Imaging of oculo-orbital trauma: more than meets the radiologist's eye.

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Learning objectives

- To describe the fundamental anatomy of orbit and eyeball.
- To illustrate the variety of traumatic oculo-orbital injuries.
- To assess the different imaging techniques available for evaluating this lesion and their use in the emergency department.

Background

Oculo-orbital trauma is one of the pathologies that require urgent radiological studies. Depending on the imaging findings and the radiological assessment, the patient may be assumed to require surgical treatment. Since CT is the first choice in evaluating orbital trauma this exhibit will illustrate the orbital bone and soft tissue lesions, as well as in different parts of the eyeball evaluated primarily using this technique.

Traumatic pathology of the orbit is often seen in the polytraumatized patients (within the context of physical assault, traffic accidents or sports injuries). It is more common during the third decade of life and it occurs predominantly in men. In some cases, orbital trauma can lead to permanent visual loss or ocular movement impairment. Therefore, it is necessary to perform a correct and opportune diagnosis, identifying those patients who might require an urgent surgery such as in the case of intraorbital or intraocular foreign bodies, ocular wounds, eye compression by hematomas or fractures with muscle entrapment.

Anatomy:

In order to make a radiological assessment of an oculo- orbital trauma, it is important to know some anatomical key points of the orbit and the eyeball:

The orbit is a pyramidal space located in the middle third of the face. It is formed by seven bones that compose the apex, the base and the different walls of each orbit:

Walls: Fig. 1 on page 4
- The **roof** is formed by the frontal bone and the lesser wing of the sphenoid.

- The **floor** is composed by the maxillar bone medially, the zygomatic bone laterally and the orbital process of the palatine bone posteriorly.

- The **medial wall** is formed by the sphenoid body, the orbital plate of the ethmoid bone, the lacrimal bone and the frontal process of the maxilla.

- The **lateral wall** is formed by the greater wing of the sphenoid bone, the zygomatic process of the frontal bone and the frontal process of the zygomatic bone.

**Apex:** The optic foramen is a 6-12mm long and 5mm wide structure that forms a 45° angle with the sagittal plane of the head and that is enclosed within the superior and inferior roots of the sphenoidal lesser wings. It contains the optic nerve whose sheath is an extension of the dura that contains the ophthalmic artery and small veins.

**The globe Fig. 2 on page 5** is a spherical structure that lies anteriorly in the orbit. It is formed by three layers: the outer or fibrous layer that includes the sclera and the cornea, the middle or vascular layer composed by choroid, ciliary body and iris, and the inner or sensory layer formed by the retina.

**The lens** is an avascular biconvex structure suspended within the eyeball and connected with the sclera through the zonular fibers. It divides the globe into an anterior and a posterior segment. The anterior segment contains the aqueous humor and is divided by the iris into anterior and posterior chambers; on the other hand, the posterior segment is filled by vitreous humor and it is in contact with the retina.

Six **extraocular eye muscles Fig. 2 on page 5** and their intermuscular fascial membranes form an intraorbital conical structure. Those muscles can be assessed by CT using multiplanar reconstruction. The Zinn annulus corresponds to the common insertion of the superior, inferior, medial and lateral rectus muscles. The superior oblique muscle has its insertion at the orbital apex above the annulus of Zinn and the inferior oblique muscle goes from the medial to the inferolateral aspect of the orbit.

**Imaging options:**
Plain radiography has 64-78% of sensitivity for orbital fractures but this value is much lower for soft tissue injuries assessment.

Ultrasound is useful for evaluating the eyeball measure, layers and content Fig. 3 on page 6. It is a non-ionizing imaging technique, but it is contraindicated when rupture of the eyeball is suspected. In addition it does not allow the assessment of all orbital components.

Emergency MRI is not always available in most of the emergency services. It is not recommended for oculo-orbital trauma initial evaluation. MRI is only indicated to visualize the optic nerve and soft tissue in cases of visual loss or ocular motility impairment in which the cause has not been identified by CT. It is important to remember that MRI is contraindicated when an intraorbital metallic foreign body is suspected.

CT is considered the best imaging technique in oculo-orbital trauma because it assesses the intracranial, facial and ocular structures. In addition it is an available imaging option in most of the emergency services in main hospitals. However, careful control of radiation exposure must be done especially because radiation effects on the lens. Some authors propose that the best protocol for orbital study includes axial acquisition of 0.625-1.25mm with posterior multiplanar reconstructions. CT is indicated when there are clinical signs of orbital fracture. An un-enhanced orbital CT scan is the first choice to evaluate orbital trauma and then if vascular injuries are suspected an enhanced CT scan is indicated.

Images for this section:
**Figure 1.** Bone anatomy of the orbit on CT MPR

1. Medial wall
2. Orbital Floor
3. Lateral wall
4. Orbital roof
5. Optical foramen

*Fig. 1: Anatomy 1*
Figure 2. The eyeball and orbital muscles on CT MPR

1. Medial rectus muscle
2. Inferior rectus muscle
3. Lateral rectus muscle
4. Superior rectus muscle
5. Superior oblique muscle
6. Optic nerve
7. Anterior Chamber
8. Lens
9. Posterior Segment

Fig. 2: Anatomy 2
Fig. 3: Ocular sonography

**Figure 3. Ocular sonography**

1. Cornea
2. Lens
3. Vitreous
4. Anterior Chamber
5. Ciliary body
Imaging findings OR Procedure details

Orbital fractures may occur on its roof, floor, apex, medial or lateral walls. They can be associated with muscle entrapment or soft tissue herniation, as well as hematoma or emphysema that may produce eyeball displacement or limited ocular motility. Injuries to the eye can be located in the lens or within the anterior or posterior chambers. In addition, foreign bodies can be found in the orbit either inside or outside the eyeball. The findings associated with these can vary according to the material that they are composed of. It is necessary to assess damage to the optic nerve and vascular changes such as a carotid cavernous fistula.

Orbital Bone injury

The orbit is a complex structure containing 4 fundamental walls as was mentioned before. The weakest of them are the medial wall Fig. 4 on page 13 and floor Fig. 5 on page 13 therefore, most of the orbital fractures are seen there. Medial wall fractures are very common because of the fragility of the ethmoid bone and they may be difficult to recognize. In this case, presence of extraconal gas adjacent to the fracture point might be the clue to recognize the fracture. However, gas can be displaced and found in other locations. For this reason, herniation of orbitary fatty tissue into the ethmoid cells is a more constant parameter.

Orbital fractures can be divided according to their mechanism of injury in blow-out and blow-in fractures Fig. 6 on page 13

- **Blow-out orbital fractures** are produced by direct impact on the orbit by an object larger than its circumference producing a floor fracture with fragment displacement out of the orbit toward the interior of the maxillary sinus. This kind of lesion is more prevalent in the orbital floor. This type of fracture can be associated with displacement of orbital fat and/or herniation of the inferior rectus muscle Fig. 7 on page 15 and the medial rectus muscle Fig. 8 on page 15 Muscle entrapment must be suspected when the patient refers diplopia, pain or limited eye movement and on CT images when the muscle loses its characteristic ovoid shape, adopting a rounded morphology or when there is rotation on its major horizontal axis. It is important to evaluate all orbitary walls because occasionally multiple muscle entrapments can be found. Fig. 9 on page 16

- **Blow-in orbital fractures** are produced by a small object impact that produces a fracture with displacement of fragments into the orbit. This kind
of trauma can produce emphysema, hematoma, muscular entrapment or optic nerve compression. Fig. 10 on page 17

**Roof fractures** and Fig. 11 on page 17 **lateral wall** fractures Fig. 12 on page 18 might be isolated fractures or associated with other fractures in different walls. In general, fractures of the lateral wall are produced by high-energy trauma and are frequently seen in association with other facial fractures. Of these, we highlight the tripod fracture that includes maxillary, orbital floor and zygomatic arch fractures, affecting the lateral orbital wall. Fig. 13 on page 18 and Fig. 14 on page 19. Additionally, optical canal fractures can be related to nerve damage Fig. 15 on page 20. It is also important to remember that almost 20% of the traumatic brain injuries are associated with orbital fractures. During assessment of an orbital trauma it is necessary to look for eyeball, optic nerve and vascular lesions, as well as the presence of foreign bodies.

**Extraocular and intraorbital soft tissue injuries**

**Intraorbital hematoma/emphysema:** Retrobulbar contusion, emphysema Fig. 16 on page 21 and hematoma Fig. 17 on page 22 are common after a high-energy traumatism. These injuries are often associated with lesions of retina, choroid or optic nerve compression. For instance, a retrobulbar hematoma might increase intraorbital pressure, causing eyeball and optic nerve compression, and leading to occlusion of the central retinal artery and optic nerve ischemia. This entity is manifested by proptosis, eye moment impairment, visual loss, afferent pupillary defect and increased intraocular pressure.

**Eyeball Injuries**

**Anterior Chamber lesion:** In normal conditions the anterior chamber is filled by aqueous humor which is a clear liquid that provides nutrients to the cornea and contributes to maintaining its convexity, giving the tomographic density to the anterior part of the eyeball. Injuries in this chamber can be expressed by blood presence or shape changes.

- **Traumatic hyphema** is caused by disruption of vessels within the iris or ciliary body allowing blood entry into the anterior chamber Fig. 18 on page 23. Hyphema is seen on CT images as increased attenuation in the anterior chamber.

- **Corneal lacerations** occur in penetrating trauma which produces fluid leak and therefore decrease of anterior-posterior diameter of the globe. The eyeball diameter and shape must be compared with the contralateral eye.
**Lens injury:** Zonular fiber keeps the lens in position, thus globe deformation or zonular rupture leads may lead to partial or complete lens dislocations. Posterior dislocations occur more because of the presence of the iris which avoids anterior movement of the lens.

- **Complete luxation:** lens moves backwards into the vitreous humor Fig. 19 on page 24

- **Partial Luxation (subluxation):** there are marginal remaining zonular fibers that impede complete lens displacement, thus there is a posterior angulation where fibers are broken. Fig. 20 on page 24

- **Lens Rupture** Fig. 21 on page 25

- **Traumatic cataract:** blunt or penetrating ocular trauma can produce traumatic cataract. They have a stellate form - or rosette-shaped posterior axial opacities. Fig. 22 on page 26

**Vitreous haemorrhage:** Defined as the extravasation of blood in or around the vitreous body, it is generally, secondary to trauma. In CT, it can be observed as an increase in the attenuation of the vitreous body Fig. 23 on page 26. It is important to rule out perforation, retinal detachment or foreign bodies related to the trauma. It is possible to use ecography for evaluation when opacity limits an adequate fundoscopic examination. The finding depend on the severity of the haemorrhage. It produces an increase in ecogenicity that is more evident in declining areas of the eye. In more serious cases, numerous irregular, poorly defined and mobile low-intensity echoes can be identified in the vitreous.

**Retinal Detachment (DR):** occurs when the retina separates from the choroid. Clinically, it produces diminished visual acuity. Ultrasound, CT and MRI can be used for diagnosis, however MRI is preffered in order to determine cause. Both in CT and in MRI the presentation depends on the volumen of accumulated liquid, the presence of haemorrhage and the organization of subretinal content. Normally, subretinal liquid collections have a V shape, with the apex in the optical disc and the extremities heading towards the ora serrata. We can also see layers of undulated retina in the interior of the eyeball. Fig. 24 on page 27

**Detachment and choriod hematoma (DC):** The choroid is the intermédiate layer of the eyeball. It extends from the optic nerve to the ora serrata and is fixed to the sclera by
the arteries and veins that irrigate it. These lesions are caused by accumulation of liquid (serous DC) or blood (haemorrhagic DC), in the suprachoroidal space, between the choroid and sclera. They occur after eye surgery, penetrating trauma or inflammatory causes; the main subjacent mechanism is eye hypotonia. In CT images it appears as hypodense suprachoroidal collections in the form of a biconvex lens. Fig. 25 on page 28

**Open globe injuries:** The most important cause of monocular blindness. They can be easily identified by the physician or ophthalmologist in some cases. The patient might refer decreased visual acuity and afferent visual defect, hyphema, chemosis or hypotonia can be found during eye examination. CT is indicated when blunt or penetrating trauma is suspected. Without clinical history or ocular examination, CT has 75% sensitivity and 93% specificity for open globe injury diagnosis. These values increase if there is a complete ocular examination previously. If there is hypotonia with no clinical evidence of anterior perforation, CT helps to evaluate the posterior region.

CT findings suggesting an open-globe injury are:

- Changes in globe shape and contour (excluding other causes such as orbital hematoma. Fig. 26 on page 29
- Loss of ocular volume Fig. 27 on page 29
- The "flat tire" sign
- Discontinuity of the sclera Fig. 28 on page 30
- Intraocular air Fig. 29 on page 31
- Intraocular foreign bodies
- Increased volume of the anterior chamber, due to volume reduction in the posterior chamber and lens displacement.

Radiological signs associated with worse prognosis are: vitreous space distortion, lens absence and vitreous haemorrhage.

**Intraocular foreign bodies:** CT scan is indicated when foreign bodies are suspected inside the orbit or the globe. Fig. 30 on page 31 and Fig. 31 on page 32 .Most of them are glass, wooden or metallic fragments. CT is the first choice when metallic fragments are suspected and but its sensitivity is less for glass and wooden materials, because they can appear as hypoattenuating structures that can be confused for air bubbles. Fig. 32 on page 32 and Fig. 33 on page 33 Radiologists must look for low-density images with geometric shapes in order to exclude the possibility of non-metallic fragments. However, MRI imaging is the best option for detecting non-metallic materials inside the globe and the orbit when CT fails and excludes metallic foreign bodies.
Imaging findings of glass fragments depends on crystal type, size and location:

- Green crystal is easier to detect than white crystal because it has higher density
- Fragments localized in the anterior chamber are better detected than those in the posterior chamber or the corneal surface.
- The bigger the fragment, the easier its detection.

**Carotid Cavernous Fistula:** Carotid Cavernous Fistula (CCF) must be ruled out if the patient presents red eye, facial pain and diplopia associated with proptosis and chemosis. CCF is a direct communication between the internal carotid artery with the cavernous sinus increasing sinus pressure and resulting in reverse flow to the tributary veins and arterializations of the conjunctiva. Symptoms might be bilateral or even contralateral due to communication between both cavernous sinuses.

A unenhanced CT is the initial imaging technique in which it is possible to identify

- Proptosis
- Extraocular muscle thickening
- Retrobulbar fat edema
- Dilated superior ophthalmic vein (also seen in cavernous sinus thrombosis, venous varix, Graves disease)

If the CCF has low flow, the CT scan might be normal. The definitive diagnosis is established by CT-angiography Fig. 34 on page 33 or conventional angiography. Fig. 35 on page 34

**Optic nerve injuries:** In most cases, optic nerve injuries are produced by nerve compression or loss of its vascular supply without identifying an associated fracture. Optic nerve contusion should be suspected in cases of severe visual loss without other intraocular injuries associated, however CT only detects indirect signs of optic nerve damage. Therefore MRI must be done to assess optic nerve injury which is expressed by T2 high intensity signal.
It is not common to find optic nerve rupture or laceration associated to ocular trauma or orbital fractures. In cases of rapid development of visual loss it should be evaluated the orbital apex looking for possible associated fractures. Fig. 15 on page 20

Images for this section:

**Fig. 4:** Medial wall fracture

**Fig. 5:** Orbital floor fracture
Figure 6. Blow-out fracture (A) and Blow-in fracture (B) of the orbital medial wall
Fig. 6: Blow-out and blow-in fracture

Fig. 7: Orbital floor fractures with inferior rectus muscle entrapment.
Fig. 8: Medial wall fracture with medial rectus muscle entrapment

Figure 8. Medial wall fracture without muscle herniation (A), and with medial rectus muscle herniation and entrapment (B).

Figure 9. Multiple orbital fractures. Medial wall fracture with medial rectus muscle herniation associated to orbital floor fracture with inferior rectus muscle entrapment.
Fig. 9: Multiple orbital fractures with muscles entrapment

Figure 10. Blow-in orbital roof fracture

Fig. 10: Orbital roof fracture
**Fig. 11:** Orbital roof fracture

**Fig. 12:** Lateral wall fracture
Fig. 13: Tripode Fracture
Fig. 14: Tripode Fracture
Fig. 15: Optical channel fracture
Fig. 16: Orbital emphysema

Figure 16. Orbital emphysema that generates globe proptosis.
Fig. 17: Orbital hematoma associated to lateral and medial orbital wall fractures.
Fig. 18: Hyphema

Fig. 19: Complete lens luxation
Fig. 20: Lens subluxacion
**Fig. 21:** Lens rupture

**Fig. 22:** Right traumatic cataract.
Fig. 23: Vitreous hemorrhage
Fig. 24: Traumatic left retinal detachment.

Fig. 25: Choroidal hematoma associated to hemovitreous
**Fig. 25:** Choroidal hematoma

**Fig. 26:** Left open globe injury. Notice changes in shape and contour suggestive of open injury.
Fig. 27: Open globe injury

Figure 27. Left open globe injury

Figure 28. Left open globe injury
**Fig. 28:** Open globe injury

**Figure 29.** Left open globe injury. Notice the air bubble inside the globe

**Fig. 29:** Open globe injury air inside globe
Fig. 30: Intraorbital extraocular foreign body

Fig. 31: Metallic intraorbital intraconal foreign body associated to open globe injury and hemovitreous

Fig. 31: Metallic intraorbital intraconal foreign body
Fig. 32: Intraorbital intraocular foreign body

Fig. 33: Intraorbital intraocular metallic foreign body
Fig. 34: Carotid Cavernous Fistula
Fig. 35: Carotid Cavernous Fistula
Conclusion

The radiological assessment of oculo-orbital trauma includes a global assessment of multiple structures and their potential injuries. It is the role of radiologist to know and to identify those requiring urgent surgical management.

Personal Information

References
