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Original Scientific Paper

ORBITAL BLOWOUT FRACTURES: A RETROSPECTIVE STUDY WITH LITERATURE REVIEW

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SUMMARY – Blowout fractures of the orbit are relatively common injuries of the viscerocranium. However, there is still no general consensus on the optimal timing and method of treatment. This article gives a comprehensive review of the pathology of the fracture, process of diagnosis, management and follow-up, including results of a retrospective study done in the Department of Maxillofacial and Oral Surgery, Dubrava University Hospital, Zagreb, in which we collected and analyzed medical records of 91 patients treated for blowout fractures in our institution over a period of three years. Our study showed that the patients admitted to our department more than 48 hours from the injury were more than 4 times likely to develop a complication that would require additional treatment. In other words, of our 91 patients, those admitted to our department in the first 48 hours from the injury had a more than 4 times lower rate of complications, likely due to early recognition of the injury with early intravenous antibiotic and corticosteroid administration, multidisciplinary treatment, and early recognition of candidates for emergency and early surgical treatment. The results of our study show the importance of treating blowout fractures in a tertiary care facility with expertise on the subject.

Key words: *Orbit; Blowout fracture; Trauma, maxillofacial*

Introduction

Blowout fractures of the orbit are relatively common injuries of the viscerocranium, very frequently treated in the Department of Maxillofacial and Oral Surgery, Dubrava University Hospital from Zagreb, where they are often referred to from other hospitals throughout the region. This article gives a comprehensive review of the pathology of the fracture, the process of diagnosis, management and follow-up, including results of a retrospective study done in our department, in which we collected and analyzed medical records of all patients treated for blowout fractures in our institution over a period of three years.

Blowout fractures are isolated fractures of the orbital wall, with the orbital rim remaining intact. The inferior orbital wall is the one most commonly involved, as its posteromedial part is considered the weakest point of the orbit. Less commonly, the medial orbital wall is affected, while isolated fractures of the superior and lateral orbital wall are extremely rare. The fracture can be linear or comminuted, and it can result in herniation or impingement of orbital contents in the fracture. When a transiently displaced bony fragment allows for herniation of orbital structures into the

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maxillary sinus and then returns to its position due to bone elasticity, consequently entrapping the orbital contents in the fracture, a so-called ‘trapdoor’ fracture occurs[1]. Blowout fractures are commonly accompanied by soft tissue damage. The three most commonly acclaimed theories on the mechanism of production of these fractures are the hydraulic theory, the buckling theory, and the globe to wall theory, as seen in Figure 1[2]. The hydraulic theory proposes that the fracture occurs after blunt-force trauma to the globe that causes an increase in intraorbital pressure. The buckling theory proposes that the fracture is a result of transmission

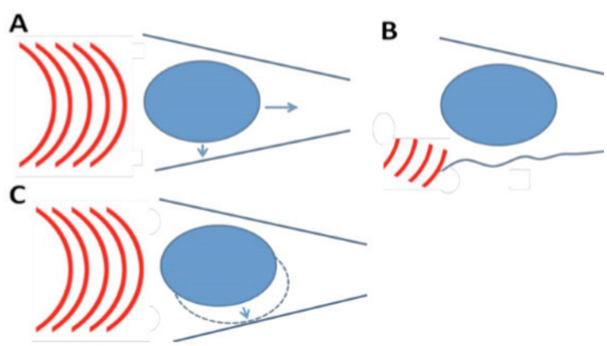

Fig. 1. Schematic drawings of the mechanisms of fracture: A – hydraulic theory; B – buckling theory; C – globe to wall theory (according to Felding[2]).

of force from a direct blow to the orbital rim. The globe to wall theory contends that the globe itself is displaced into the orbital wall and causes the fracture directly. A study of the buckling and hydraulic theories with simulation of injury on human cadavers showed that both mechanisms produced isolated orbital wall fractures. However, the fractures differed in size and position. The study showed that the force applied to the orbital rim caused smaller fractures, often confined to the anterior and mid-medial portion of the orbital floor, whereas the force applied to the globe caused larger fractures, always involving the orbital floor and medial orbital wall, often with herniation of orbital contents[3]. As the globe and periorbital soft tissues are relatively elastic and the surrounding orbital walls are very thin, blunt-force trauma to the region often causes isolated orbital wall fractures, and not severe globe injuries, which is actually one of Nature’s interesting evolutionary mechanisms to prevent loss of eye sight.

Blowout fractures are more common in men than in women, and are usually associated with falls, violence, sports and motor vehicle accidents[4,5]. The exact mechanism of injury is important to note because higher energy mechanisms are associated with greater soft tissue damage. A typical patient presents with pain, periorbital edema and hematoma, restriction of eye movement, diplopia, enophthalmos, and hypoesthesia of the infraorbital nerve[1,5]. Most patients are examined by an ophthalmologist to evaluate any possible injury to the globe itself and to confirm the clinical finding of double vision by objective methods. Patients can also present with blurred vision or even blindness, especially linked to possible retrobulbar hematoma formation, but the hallmarks of vision impairment in blowout fractures are diplopia and enophthalmos[2]. Ocular motility disturbances are evaluated by Hess charts and Hess Area Ratio (HAR). A method of quantifying diplopia which has been proposed as routine evaluation of orbital trauma patients is a binocular single vision test (BSV) using the Goldmann perimeter[6]. A study by Alhamdani *et al*. showed that the BSV score could be useful in determining the need of early surgical treatment, as opposed to ‘watchful waiting’[7]. Enophthalmos can be quantified by Herthel’s exophthalmometry. A study showed that enophthalmos becomes apparent to the naked eye when measuring between 3 and 4 mm[8]. In most cases, it is primarily an aesthetic problem, but it can also cause functional issues such as eyelid retraction, lagophthalmos and keratitis, which can require surgical treatment. In children, a common phenomenon is the so-called ‘white-eyed’ blowout fracture; they often do not present with periorbital hematoma or edema. However, they often present with headache, nausea and vomiting, i.e., signs that can mimic commotion syndrome. That happens because of bone elasticity, which causes the fractured fragment of the orbital floor to return to its position with consequential entrapment of the periorbital soft tissues in the ‘trapdoor’ fracture and development of the oculocardiac reflex, i.e., bradycardia, nausea and vomiting, mediated by an increase in vagal tone[9].

After taking a good patient history and detailed clinical examination, the patient needs to have a multi-slice computed tomography (MSCT) scan, which is the gold standard for diagnosis of this fracture (Fig. 2). It is essential to analyze coronal and sagittal slices,

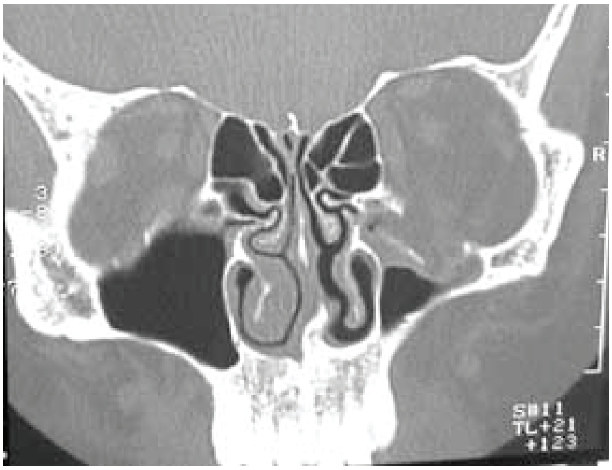

Fig. 2. Multi-slice computed tomography scan – coronal slice.

without which proper analysis of orbital wall defect and existence of soft tissue prolapse or impingement is impossible. However, it is important to be aware of the possibility of a false-negative MSCT scan, especially in the pediatric population with greenstick, 'trapdoor' fractures that result in a minimal fracture line[10]. A study also confirmed that MSCT findings underestimated the extent of soft tissue entrapment in the pediatric population and that magnetic resonance imaging (MRI) was superior to MSCT in the assessment of soft tissue herniation[11]. These findings give even more importance to detailed clinical examination. Generally, dexamethasone is administered on admission to help reduce the swelling. Some patients may not present with enophthalmos initially because of significant tissue edema, which is why MSCT scan analysis is often essential in recognizing the surgical candidate. Absolute indications for surgical treatment of an orbital wall fracture are dysfunction of the bulbomotor muscles resulting in limitation of eye movement and double vision and/or enophthalmos greater than 2 mm measured on MSCT and/or fractures involving more than 50% of the orbital floor. Extraocular muscle entrapment, which presents with severe limitation of eye movement, double vision and pain on eye movement, can be more adequately assessed on an MRI scan, which is considered a valuable complement to MSCT analysis (Fig. 3). Prolonged muscle entrapment can cause muscle ischemia and fibrosis, which can lead to persistent diplopia after appropriate but delayed surgical treatment. Clinical signs of muscle entrapment or oculocardiac reflex are an indication for emergency surgical treatment[1]. Patients without an indication for emergency surgery and without an absolute indication for surgical repair are followed-up closely. In some cases, diplopia is caused by edema or muscle contusion, and can be resolved spontaneously in a few weeks, which is an argument for delayed surgical treatment. In addition, enophthalmos or hypoglobus can be revealed only after edema resolution, which is also a strong argument for close follow-up of these patients.

Fig. 3. Magnetic resonance imaging scan – coronal slice.

Optimal timing of surgical reconstruction has long been a subject of debate. Most experts agree that the indications for immediate surgical treatment are signs of muscle incarceration, retrobulbar hematoma formation with acute vision impairment or signs of oculocardiac reflex development. These patients should undergo surgery in the first 6-24 hours after the injury[12]. Early surgical repair, i.e., repair in the first 14 days from injury, is indicated for enophthalmos greater than 2 mm with significant diplopia and for bony defects larger than 50% of the wall surface. Such large defects will often expectedly result in enophthalmos, which can be inapparent until the edema subsides. However, by that time fibrosis may already have developed, which can complicate the reconstructive procedure later on. Lastly, delayed surgical repair, 14 or more days after injury, is indicated in cases of late-onset enophthalmos and persistent significant diplopia in patients with a negative forced duction test and without proof of entrapment on MSCT, but with minimal improvement over 2-week time. There is insufficient evidence to determine strict guidelines for optimal timing of non-immediate surgical repair[13].

Surgical treatment can consist only of mobilizing the prolapsed soft tissue out of the fracture. This is enough in some cases, especially in children. If the defect of the orbital floor is large, reconstruction is needed. The ideal material for wall reconstruction should be sturdy enough to support the orbital contents, easy to contour, biocompatible, and inexpensive[14]. Autogenous bone grafting is the gold standard of reconstructive bone surgery in general, so autogenous bone and cartilage were some of the first materials used in reconstruction of orbital wall defects. Some of their major drawbacks are their limited amount, involvement of a second operative site and longer operative time, as well as unpredictable degree of resorption. The most widely accepted option in orbital reconstruction today is using alloplastic materials, which can be nonresorbable (most commonly titanium, polyethylene, silicone) or resorbable (most commonly polyglycolide, polylactide, polydioxanone [PDS])[15]. Using alloplastic materials eliminates donor site morbidity and shortens operative time. We mostly use titanium mesh, which is thin, sturdy, highly biocompatible, easy to contour, and maintains its shape. It can easily be contoured preoperatively to a stereolithographic model (Fig. 4) of the mirror image of the contralateral orbit, provided it is intact[16]. This 3D model, printed according to preoperative computed tomography (CT) image of the non-affected orbit, is used to shape the alloplastic reconstructive material, thus making it patient-specific, which enables a more accurate reconstruction, reduces operative time and intraoperative manipulation. Titanium mesh and Prolene mesh used in our department are shown in Figure 5. A recent multicenter study on 195 patients showed that using individually customized titanium mesh implants resulted in significantly more precise reconstruction, which was measured by comparing operated and contralateral orbit volume differences on CT[17]. Still, there is no general consensus on the best material for reconstruction.

Fig. 4. 3D printed models of the orbit.

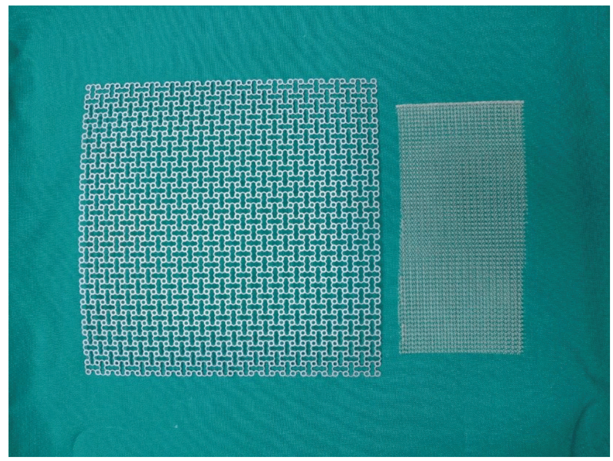

Fig. 5. Titanium (left) and Prolene mesh (right).

Patients without an indication for immediate surgical treatment are treated with dexamethasone and/or intravenous antibiotics. If after edema/hematoma regression the patient shows neither restriction of eye movement with double vision nor dystopia, they are discharged from the hospital. They are closely followed-up in the outpatient department to reevaluate clinical findings in the forthcoming weeks. Blowout fractures differ from other fractures in this respect; the goal of surgical repair is normally not to achieve bone healing, but only to reconstruct the contour of the orbital wall, which is one of the reasons surgery is not necessary when abnormal clinical signs and symptoms are not present[14]. There are a few special considerations in treating orbital blowout fractures in the pediatric population. Some argue that pediatric orbital blowout fractures should be treated conservatively regardless of the bony defect size, provided there is no sign of entrapment, no enophthalmos, and no vertical orbital dystopia[18]. Additionally, when surgical treatment is needed, the potential growth disturbances should be considered when choosing reconstructive material[9,19]. Any signs of a 'trapdoor' fracture with muscle incarceration, which is considerably more often in the pediatric population, is an indication for emergency surgery. Children are more prone to muscle incarceration in blowout fractures due to close proximity of the inferior rectus to the orbital floor and relative lack of periorbital adipose tissue for protection, as shown by CT-based assessment[20]. In this group, the presence of nausea or vomiting and longer injury-to-operation time is associated with prolonged complications despite proper surgical treatment[10]. All patients are closely followed-up in the early postoperative period to recognize any postoperative complications or residual dysfunction. The most common postoperative complications are persistent diplopia, enophthalmos and infraorbital nerve dysfunction, which develop in a percentage of cases despite clear indications for surgery and appropriate surgical technique. A recent study showed that orbital exploration and surgical reconstruction could worsen diplopia in 10% of the cases by compromising the oculomotor nerve function[21]. Persistent diplopia after surgical repair is thought to be caused by direct damage to the muscles or nerves, persistent entrapment or fibrosis formation around the reconstructive material. A study by Shah *et al*. found an association between postoperative diplopia and use of porous titanium mesh. This is explained by the properties of titanium which induces an inflammatory and fibrogenic response of the surrounding tissue. While these properties result in lower extrusion and infection rates, the fibrotic effect of titanium may cause movement restriction which is called 'orbital adherence syndrome'[22]. Another study showed that the incidence of postoperative complications was significantly lower with early surgical repair, i.e., within two weeks from injury[23]. A recent multicenter study showed no association between the presumed predictors of unwanted outcome (implant surface contour, dimension and position, accuracy of volume restoration, and topography of the fracture) and unwanted outcomes (diplopia and dystopia), which is further proof that the effect of appropriate mechanical reconstruction is not sufficient, that clinical outcomes are less predictable than we presumed, and that some other, unknown, individual soft-tissue-related factors play a significant role in the outcome[24]. To assess the position of the reconstructive material, an MSCT scan can be ordered postoperatively. If available, an MRI scan is even more appropriate to evaluate the position of reconstructive material in relation to intraorbital structures. Depending on their clinical condition, patients are usually discharged in the next few days after surgery and switched to oral administration of antibiotics for up to 7 days.

Material and Methods

Medical records of patients treated in the Department of Maxillofacial and Oral Surgery, Dubrava University Hospital, Zagreb during the period from January 1, 2016 until December 31, 2018 were searched for the International Classification of Diseases (ICD) code „S02.3“ representing fractures of the orbital floor. After analysis of medical records, many of the patients were excluded from the study since they were filed under a wrong code, and actually had a different kind of fracture, most commonly that of the zygomatic bone. This left 91 patients in our registry. We are, of course, aware that a certain number of patients who were actually treated for blowout injury might not be included in our registry due to filing under different codes. However, since our registry of 91 patients provided us with enough data to do statistical analysis, we chose not to address this issue in this study. Medical records of our 91 patients were analyzed. Age, sex, mechanism of injury, localization of fracture, clinical presentation, diagnostic tests, treatment, length of hospital stay, outcome and follow-up period were noted. Descriptive statistics was generated with proportions for categorical data. Arithmetic mean and standard deviation were calculated for normally distributed data, as well as median with interquartile range if continuous data were skewed. According to the small sample size, Fisher exact test was performed in cross-tabulation analysis for examining the relationship between categorical data. When significant association was found, odds ratio was calculated. In the receiver operating characteristic (ROC) curve analysis, area under the ROC curve, sensitivity and specificity with corresponding 95% confidence intervals were calculated and a criterion was determined for participants with and without complications. All results were considered statistically significant at the level of significance $p<0.05$. Statistical analyses were performed in IBM Statistics for Windows, version 25.0 and MedCalc Statistical Software version 19.1 (MedCalc Software bv, Ostend, Belgium; https://www.medcalc.org; 2019).

Results

Of our 91 patients, 74.7% were males and 25.3% were females, average age 48 years and median 46 years. By far the two most common mechanisms of injury were the same level falls (45%) and violence (35%). Less commonly, the fracture was caused by sports injuries, motor vehicle accidents, and workplace-related accidents. The majority (78%) of the fractures occurred through the orbital floor, 15% involved both the orbital floor and medial wall, and 7% involved only the medial orbital wall. Most of the patients (71%) were initially examined in a different institution and then referred to our department, and the remaining 29% were initially examined and admitted to our institution. Among those initially examined in a different institution, the mean delay from the time of injury to referral to our department was 1.58 days. The median value of the delay time was zero, meaning that 50% of the patients were referred to us on the day of the injury. All of the patients except for one had an MSCT scan done. The only patient without an MSCT had an MRI. A total of eight patients (8.8%) had an MRI scan, 4 of which were ordered preoperatively (one of which was ordered by an ophthalmologist to assess optical nerve due to blurred vision), and 4 were ordered postoperatively due to residual diplopia. Blurred vision was noted in one patient only, and none of the patients presented with blindness. More than half (59%) of the patients needed surgical repair, and 41% were treated without surgery. Out of the 54 (59%) surgically treated patients, 39 presented with limitation of eye movement with double vision, 12 had both limitation of eye movement with double vision and enophthalmos, while in 3 patients enophthalmos was the only indication for surgical repair. The median time elapsed from initial examination to surgery was 3 days. Three of the 91 patients were underage (ages 12, 13 and 14). All of the children were initially examined in a different institution where they had an MSCT scan done. All the three children were treated by surgical release of the herniated soft tissue, without reconstruction of the orbital floor, as it was not needed. Among other patients treated surgically with reconstruction of the orbital floor, in the majority of these cases (90%) a titanium mesh was used, while in the other 10% a Prolene mesh was used. In four patients (8% of the surgically treated patients with reconstruction of the orbital floor), it was noted in medical records that the titanium mesh was preoperatively modelled to a 3D-printed model of the contralateral orbit. The patients were hospitalized for a mean of 5.8 days, range 2-18 days. The mean follow-up was 91.9 days with 2.5 check-ups. In 13 (14.3%) cases, there were complications in the follow-up period, which required additional treatment. The complications were residual diplopia in 6, enophthalmos in 3, mesh protrusion in 2, and lower lid ectropion in 2 cases. Fisher exact test was performed in cross-tabulation analysis to examine the relationship between the institution of initial examination and incidence of complications, and we found no statistically significant relationship between the two. ROC curve analysis showed that the cut off value of delay time from injury to referral to our department as a criterion for development of complications was 48 hours. Fisher exact test was now performed to examine the relationship between the incidence of complications in two groups of our patients, i.e., one in which the patients were admitted to our department up to 48 hours from the injury, and the other in which the patients were admitted more than 48 hours from the injury. Significant association ($p<0.05$) was found. Odds ratio was 4.097, meaning that the patients admitted to our department more than 48 hours from the injury were more than 4 times likely to develop a complication that would require additional treatment. In other words, of our 91 patients, those admitted to our department in the first 48 hours from the injury had a more than 4 times lower rate of complications.

Discussion

Isolated orbital wall fractures are relatively common injuries in maxillofacial trauma that can cause permanent functional and/or aesthetic impairments if they are not treated properly and on time. Thus they have been the focus of many studies by surgeons who deal with maxillofacial trauma. Reviewing the literature and our own experiences, it seems that we know plenty, i.e., the mechanisms of injury have been well-elaborated, we know when and in whom to suspect them, how to make the diagnosis, we know about the pearls and pitfalls of the reconstructive procedure and post-procedural care. However, diplopia and enophthalmos are still relatively common complications even with proper surgical care, and there is still a lot of debate as to when, how and if the reconstructive procedure is needed. The reconstructive procedure itself is normally not considered technically demanding; however, there are many potential risks including infection, bleeding or implant migration, which can lead to diplopia worsening, implant protrusion, or even blindness. Some studies have shown that the surgeon's experience may also be an important factor in the outcome of complex orbital wall reconstruction[25].

A recent study conducted in Sweden proposes new algorithms for treating blowout fractures based on certain CT characteristics, including the herniated orbital volume. Their findings indicate there may be less need for surgical treatment in cases of diplopia without muscle entrapment, which, according to the study, are mostly benign and resolve within a year in 97% of the patients[26]. Therefore, the question 'to operate or not to operate' is a question we must be willing to ask ourselves time and again, for each patient individually, taking into account all the most recent knowledge and experience. Our study showed that admission to our department in the first 48 hours from injury was associated with a 4 times lower rate of complications that would have required additional treatment. Possible explanations for that result are early recognition of the injury with early intravenous antibiotic and corticosteroid administration, multidisciplinary treatment, and early recognition of candidates for emergency and early surgical treatment. The results of our study show the importance of treating blowout fractures in a tertiary care facility, like our department, with expertise on the subject.

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Sažetak

BLOWOUT PRIJELOMI ORBITE: RETROSPEKTIVNO ISTRAŽIVANJE I PREGLED LITERATURE

M. Lorencin, Ž. Orihovac, R. Žaja i *I. Begović*

Blowout prijelomi orbite su relativno česti prijelomi u području viscerokranija, no još uvijek postoje dvojbe oko optimalnog načina njihova liječenja. Ovaj rad uključuje pregled novije literature o patologiji prijeloma, dijagnostici, liječenju i praćenju, uz rezultate retrospektivne studije provedene u Klinici za kirurgiju lica, čeljusti i usta Kliničke bolnice Dubrava, Zagreb. Analizirani su medicinski podaci bolesnika liječenih u našoj Klinici zbog izoliranog prijeloma orbite u razdoblju od tri godine. Istraživanje je pokazalo da su bolesnici primljeni u našu Kliniku više od 48 sati od ozljede imali 4 puta veću stopu komplikacija koje su zahtijevale dodatno liječenje u odnosu na bolesnike primljene unutar 48 sati od ozljede. Takav rezultat vjerojatno je posljedica ranog prepoznavanja ozljede, ranog započinjanja intravenske antibiotske terapije, liječenja u multidisciplinarnom timu i rano prepoznavanje bolesnika kod kojih je indicirano rano kirurško liječenje. Ovakav rezultat potvrđuje važnost liječenja diferentnih ozljeda poput *blowout* fraktura u tercijarnoj bolničkoj ustanovi s iskustvom u tom području.

Ključne riječi: *Orbita; Blowout prijelom; Trauma, maksilofacijalna*