident.

With many years experience in orbital surgery, we have good understanding of the proper timing for surgical intervention. Two weeks are enough for the orbital hematoma and edema to subside or reduce and to prepare the patient for surgery[4].

Kwon et al. divided orbital floor fractures into anterior, posterior and anteroposterior[12]. But there is a very large dispersion of functional results, 8.7-67%, especially in the persistence of postoperative diplopia[5,7,13-17]. Worth noting is the contribution of CT-guided surgery, leading to the complete disappearance of postoperative diplopia. The first functional results with CT navigation were not published until 2014 (ref.[5-6]).

Beumer, Pham and Schramm[18-20] recommend the use of CT navigation in maxillofacial bone fractures to minimize post-traumatic enophthalmos and for improved facial symmetry.

CONCLUSION

Given that on average only 50% of patients with orbital floor fractures require surgical treatment, it is desirable to be able to predict these patients immediately after the injury. Clinical sequelae shortly after injury include hematoma, pneumoorbit and, subcutaneous emphysema, which usually change the clinical picture towards the expected pathology (which subsides in a few days), or they appear falsely to be functionally insignificant (latent symptoms). The proposed calculation of the volume of herniated soft tissues of the orbit helps us considerably in the selection of treatment.

The accuracy of our mathematical model is supported by excellent anatomical and functional results with minimal permanent diplopia, based on experience with CT navigated and video assisted CT-assisted surgery and consistent, long-term monitoring of patients, including outcomes in conservative treatment. Since 2014 we have indicated patients with orbital floor fractures for surgery based on clinical criteria and mathematical calculation.

Author contributions: DK: reviewed the literature and drafted the manuscript. All authors contributed equally to data collection, analysis, interpretation and correction of the final manuscript version.

Conflict of interest statement: The authors state that there are no conflicts of interest regarding the publication of this article.

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