

Multidisciplinary approach to orbital fracture repair

V.V. Costan¹, M. Dabija²

“Grigore T. Popa” University of Medicine and Pharmacy Iasi, ROMANIA

¹Faculty of Dental Medicine, Department of Surgery, Oral and Maxillofacial Surgery

²Faculty of Medicine, Department of Surgery II, Neurosurgery

Abstract: The orbit is a frequent location for fracture occurrence, often in association with other fractures of the facial skeleton. Due to the anatomical situation of the orbit at the crossroads of multiple specialties, including maxillofacial surgery, ophthalmology, neurosurgery and otolaryngology, this territory must be managed by multidisciplinary teams for an accurate diagnosis and treatment. This paper focuses on reviewing the main types of orbital fractures, the indication for surgical repair and the contribution of different specialties in the management of various orbital fracture patterns.

Key words: orbit, fracture, multidisciplinary, blow-out, blow-in

Introduction

Fractures of the orbit are often encountered in the context of facial trauma, either isolated or in association with other fractures of the facial skeleton. Over 40% of all facial fractures have an associated orbital involvement (1). The most frequent patterns of fractures including the orbit are orbito-zygomatic fractures and naso-orbito-ethmoidal fractures. Isolated fractures of the orbital walls are reported in between 4-16% of facial fractures cases (2). With such a high occurrence and potential for important functional and morphologic impairment, it is important to accurately diagnose and treat orbital fractures.

The orbit pathology is situated at the intersection of multiple medical specialties due to the anatomical location, the

neighboring anterior skull base and paranasal sinuses, but also due to its contents consisting of the globe and optic nerve. In a traumatic setting, all the named structures can be damaged to various degrees, necessitating a collaboration between the maxillofacial surgeon, the neurosurgeon, ophthalmologist and otolaryngologist for an accurate diagnosis, treatment and follow-up, aiming for minimal complications.

The anatomic characteristics of the orbital region explain the various fracture patterns and the frequent association of fractures involving multiple facial bones. The orbits and the anterior skull base form a guarding ensemble, in the biomechanical context of the naso-ethmoido-maxillo-fronto-orbital complex. The whole architecture of the nose, paranasal sinuses, the orbits and the anterior

skull base comprises an anterior strength zone (the glabella, the naso-maxillary suture, the nasal process of the frontal bone, the orbital rims) absorbing the impact and a posterior fragile complex (the cribriform plate, the ethmoidal labyrinth, the perpendicular plate of the ethmoid bone, the sinus cavities) dissipating the forces (1, 3).

The design of the orbit is well adapted to soften any traumatic impact on its fragile contents. The orbital rims are thickened bone structures forming horizontal and vertical buttresses of the facial skeleton absorbing and resisting the direct force of the impact (4). The orbital fat behaves like a cushion dissipating forces to protect the globe and optic nerve. The thin orbital walls allow for pressure to escape the orbit by fracturing in case of important traumatism, thus avoiding crushing of the intraorbital structures. Similarly, the orbital roof also serves as a pressure release for superior traumatisms, impacting the skull and brain. Its down-fracture dissipates the crushing force directed on the brain substance. In addition to these protective features, the surrounding paranasal sinuses act as air-bags consuming the strength of the traumatism (5, 6, 7). Their role is emphasized by the increased frequency of orbital blow-in fractures in children due to the absence of frontal sinus pneumatization (8).

In relation to the anatomical characteristics, the impact point, strength and direction, the fracture trajectory may interest to various degrees the orbital rims, the walls of the orbit, as well as the adjacent bones of the facial skeleton translating into the frequently encountered clinical forms: naso-ethmoido-maxillo-fronto-orbital complex (CNEMFO)

fractures (3), more commonly named NOE complex (naso-orbito-ethmoidal) fractures, orbito-zygomatic fractures, isolated orbital walls fractures including blow-in and blow-out types, and combined orbital fractures comprising the orbital frame and walls (1). Less frequent, but with a high morbidity, is the association of orbital fractures with skull and skull base fractures in high-velocity traumatisms.

The complex shape of the orbit, as well as the anatomical situation in areas of high risk of injury to important structures, make the reconstruction of the orbital cavity a difficult task, often requiring multidisciplinary evaluation, diagnosis and management.

Multidisciplinary evaluation and management

A facial trauma patient is habitually evaluated by a multidisciplinary team in the emergency setting, including maxillofacial, neurosurgical, ophthalmological and otolaryngology consultations together with other necessary consultations for excluding serious injuries in other body parts. Common emergency procedures include maintenance of a patent airway, management of epistaxis and hemostasis for bleeding in soft tissue lacerations, drainage of retrobulbar hematoma, management of persistent oculo-cardiac reflex, and intracranial vascular lesions. The initial consultation is usually determined by the predominant emergency in each case. Diagnostic imaging is recommended in hemodynamically stable patients. Facial fracture repair is performed after the resolution of acute life-threatening injuries.

Clinical examination is often indicative of the type of fracture, but a thin slice CT (Computer Tomography) evaluation is cardinal for the assessment of orbital injuries (9, 10) that may otherwise be missed due to the presence of edema and masked clinical signs and symptoms. Even more so, CT is necessary due to the possible presence of skull base fractures, dura tears, posttraumatic intracranial lesions, possible occurrence of orbital apex syndrome, extraocular muscle incarceration, globe injuries. The three-dimensional reconstruction of the CT images aids the greater understanding of the fracture characteristics and assists in deciding the treatment plan (11, 12). Stereolithic models obtained by mirroring techniques and three-dimensional printing are useful for the choice and modelling of the reconstruction material, particularly in cases of comminuted fracture repair (13).

There is controversy on the indication for surgery and particularly regarding the most appropriate timing for performing surgical repair in orbital fracture cases. The indications for immediate surgery, performed within 24 hours, are less of a subject for debate. Consensus has been achieved regarding emergency interventions in cases of diplopia, incarcerated extraocular muscle and persistent oculo-cardiac reflex (syncope, bradycardia, heart block, nausea, vomiting), emergency intervention for “white-eyed” blowout fracture (patient under 18, minimal clinical signs, superior gaze restriction, muscle entrapment, trap-door mechanism), and also in cases with severe displacement of the globe, orbital apex syndrome, optic nerve compression and high risk of vision loss (14).

The debate is ongoing regarding the indications for early (within two weeks) and late surgery (beyond two weeks). Consideration is given to the amount of fracture displacement, orbital volume changes, the comminution of the fracture, the degree of functional and esthetic impairment, the presence of priming neurosurgical lesions, and to the existence of important comorbidities as contraindications for surgery.

It is most difficult to determine the indication for the surgical repair or conservative management in minimally displaced fractures, in the absence of initial symptoms, since posttraumatic changes in the orbital soft tissues could progress with the apparition of late enophthalmos. Most authors agree that in the absence of contraindication, the best functional and cosmetic results are obtained by performing the primary repair of volume modifying orbital fractures, with primary grafting when necessary, or reconstruction using alloplastic materials (15, 16). This is true for the majority of inferior wall, medial and lateral wall orbital fractures. Orbital roof fractures, however, are commonly managed conservatively in almost 90% of cases comprising minimally displaced fractures (12). Possible complications include the onset of pulsatile exophthalmos and orbital encephalocele that has been reported to also occur late after the conservative management of minimally displaced fractures of the superior orbital wall (12). Blow-in fractures with severe displacement, as well as orbital roof fractures with a surface greater than 2 cm² must be closely monitored since there is a high risk of encephalocele development and orbital dystopia (8). For severely and moderately

displaced orbital roof fractures the surgery indication is maintained. The presence of an orbital encephalocele is a surgical indication for the removal of the herniated tissue with closure of the dura and orbital reconstruction (17). Surgery is also performed in the presence of superior orbital wall fractures in association with dural tears and cerebrospinal fluid (CSF) leaks (18). Other situations in which surgery is necessary encompass the presence of intraorbital foreign bodies, or impinging bone fragments causing the compression and lesion of the optic nerve, or of the extraocular muscles.

There is no agreement regarding the best reconstructive material, with some authors advocating for the use of autologous bone grafts (16), while others have obtained good outcomes by titanium mesh reconstruction and thus avoidance of donor site morbidity and associated complications (15, 19). In the absence of treatment due to late presentation, missed diagnosis or delayed surgery due to contraindication, the resulting orbital sequelae can be addressed in late correction procedures, performed after six months from the initial injury, for the maturation of the scar tissue (20, 21). Common orbital sequelae include the presence of enophthalmos, exophthalmos, orbital dystopia, hypoglobus, diplopia, orbital contour changes and facial asymmetry, eyelid malpositioning, epiphora, restriction of eye movements and soft tissue contraction. Following orbital roof fractures in the pediatric population that were managed non-operatively, and other skull and skull base fractures, there is concern for the development of "growing skull fractures" with enlargement of existing communications with the

intracranial space, dural tears and brain herniation (22, 23). Timely diagnosis facilitates early intervention and prevention of complications.

Maxillofacial surgery contribution

Fractures of the inferior, medial and lateral orbital walls and rims, in the absence of associated skull and skull base fractures, in conjunction or not with other fractures of the facial skeleton, are managed by the maxillofacial surgeon, after the initial emergency multidisciplinary evaluation. Other fractures that comprise neurosurgical lesions, such as orbital roof fractures, or panfacial and skull fractures, are often managed in mixed surgical teams. Isolated blow-out fractures of the inferior orbital wall account for 22-47% of orbital injuries (24, 25, 26). Orbital floor fractures are often found in association with fractures of the medial orbital wall. Most remaining orbital fractures are found in the context of other facial fractures, mainly orbito-zygomatic fractures, or naso-orbito-ethmoid fractures (1, 3) (Fig. 1-6).

The recognition of emergency situations is key for preserving unaltered visual function. Retrobulbar hematomas in the context of orbital fractures is encountered in 0.45-0.6% of cases. The key to avoiding permanent injury to the optic nerve and posttraumatic blindness is the early recognition of the condition, with the help of the ophthalmologist and adequate imaging, followed by the drainage of the hematoma by lateral canthotomy. It is recommended to perform the drainage within one hour from onset, and under 24 hours, since studies showed that function preservation is better when the interval from

onset to treatment is shorter (27). Careful monitoring for retrobulbar hematomas must also be performed in the postoperative period. Compression of the optic nerve by displaced bone fragments or intraorbital foreign bodies are also indications for emergency surgery, just like the un-resolving oculo-cardiac reflex. Other lesions indicating the need for immediate surgical treatment are related to the entrapment of the extraocular muscles and orbital fat (trap-door fracture) especially in children, when the thick periosteum causes more pressure on the entrapped tissues (14). The early and late treatment indications vary on the presence of clinical signs, the amount of fracture displacement and orbital volume change, the presence of comorbidities and associated traumatic lesions (19).

The maxillofacial surgeon is familiar with several types of access for repairing orbital fractures and complex midfacial fractures, such as the superior eyelid, inferior eyelid, transconjunctival, intraoral approaches, and the coronal flap offering exposure for the frontal skull, temporal regions, the superior, medial and lateral orbit (28, 4). The coronal flap is often used in mixed approaches for repairing skull fractures, frontal sinus fractures, superior orbital rim fractures, NOE fractures, and fractures of the orbital roof, particularly the blow-out type. The blow-in type of orbital roof fracture can be adequately accessed and repaired through an upper lid approach, in mixed surgical teams (29). Additionally, the closure of large CSF fistulas associated with tissue loss may be performed in mixed surgical teams, by using various types of pedicled or free flaps.



Figure 1 - Three-dimensional CT reconstruction of a patient with a displaced naso-orbito-ethmoidal fracture managed by a multidisciplinary approach-soft tissue frontal view demonstrating facial asymmetry due to left nasal displacement and orbital contour change



Figure 2 - Three-dimensional CT reconstruction of the same patient demonstrating the displaced fractures of the nasal bones and right inferior orbital rim, ascending process of the maxilla and anterior wall of the maxillary sinus



Figure 3 - Inferior view showing the inward and inferior displacement of the right medial fractured maxillary fragment comprising the inferior orbital rim and ascending process of the maxilla with orbital volume change



Figure 4 - Transverse CT section showing the displacement of the right medial maxillary fragment with obstruction of the right nasal fossa



Figure 5 - Coronal CT section demonstrating right maxillary sinus fracture and hemo sinus

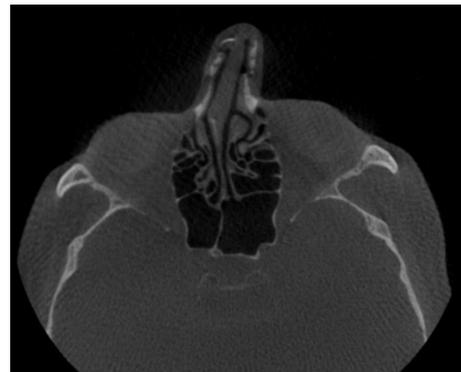


Figure 6 - Transverse CT section showing the displacement of the nasal fracture

Neurosurgical contribution

Orbital roof fractures are encountered in less than 9% of facial fractures in most studies (12, 18, 30). They are reported more often in children under the age of seven, because of the anatomical characteristics with incomplete frontal sinus development and a more prominent frontal region (18, 30, 31). In isolated superior orbital wall fractures, the direction of the impact force determines the type of fracture, with either a “blow-out” mechanism, which is more common and often determining orbital volume enlargement and

enophthalmos, or a “blow-in” mechanism seen in high velocity traumatism, determining the diminution of the orbital volume and the onset of exophthalmos. As previously described, most orbital roof fractures are managed conservatively. Still, indications for surgery should be carefully revised and adequate monitoring of the patient must be implemented, for early diagnosis of possible complications. Surgical procedures for repairing orbital roof fractures often imply a collaboration between the neurosurgeon and maxillofacial surgeon for achieving adequate access. Simple blow-in orbital roof fractures can be surgically approached through an upper blepharoplasty palpebral incision, while blow-out fractures are more challenging, requiring a neurosurgical craniotomy approach via a coronal incision (29).

Severe neurosurgical lesions and ophthalmologic injuries may be encountered in conjunction with orbital roof fractures, consisting of brain injuries, pneumocephalus, dura tears, CSF leaks, pulsatile exophthalmos, orbital meningoencephalocele, entrapment of the extraocular muscles, globe rupture, optic neuropathies, retrobulbar hematoma (18). The morbidity is increased when there is association with other fractures of the orbital rims (Fig. 7-10), skull, skull base and facial skeleton. Orbital roof fractures, skull and skull base fractures in children require special neurosurgical surveillance, especially in cases where there is evidence of dural tears. This is due to the possibility of developing “growing skull fractures”, needing early diagnosis and management for prevention of complications and sequelae (22, 23).



Figure 7 - Three dimensional CT reconstruction of a patient with a displaced fracture of the left superior orbital rim that necessitated a multidisciplinary management including a neurosurgeon and a maxillofacial surgeon



Figure 8 - Transverse CT section proving the intraorbital displacement of the left superior orbital rim fragments

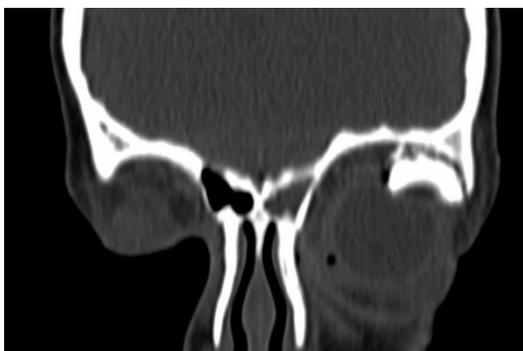


Figure 9 - Coronal CT section demonstrating the displaced left intraorbital fractured fragment impinging on the left globe and the superior rectus muscle



Figure 10 - Sagittal CT section showing the presence of the displaced intraorbital fragment causing pressure on the globe and on the superior rectus muscle

Otolaryngology contribution

Otolaryngology is often the first examination performed in the emergency setting for the management of epistaxis, frequently encountered in facial traumatism, particularly in association with midface, lateral face and central face fractures.

Isolated naso-orbito-ethmoid fractures represent approximately 5% of facial fractures

in adults, but they have a high incidence in the context of other facial fractures. More than half of all NOE fractures are associated to orbito-zygomatic fractures, while 20% are found in the context of panfacial fractures (32). The most challenging part in the treatment of central face fractures is management of the frontal sinus. Fractures located here often interest both the anterior and the posterior bone plates, with the possible occurrence of dura tears and brain herniation. Multidisciplinary management is important for minimizing the morbidity and achieving good functional and cosmetic outcomes. Complications of frontal sinus fractures include the formation of mucocoele, sinusitis, osteomyelitis, meningitis, encephalocele, cerebrospinal fluid fistula, central face deformity (33). In the presence of small dural discontinuity and CSF leaks, conservative treatment may often lead to the spontaneous closure of the fistula, justifying the observation of these fractures for up to one week before considering surgery. Frontal sinus obliteration or cranialization is indicated in cases where the ventilation of the frontal sinus cannot be reestablished (33). The endoscopic management of central face fractures allows for a minimally invasive approach and accurate visualization (32). In skull base fractures with cerebrospinal fluid fistulas, local flaps from the nasal cavity can be utilized for the closure of CSF leaks using an endoscopic technique.

Fractures of the medial and inferior orbit can also be accessed endoscopically, or by a combined approach comprising a transconjunctival and an endoscopic trans-

nasal access (34, 35). There are some disadvantages to the entirely endoscopic approach consisting of difficult insertion of the reconstruction material, with the orbital contents being supported by the nasal packing, which predisposes to the onset of postoperative enophthalmos. Thus, a combined open and endoscopic approach would associate the superior endoscopic visualization of the posterior bone ledges, with the improved access for titanium mesh insertion (34, 35).

Ophthalmology contribution

Careful observation and interdisciplinary management are mandatory in orbital fractures, frequently requiring multiple ophthalmological examinations. One in four patients with orbital fractures has an associated ocular lesion (36). It is for this purpose that any periorbital trauma patient must be initially evaluated by an ophthalmologist. The eye examination involves determination of ocular lesions in the anterior or posterior segments, diagnosis of a globe rupturing or retrobulbar hematoma. Evaluation of eye mobility and the degree of exophthalmos and enophthalmos may not be accurate in the presence of posttraumatic edema and necessitates subsequent examinations. Studies have shown that the greatest risk for posttraumatic vision loss in orbital fracture patients is found in the ones presenting with penetrating orbital lesions, in patients with diagnosed fractures of the posterior orbit, involving the orbital apex, patients exhibiting a decrease in visual acuity, or an afferent pupillary defect (36, 37).

Ophthalmologic examinations are important in the perioperative period to rule out the occurrence of a retrobulbar hematoma, which represents an indication for emergency drainage surgery through lateral canthotomy. The finding of postoperative retrobulbar hematomas has decreased since the implementation of fenestration for reconstructive materials used in orbital surgery (38), but nevertheless the importance of periodic inquiry regarding visual acuity in the postoperative time remains crucial for the timely intervention in case of compressive hematoma development.

The ectropion-related ophthalmologic sequelae that are frequently linked to periorbital traumatism may lead to a decrease in the life quality of the patient and often necessitate repeated correction procedures.

Conclusion

Maxillofacial surgeons, neurosurgeons, otolaryngologists and ophthalmologists handling the acute orbital trauma patient should be familiar with the possible complications, the indications for immediate, early and delayed surgery, or for the conservative management in different patterns of orbital fractures. Good collaboration between the different specialties increases the chances for early diagnosis, accurate operative or non-operative management with proper follow-up and minimal complications. The surgical approach often requires a multidisciplinary participation for achieving a good exposure, performing a proper anatomical repair, resulting in favorable functional and aesthetic outcomes.

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