## Title

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*Case Report*

# Worsening orbital roof "blow-in" fractures following traumatic brain injury: A report of two cases

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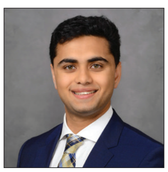

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## ABSTRACT

**Background:** Orbital roof fractures are often the result of high-velocity collisions and are seen in 1–9% of patients with craniofacial trauma. Although the majority of orbital roof fractures are displaced superiorly, a subset results in inferior displacement of fracture fragments, posing a risk for muscle/nerve entrapment and possible blindness. Many of these patients have severe traumatic brain injury (TBI) and, in addition to orbital fractures, also have elevated intracranial pressure (ICP). Management of depressed orbital roof fractures in the setting of severe TBI with elevated ICP represents a management dilemma.

**Case Description:** Two cases of severe TBI with associated downward displacement of orbital roof fractures were reviewed. Both cases exhibited elevated ICP correlated with the degree of orbital roof fracture depression. Surgical intervention involving elevation and repair of the fractures was undertaken when there was a significant risk of injury to the extraocular muscles and/or the optic nerve due to the extent of the fracture depression.

**Conclusion:** Depressed orbital roof fractures may migrate in response to changes in ICP. Serial computed tomography scans and eye examinations may aid with determining the need for and timing of surgical intervention.

**Keywords:** Cerebral spinal fluid, Intracranial pressure, Supraorbital roof fracture, Transpalpebral

## INTRODUCTION

Orbital roof fractures are often the result of high-velocity collisions and are seen in 1–9% of patients with craniofacial trauma.[3,4,7,9,10,15] "Blow-in" fractures refer to the inferior displacement of the orbital roof without involvement of the supraorbital rim or frontal sinus.[2] This injury pattern has been attributed to a spike in intracranial pressure (ICP) at the time of trauma.[1,17] While the management of these injuries has been described in the literature, there is a paucity of neurosurgical reports discussing the unique challenges posed by depressed orbital roof fractures in the context of severe TBI and elevated ICP.[2,12] These cases require a nuanced approach due to the interconnection between elevated ICP and the risk of further orbital roof displacement, which can compromise ocular structures and lead to long-term complications. In addition, the presence of severe TBI complicates the clinical assessment and management of these patients, making it imperative to establish clear guidelines and protocols. In this report, we present two cases of orbital roof fractures that demonstrated delayed orbital roof migration secondary to increased ICP [Figures 1a and b].

## CASE #1

A 26-year-old male was admitted after a high-speed motor vehicle accident. His Glasgow Coma Scale (GCS) score was 7 on arrival, and he was emergently intubated. His head computed tomography (CT) scan demonstrated multiple comminuted and depressed skull fractures as well as bilateral orbital roof fractures [Figure 2a]. There was 8.3 mm and 8.8 mm of downward depression on the right and left orbital roof, respectively [Figure 2b]. CT also demonstrated soft tissue signal in the extraconal orbit, causing local and regional mass effects and displacement of the extraocular muscles. The ophthalmologic evaluation demonstrated normal intraocular pressures and intact pupillary responses with no relative afferent pupillary defect. Extraocular movements were intact to forced ductions. There were no signs of a globe injury.

The patient underwent left decompressive hemicraniectomy and external ventricular drain placement. ICP was monitored throughout treatment [Figure 1a]. The immediate postoperative CT scan revealed decreased mass effect and reduction in the shift of intracranial contents [Figure 2c]. Notably, the orbital roof fragments had migrated superiorly from 8.3 mm and 8.8 mm to 3 mm and 2.9 mm of inferior displacement on the right and left side, respectively [Figure 2c], and ICP was <5 mmHg.

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A follow-up CT scan on postoperative day (POD) 2 demonstrated an interval increase in the frontal lobe edema and increased inferior displacement of orbital roof fragments to 7.3 mm and 6.0 mm on the right and left side, respectively [Figure 2d]; this correlated with an increase in ICP values from <10 mmHg to 13–18 mmHg. No changes were found on ophthalmologic examination and these injuries were managed conservatively. Another CT scan on POD 7 demonstrated further inferior migration to 7.9 mm and 8 mm [Figures 2e-h]; this correlated with ICP values of 14–22 mmHg. Due to continued inferior displacement of fracture fragments and concerns about long-term sequelae, operative repair was performed 11 days after decompressive hemicraniectomy.

A bilateral upper blepharoplasty approach was used to expose and reduce both orbital roofs, stabilizing them with customized mini-plates bent to a sterile anatomic model. The plates were fixated just behind the superior orbital rim, avoiding screw placement in the mobile bone segments. Intraoperative CT imaging facilitated the repositioning of the left plate for proper reduction. The remainder of the patient's hospital course was uneventful. The patient was discharged to a skilled nursing facility on post-injury day 81. At 3 months after surgery, the patient was doing well with intact visual fields and no diplopia.

## CASE #2

A 40-year-old female was brought in following a motor vehicle accident. Her GCS score was 7, prompting emergent intubation. A post-resuscitation head CT scan demonstrated multifocal intracerebral hemorrhages and bilateral orbital fractures. The right and left orbital roof fragments were inferiorly displaced by 2.6 and 7.0 mm, respectively [Figure 3a]. Fractures involved the left lateral orbital wall, orbital roof, and lamina papyracea with superior extraconal hematoma. Although the right orbit was stable, the left was mobile with expanding displacement due to the developing hematoma and expanding left frontal contusion. An external ventricular drain was placed for ICP monitoring and management [Figure 1b].

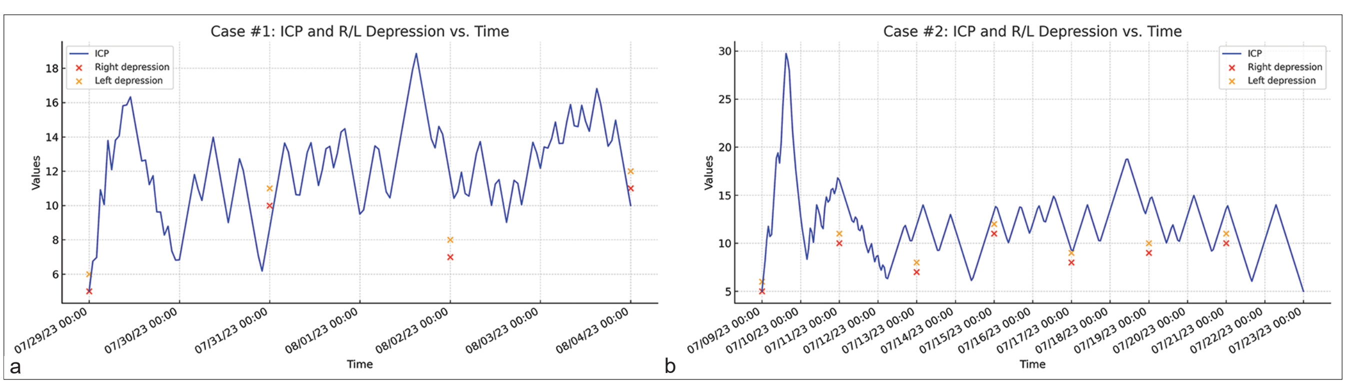


**Figure 1:** (a) Case 1: Intracranial pressure (ICP) versus fracture fragment migration. (b) Case 2: ICP versus fracture fragment migration.

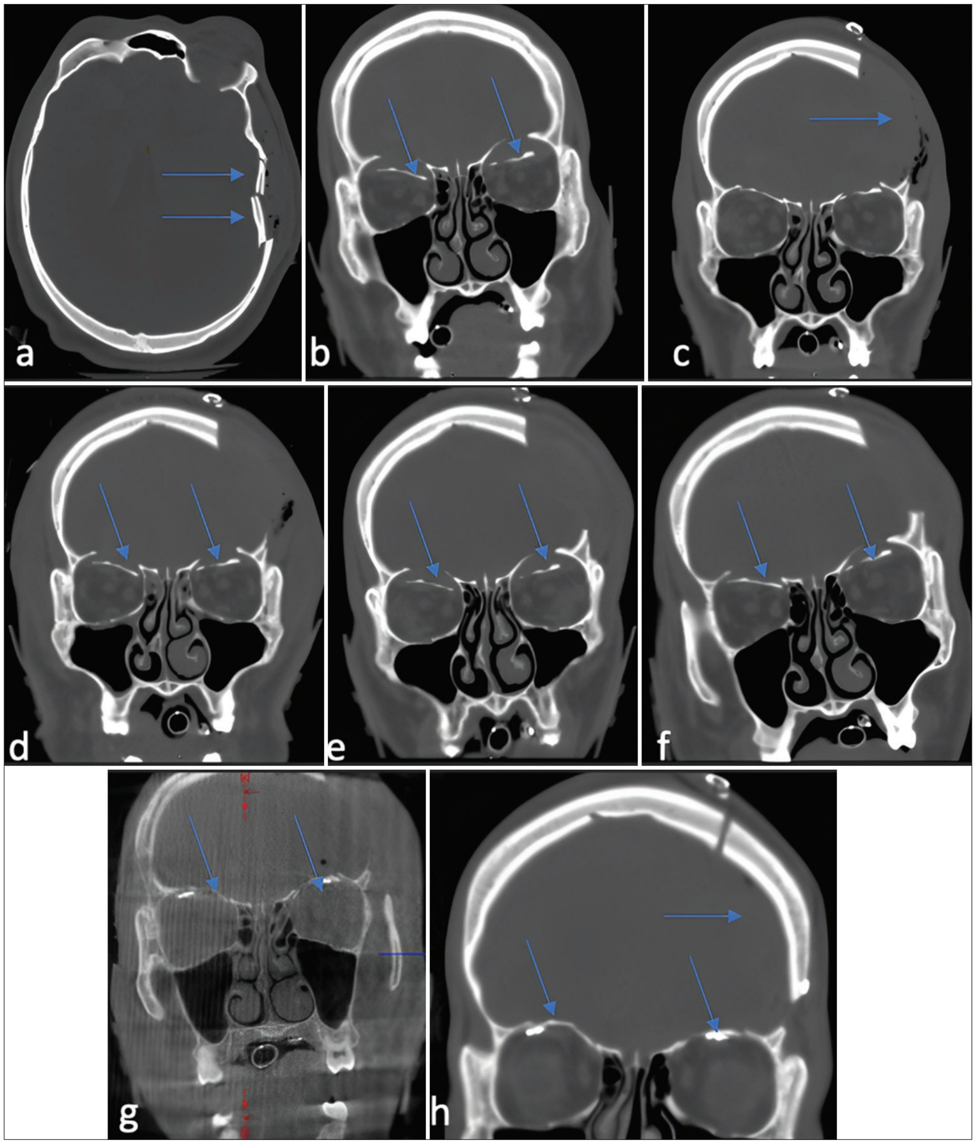


**Figure 2:** (a and b) Case 1: Computed tomography (CT) imaging of fracture fragments over time. Axial and coronal bone window CT images from admission demonstrating left calvarial depressed skull fracture fragments and bilateral orbital roof blow in fractures. (c) Coronal CT bone window status post left-sided decompressive craniectomy on postoperative day 0. (d-f) Migration of fragments over time shows 3 mm and 2.9 mm of inferior displacement on the right and left side, respectively. (g) Intraoperative O-arm CT after orbital roof reduction and fixation and (h) post cranioplasty 1 month after orbital roof repairs. *Arrows denote findings described in each image.

Ophthalmologic examination demonstrated mild anisocoria, briskly reactive pupils, and no relative afferent pupillary defect. Intraocular pressures were slightly elevated and felt to be secondary to periorbital edema and swelling.

A repeat head CT 20 h after injury demonstrated stable multicompartmental hemorrhages and slight worsening of the inferior displacement of the right and left orbital roofs, now at 3.1 and 9.1 mm, respectively [Figure 3a]. This progression of fracture displacement corresponded with an observed trend of increased ICP, underscoring a quantifiable relationship between elevated ICP and the extent of orbital roof depression [Figure 1b]. ICP values ranged from 13 to 22 mmHg, with a trend toward higher ICP as the depression of the fracture fragments increased. Another CT scan performed the following day demonstrated 2.8 and 13.2 mm of inferior displacement of the right and left orbital roof, respectively [Figures 3b-f]. A repeat ophthalmologic examination was unchanged. The greatest left-sided orbital roof displacement occurred after an ICP peak of 33 mmHg [Figure 1b].

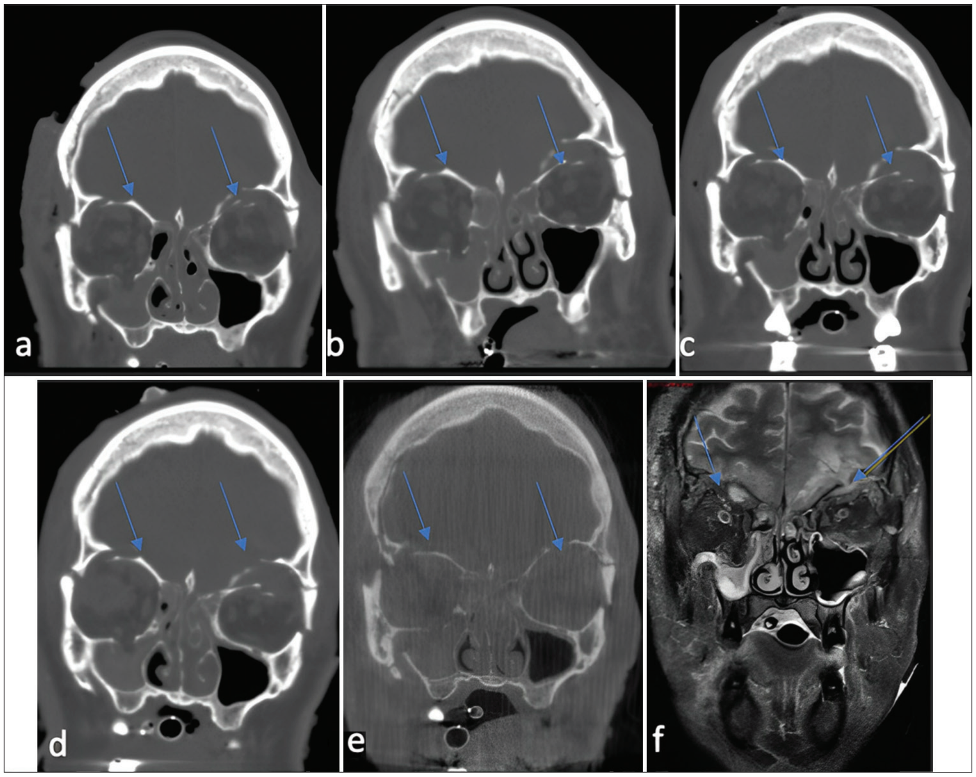


**Figure 3:** (a) Case 2: Computed tomography (CT) and Magnetic resonance imaging of fracture fragments over time. Coronal CT bone window image from admission showing inferior displacement of the right and left orbital roofs, now at 3.1 and 9.1 mm, respectively, and (b) 20 h later showing 2.8 and 13.2 mm of inferior displacement of the right and left orbital roof respectively. (c and d) The continued increase in depression over 2 days (e) led to repair and intraop O-arm image after reduction of fracture. (f) T2 coronal image with arrow denoting collagen onlay duraplasty. *Arrows denote findings described in each image.

Due to concerns about worsening inferior displacement on the left side [Figures 3c and d], the patient was brought to the operating room for orbital roof fracture reduction and fixation. An eyelid incision was performed, and dissection to the orbital rim and roof, as described above, was accomplished by the otolaryngology team; simultaneously, the neurosurgical team evacuated the frontal lobe hematoma and debrided a loose orbital roof fragment. The cerebrospinal fluid (CSF) leak was repaired primarily and covered with an epidural collagen graft on-lay. CT imaging confirmed the removal of free fracture fragments and no further reduction of the anatomic intraconal space [Figures 3c-f].

The patient was discharged to a board and care home on post-injury day 57. The patient did not attend follow-up appointments with neurosurgery, ophthalmology, or otolaryngology after discharge.

## DISCUSSION

This report highlights the potential for orbital roof fractures to migrate inferiorly in patients experiencing elevated ICP. The dynamic progression of associated injuries, such as hematomas and contusions, demands comprehensive imaging and clinical surveillance. Our observations reveal that all orbital roof fractures, regardless of being non-displaced or minimally displaced, necessitate reassessment, especially in scenarios of elevated ICP.

### Indications for surgical management of orbital roof fractures

Management of orbital roof fractures is focused on preserving visual acuity, maintaining normal extraocular movement, and preventing the functional and cosmetic consequences of enophthalmos or exophthalmos. The presence of orbital dystopia, enophthalmos, exophthalmos, extraocular muscle entrapment, high intraocular pressure, and alterations in visual acuity have all been proposed as indications for surgical intervention.[8,11] A significant challenge in managing patients with orbital fractures after severe TBI is the inability to perform a complete assessment of visual function. Visual acuity and diplopia are impossible to determine, so one must rely more heavily on objective measures of extraocular movement (i.e., forced ductions), intraocular pressure, and eye position. While most orbital roof fractures are successfully managed conservatively, our report suggests that elevated ICP with radiographic evidence of mobile/migrating fragments warrants close follow-up for progression of orbital roof displacement and possible ophthalmologic sequelae.[14]

### Surgical approaches for orbital roof fracture management

Most orbital roof fractures can be addressed through a transpalpebral or a bicoronal/frontal craniotomy approach.[13] Approach selection depends on the extent of the fracture, the presence of concomitant facial injuries, and patients' overall medical conditions. For patients with isolated orbital roof fractures, a transpalpebral approach can allow for minimal disruption of surrounding tissues.[6,13] In patients that require intracranial access to repair adjacent anterior skull base injuries, however, a bicoronal incision with frontal craniotomy is preferred. The morbidity associated with the transpalpebral approach is generally lower, with the primary risks including scarring, infection, and temporary sensory deficits in the supraorbital region.[6] The frontal craniotomy approach is a longer operation that introduces the risks associated with intracranial surgery (meningitis, brain injury, stroke, etc.) and can result in worse cosmetic outcomes.[13,16]

Connon *et al*. developed a classification and treatment algorithm for orbital roof fractures, advocating for craniotomies in cases with "blow-in" fractures associated with intracranial trauma and functional impairments of extraocular muscles, ocular function, or nerves.[2] Kim *et al*. reported a series of eight patients treated with frontal craniotomies and orbital reconstruction using titanium; no postoperative neurological complications such as cranial nerve deficits, meningitis, or CSF leaks were observed.[5] In this series, of the five patients with traumatic optic neuropathy, two regained full vision, one's vision worsened, and two lost vision completely.[16] The choice between transpalpebral and coronal approaches for orbital roof reconstruction should be based on surgical goals and risk assessment, with a multidisciplinary team approach allowing for tailored treatment plans.

## CONCLUSION

The management of orbital roof "blow-in" fractures involves a multidisciplinary approach to ensure optimal outcomes. It is important to recognize that these fractures can be mobile and may migrate with elevated ICP. Therefore, serial eye examinations and/or CT imaging should be considered in patients with depressed orbital roof fractures and episodes of elevated ICP.

### Ethical approval

The Institutional Review Board approval is not required.

### Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

### Conflicts of interest

There are no conflicts of interest.

### Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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