FRACTURES OF THE ORBITAL ROOF

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Introduction

Isolated fractures of the orbital roof are an uncommon clinical entity. Fractures often co-exist with fractures of the nearby structures, notably the frontal bone, frontal sinus and orbit. Management then needs to take these additional sites into consideration. This review focuses on fractures of the orbital roof, discussing those factors which influence assessment and the decision to surgically intervene.

ANATOMY OF THE FRACTURE

The superior roof of the orbit is made up mostly of the orbital plate of the frontal bone with the lesser wing of the sphenoid bone posteriorly, near the apex of the orbit (Fig 1). These comprise the anterior cranial fossa together with the cribiform plate of the ethmoid bone. The orbital roof itself is bound medially by the trochlear fovea and laterally by the lacrimal fossa (1). Orbital roof fractures themselves are uncommon, and rarely occur on their own. They usually occur following high energy trauma, for example following falls and motor vehicle accidents. Hence they are often seen in association with other craniofacial injuries. Orbital roof fractures are especially associated with fractures of the frontal bone, where they are likely to be associated with significant head trauma. Fractured patterns commonly include fractures of the forehead/frontal bone with extensions into the superior orbital rim (2). However, fractures may occur in isolation, for example following penetrating globe injuries.
Orbital roof fractures involve an important watershed area between the meninges and brain above, and the globe and orbital contents below. For this reason, it is important that both these sites are carefully assessed when a fracture is found. Concomitant ophthalmologic injuries such as globe trauma and traumatic brain injury / intracranial haemorrhage are commonly associated

GROWING SKULL FRACTURES

Growing skull fractures (GSF) are a rare complication of paediatric skull fractures which can result in dystopia, delayed neurological deficits, seizures, headaches and cranial asymmetry. These are often missed because they are usually associated with closed head injuries. Scalp haematoma and progressive scalp swelling often occur. Growing skull fractures commonly involve the orbital roof. CT scan is usually required to define the fracture, although MRI maybe also be required to further assess for soft tissue injury. Both CT and MRI are usually required pre-operatively.

Follow-up of children with skull fractures is therefore important to avoid misdiagnosis. In some cases surgery may subsequently be required. Patients may need to undergo dural repair with patching using pericranium or fascia lata, depending on the extent of the defect. The cranial defect is then covered/closed with local bone fragments or calvarial grafting. In more severe cases a cranioplasty may be needed.

SYMPTOMS AND SIGNS OF ORBITAL ROOF FRACTURES

Symptoms and signs can vary and are usually suggestive, not diagnostic, of an orbital fracture. In most cases the precise site may not be immediately apparent (Table 1). These include:

1. Periorbital bleeding (i.e. haematoma, haemorrhage or ecchymosis)
2. Pain or ocular discomfort that may be associated with eye movements or nose blowing
3. Epiphora (excess watering of the eye)
4. Facial lacerations (given high impact of trauma)
5. Periorbital oedema
6. Chemosis
7. Ocular misalignment
8. Proptosis (this may be pulsatile)
9. Enophthalmos and hyperglobus – here too, a pulsatile eye suggests ORF
10. Exophthalmus
11. Hypoglobus
12. Loss of visual acuity
13. Diplopia – Involvement of the superior oblique and recti muscles (intorsion, depression, elevation) \(^{(2)}\) may be difficult to detect clinically, but would suggest involvement of the orbital roof

14. Altered sensation in distribution of the supraorbital and supratrochlear nerves may be present \(^{(2)}\)

It is not uncommon to find lacerations too \(^{(7)}\). Intracranial haemorrhage is commonly associated with severely displaced fractures\(^{(3)}\).

**ASSESSMENT**

1 **Initial assessment (in the emergency department).**

Since orbital roof fractures typically present following high energy injuries, ATLS principles are usually applied. The eye may be crudely assessed during “D” when the pupil and vision can be noted, but it is usually assessed in detail during the secondary survey, once the patient has been stabilised and life-threatening injuries managed. A full ophthalmic examination should be carried out, noting signs of globe trauma. This involves assessment of visual acuity, eye movements, and optic nerve function via the pupillary reflex. Red desaturation and colour plate assessment should also be included if possible. Serial examinations may be necessary during the early stages, when swelling may evolve. Examination should also include palpation of the orbital rim to check for steps and/or other defects\(^{(7)}\). The position of the globe should be noted. If this is found to be abnormal or the globe proptosed or pulsatile, urgent imaging is required.

Imaging of the head should also include facial CT. MRI may also be required, although this is rarely undertaken acutely. CSF leaks and epiphora must be quickly and clearly differentiated. Any watery discharge from around the globe should be viewed with suspicion if orbital roof fractures have been identified and may require analysis for protein and glucose levels. This will help differentiate tears/aqueous humor from CSF.

2 **Late assessment (in out patients).**

Orbital fractures usually require formal ophthalmic and orthoptic assessment, depending on local protocols. The globe is assessed for signs of injury and eye movements recorded. Exophthalmometry, although rarely done, may reveal proptosis or enophthalmos \(^{(6)}\). For these to be reliable, it is best to wait for periorbital swelling to settle before measuring this\(^{(7)}\).
IMAGING

Fractures of the orbital roof are poorly visualised on plain radiographs. CT scanning of the head is usually the first line of imaging as these injuries typically have co-existing head trauma. Thin-section (thickness of 3 mm or less) orbital CT scan studies are best suited for all orbital roof fractures, in order to define the bony structures of the midface and orbits. With helical CT Scanning this is now possible without the need for repeat scanning. Orbital roof fractures are best visualised in the coronal views. These will show the exact size and displacement of any fractures as well as any associated fractures to the remaining orbit, face and skull. Both coronal and sagittal reconstructions provide a detailed view of the skull base and are therefore should be utilised to diagnose orbital roof and other anterior cranial fossa fractures. CT is also sensitive in visualising muscle entrapment, however its sensitivity in detecting muscle laceration and intramuscular injury is much lower.

At the same time other injuries may be noted, notably foreign bodies (which may contraindicate MRI), haematoma and globe rupture. Optic nerve injury, muscle laceration and intramuscular injury however are best seen on MRI scan. A guide to what imaging to request is shown in Table 2.

MRI is particularly useful in evaluating the complications of orbital roof fractures. Significantly displaced bony fragments can impale the under surface of the frontal lobes, result in encephaloceles, or be associated with herniation of orbital contents into the anterior cranial fossa. MRI may also identify globe injuries, retrobulbar fluid collection (e.g. haematoma), subperiosteal haemorrhage, and define haemorrhage or oedema along the optic nerve sheath. It can also help define the proximity of the extraocular muscles to the fracture edges. Although no studies have shown its superiority to CT in the detection of extra-ocular muscle injuries, several reports have suggested that MRI appears better in distinguishing muscle contour irregularity from a lacerated muscle. Is the reports, muscle changes initially missed on CT were later on identified on MRI. However, MRI scans are not undertaken routinely, but in some cases should be considered, (once the presence of a metallic foreign body has been ruled out). It is best indicated when there is suspicion of extraocular muscle lacerations and/or when CT studies are inconclusive.

With both high energy impacts and penetrating injuries there may be suspicion of intracranial vessel injury. In such cases a CT angiography or carotid angiography may be required. Anatomically, the ophthalmic artery is
the most “at risk” vessel (as well as supraorbital and supratrochlear, although these are less important) due to its position in the anterior cranial fossa. Trauma to the ophthalmic artery can result in reduced perfusion to both the optic nerve and retina, as well as the ocular muscles.

CLASSIFICATION

Classifying orbital roof fractures helps provide guidance in management. It also helps define the neighbouring structures that may be at risk and the need for involvement of other specialties. The following classification provides a useful guide. This is based on a study conducted at the Royal Melbourne Hospital between January 2011 and July 2013 where 47 patients with ORFs were treated (2).

<table>
<thead>
<tr>
<th>Orbital roof fracture</th>
<th>Associated injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Undisplaced</td>
<td>Suspected or proven:</td>
</tr>
<tr>
<td></td>
<td>F—other facial fractures</td>
</tr>
<tr>
<td></td>
<td>N—neurological/intracranial injury</td>
</tr>
<tr>
<td></td>
<td>O—ocular/intraorbital injury</td>
</tr>
<tr>
<td></td>
<td>S—frontal sinus injury</td>
</tr>
<tr>
<td>II. Rim</td>
<td></td>
</tr>
<tr>
<td>III. Roof</td>
<td></td>
</tr>
<tr>
<td>a. Blow-out</td>
<td></td>
</tr>
<tr>
<td>b. Blow-in</td>
<td></td>
</tr>
<tr>
<td>IV. Roof and rim</td>
<td></td>
</tr>
<tr>
<td>a. Blow-out</td>
<td></td>
</tr>
<tr>
<td>b. Blow-in</td>
<td></td>
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</tbody>
</table>

Orbital roof fractures (ORF) can thus be classified as displaced or non-displaced, isolated or extended.

Displaced ORFs include the “blow-in” fracture, with inferior displacement of the orbital roof due to an increase in the intracranial pressure (ICP). In these fractures it is very likely that there are bony fragments within the orbital cavity, possibly with ocular injury. In “blow-out” fractures there is superior displacement of the orbital roof into the anterior cranial fossa due to increased intraorbital pressure. In these fractures, fragments will be present in the anterior cranial fossa and possibly associated with brain injury / dural tears.

Supraorbital rim fractures can extend to involve the anterior, posterior or both tables of the frontal sinus.

CSF LEAKS AND ORFs

Fractures of the anterior skull base are often associated with dural tears. CSF leaks though the defect in the dura and then via the fracture into the nose or eyelid. This can be easily missed or considered to be simple physiological tearing, or ocular fluid. CSF leaks occurring into the orbit are sometimes referred to as “oculorrhoea” (9). These are rare. However they should be considered in all cases of forehead trauma presenting with significant or persistent eyelid / periorbital oedematous swelling. In some cases
CSF can leak through the nearby fracture (with associated dural tear) into the eyelid. This type of fistula occurs solely in orbito-cranial injuries. Its presence indicates that both the meninges and conjunctiva are compromised. As the CSF is contained, the patient develops boggy eyelids and conjunctival swelling. This type of presentation is called “refractory oculorrhoea”. It occurs more often than overt leaks and can be easily overlooked. Unrecognised this can lead fistula formation. It is easily confused with epiphora especially if lacrimal duct injury is present.

Untreated, CSF leaks can result in an increased risk of meningitis, intracranial hypotension, seizures and encephalocele development. As a result of the multiple breached layers, the arachnoid membrane and rarely brain tissue may herniate into the orbit resulting in neurological or vascular compression with subsequent loss of vision, or focal neurological signs due to brain displacement. Leaks also carry an increased risk of a cerebral infection.

True oculorrhoea is likely to be associated with orbital roof fractures following direct orbital trauma or penetrating injuries. This sign is easily missed and should therefore be thoroughly investigated if suspected. Fistulae formation may also occur following surgical procedures to the orbit, or near surrounding structures.

**DIAGNOSING CSF LEAKS IN ORFs**

A key element is awareness. CSF oculorrhoea should always be suspected if there are signs of associated intracranial / orbital injuries. Visible signs of fracture and epiphora (watery drainage from the eye) are the key to diagnosis. Any past history of surgery to the orbit should also raise suspicion.

Imaging is usually the first step in diagnosing CSF oculorrhoea. Preferred imaging techniques include:

1. **CT head.** Thin-cut coronal and sagittal reconstructions is usually the first line imaging technique. In addition to being highly sensitive for anterior skull base fractures, it may show intracranial air (pneumocephalus): this is highly indicative of CSF fistulae. For high sensitivity, coronal and sagittal reconstructions are recommended.

2. **MRI of neurocranium.** This may reveal a smaller fistula from the anterior cranial fossa to the orbit.

Diagnosis is confirmed following analysis of the epiphoric fluid, or any other leak that is coming from around the surrounding area. Fluid from the opposite eye should also be analysed, to
compare sides. Some authors recommend measuring and comparing the fluid’s glucose levels: anything above 30 mg/dL indicating cerebrospinal fluid (9). Others recommend measuring more specific protein levels, such as beta-2 transferrin, with high levels indicating cerebrospinal fluid. This protein is absent in tears and nasal secretions but is found in significant levels in CSF. Together with a CT assessment these tests should reliably determine whether the epiphora results from excess tear formation or CSF oculorrhoea (9).

**TREATMENT OF ORF AND CSF OCULORRHOEA**

In most cases the management of closed orbital roof fractures is dependent on the presence or absence of brain injuries and CSF oculorrhoea. Open injuries (most commonly penetrating injuries) will usually require surgical exploration, debridement and repair as necessary. With closed injuries surgical repair is usually dependent on the presence of associated brain injury, globe injury, CSF leaks or pulsatile proptosis.

Many patients present with minimal displacement of their fractures and no CSF leak. These can be managed non-surgically with observation. The risk of complications occurring is low (3). Conservative management which includes avoidance of straining and nose blowing is recommended. Minor CSF leaks may be expected in some orbital roof fractures, however these will rarely require surgical repair. Some surgeons choose to use oral steroids to reduce oedema and congestions (6).

In the presence of major CSF leaks, surgical repair is indicated. Displaced bone, penetrating trauma and refractory oculorrhoea are consistent with a significant leak. Cisternography with metrizamide or iopamidol contrast, followed by a thin section coronal CT scan have been reported as useful in localising the fistula pre-operatively. Cisternography may also be done with radionuclide contrast, but this method is less sensitive. Other surgeons simply explore the area and repair / patch any dural defects encountered.

If significant enophthalmos is present or eye-movements are significantly limited, secondary to entrapment, surgical repair is indicated (7). However if significant globe trauma is identified repair will need to be postponed due to the increased risk of complications to the damaged lobe. An interdisciplinary approach is therefore crucial to identify high risk patients and provide timely and comprehensive care (3).

Surgical repair may be undertaken via an intracranial / extracranial or combined approach. The primary aim of
surgery is to locate the fistula and to then seal the structures finishing with a watertight closure (9). The orbital roof itself may or may not require reconstruction.

The following are the most widely used surgical techniques to repair the orbital roof:

1. Accessing through a superior lid approach (also called superolateral orbital rim)

2. Via a coronal flap with craniotomy (also called a bitemporal approach). This is used in complex or extensive injuries with difficult access.

3. Use of existing lacerations can be a good approach in order to reduce scarring (12).

Post-operatively, patients should follow the same advice as above, i.e. no strenuous exercise or nose-blowing. Surgical follow-ups should be scheduled for the following weeks.

**PULSATING EXOPHTALMOS**

Pulsating exophthalmos (or pulsating proptosis) is a rare complication, which often follows high-energy impacts. It can present in association with orbital roof fractures. This is recognised by rhythmical and often systolic pulsations of the eye secondary to transmitted pulsation of the brain. Caroticocavernous fistula is included in the differential diagnosis. Additionally, the eyelids may be very swollen and lacerations of the peri-orbital skin are often associated (13). The aetiology of pulsatile exophthalmos in the context of orbital roof fractures relates to an abnormal cranio-orbital communication (13). Pulsation may also occur without proptosis as a result of transmission of normal brain pulsation into the orbit.

Pulsating exophthalmos is divided into two categories: vascular and cerebral.

1. Vascular pulsatile exophthalmos may be caused by an arteriovenous aneurysm or communication, residing in the cavernous sinus. This occurs between the ICA and cavernous sinus. Less frequently an abnormal communication can occur in the orbit between the ophthalmic artery and an orbital vein. These vessels normally lay inferiorly to the orbital roof, hence their vulnerability following orbital roof injuries. Saccular aneurysms may also occur, either originating from the ICA in the cavernous sinus or the ophthalmic artery (14).

2. Cerebral pulsatile exophthalmos occurs when the orbital roof (or occasionally medial orbital wall) is defective and is associated with a meningocele and/or encephalocele. Pulsations may also be caused by a traumatic hiatus in the orbital roof (15).
The type of tissues within the defect i.e. blood vessels, aneurysms, brain tissue, meninges, determines whether or not cerebral pressure and pulsations will be transmitted to the orbital content (16).

Pulsating exophthalmos presents with pulsation of the eye along with a bruit. The lids become swollen, oedematous, discoloured and the conjunctiva is chemotic. On visualisation of the vessels, the veins are congested with thickened walls. Most of the time the pulsation is visible, but this can also be palpated or a bruit auscultated through a closed lid. Bruits should be continuous, increased at systole and best heard over the globe. Another diagnostic technique is through compression of the carotid on the affected side: this should be followed by disappearance of the pulsation and bruit, and lessening of protrusion of the eyeball. The initial signs should return upon compression cessation (14).

To confirm the diagnosis, angiography and/or computed angiography are indicated: in most cases these will identify whether pulsations are caused by an aneurysm, a herniated vessel, meningocele or encephalocele (16). Early consultation with neurosurgery is needed as an intracranial approach may be required to reduce the herniated brain.

Depending on the underlying cause, a variety of surgical approaches may be used. The aim is to repair the damaged orbital roof, and allow for the herniated content to retract back to their original location. In the case of a vascular aetiology, endovascular techniques may be used: trapping, clipping, coiling (17).

**Learning points**

1 What sorts of patients get these injuries? – men seem to be more likely to get ORF than women and mostly following high energy trauma, such as motor vehicle/bike accidents, falls, and assaults.

2 What should raise suspicion? – any high impact trauma to the face and forehead, especially the frontal bone and the ocular region, in correlation with any of the signs and symptoms discussed in this paper.

3 What are the key investigations and how soon should they be requested? – CT head is the main imaging modality, followed by MRI to assess for soft tissue/extra-ocular muscle involvement and define neural/cerebral injury. CT head should be requested on initial attendance. MRI may be required later, if CT proves inconclusive or suspicion of soft tissue involvement e.g. muscle
laceration, haematoma, herniation has increased.

4 Important signs – periorbital ecchymosis, oedema, pulsatile exophthalmos, CSF oculorrhoea, enophthalmos

5 Once diagnosed, what should be done? – Focus initial on the management of any head injury. However, remember that eye trauma is also a surgical emergency.

Fig 1 Cranial surface of the orbital roof (Anterior cranial fossa)
### Table 1. Distinguishing ORFs

<table>
<thead>
<tr>
<th>Symptoms and signs suggestive of an orbital/skull base fracture</th>
<th>Symptoms and signs suggestive of ORF</th>
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</thead>
<tbody>
<tr>
<td>Poor vision</td>
<td>Pulsatile proptosis</td>
</tr>
<tr>
<td>Diplopia</td>
<td>CSF leaks from laceration (7)</td>
</tr>
<tr>
<td>Pain/ocular discomfort associated with eye movements or nose blowing</td>
<td>Exophthalmos</td>
</tr>
<tr>
<td>Epiphora: excessive eye watering (1)</td>
<td>Enophthalmos</td>
</tr>
<tr>
<td>Altered sensation in distribution of the supraorbital and supratrochlear nerves (2)</td>
<td>Peri-orbital haematoma</td>
</tr>
<tr>
<td>Peri-orbital haematoma/ ecchymosis</td>
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<tr>
<td>Peri-orbital oedema</td>
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<tr>
<td>Haemorrhage</td>
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<td>Chemosis (7)</td>
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<td>Enophthalmos</td>
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<tr>
<td>Peri-orbital haematoma</td>
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### Table 2 Key clinical signs and their manifestation on imaging i.e. what to look out for

<table>
<thead>
<tr>
<th>Subperiosteal haematoma</th>
<th>CT: blood presence between periosteum and bony orbit (good at differentiating between acute/subacute/hyper acute haematoma (19) MRI: hypo intensity on T1-weighted imaging and hyper intensity on T2-weighted imaging (18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraocular muscle laceration</td>
<td>(Often accompanied by haematoma) MRI: muscle contour irregularities, muscle desinsertion (10)</td>
</tr>
<tr>
<td>Extraocular muscle entrapment</td>
<td>CT: muscle herniating into frontal sinus or any fractured surface of the roof of the orbit</td>
</tr>
</tbody>
</table>
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