

Imaging of Orbital Trauma¹

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LEARNING OBJECTIVES

After reading this article and taking the test, the reader will be able to:

- Describe the relevant imaging anatomy of the orbit.
- Identify the common posttraumatic orbit lesions.
- Discuss potential pitfalls and mimics that can be mistaken for posttraumatic orbit lesions.

TEACHING POINTS

See last page

Assessing traumatic orbital injuries is an important challenge for radiologists; this assessment is even more difficult when the orbital injury is associated with injuries involving multiple organs. Common posttraumatic orbital injuries include anterior chamber injuries, injuries to the lens, open-globe injuries, ocular detachments, intraorbital foreign bodies, carotid cavernous fistula, and optic nerve injuries. Radiographic examination of the orbits is rarely performed. Ultrasonography (US) can be very useful for evaluating the globe and its contents; however, US is contraindicated if a ruptured globe is suspected. Magnetic resonance imaging may be difficult to perform emergently; it is contraindicated if there is a possibility that a metallic intraorbital foreign body is present. Computed tomography (CT) is considered to be the top choice for evaluating orbital trauma. The best protocol is to obtain thin-section axial CT scans, then to perform multiplanar reformation. When evaluating a patient with an orbital injury, the radiologist should do the following: (a) evaluate the bony orbit for fractures, note any herniations of orbital contents, and pay particular attention to the orbital apex; (b) evaluate the anterior chamber; (c) evaluate the position of the lens (the lens may be displaced, and it may be either completely or partially dislocated); (d) evaluate the posterior segment of the globe, look for bleeds or abnormal fluid collections, and evaluate for radiopaque or radiolucent foreign bodies; and (e) evaluate the ophthalmic veins and the optic nerve complex, especially the orbital apex.

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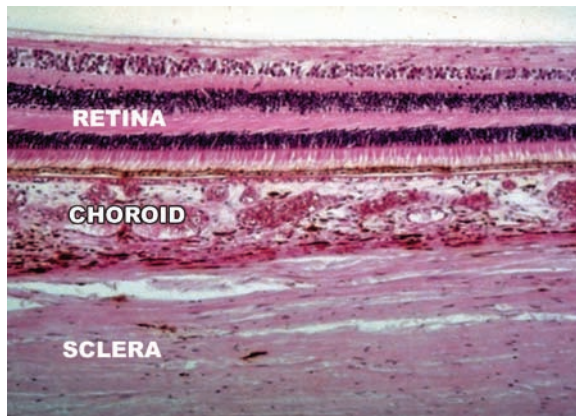


Figure 1. Photomicrograph (original magnification, $\times 80$; hematoxylin-eosin stain) shows the three layers of the globe.

Introduction

Trauma to the eye accounts for approximately 3% of all emergency department visits in the United States (1). Knowledge of the potential injuries to the eye and their imaging correlates is essential to making an accurate and rapid radiologic diagnosis of posttraumatic orbital injury. The goal of this article is to help provide this information. Orbital injuries are often seen in patients with multiple traumas. Motor vehicle collisions and sports-related injuries are common causes of orbital trauma. Fortunately, both of these causes are somewhat preventable. Seat belts have been shown to reduce the prevalence of eye injuries by more than 50%; the prevalence is even further reduced when airbags are deployed. Preventive measures have also caused significant reductions in sports-related eye injuries. For example, in Canadian youth ice hockey, eye injuries decreased by 68% after the players were required to wear face visors (2). Unfortunately, trauma is still responsible for significant orbital morbidity. In 1990, it was estimated that 40% of cases of monocular blindness in the United States were caused by trauma (2).

Imaging options and the pertinent anatomy involved with imaging orbital trauma are also described. We review in more detail the common posttraumatic injuries and their appearances on images. The injuries are grouped into the following subtopics: anterior chamber injuries, injuries to the lens, open-globe injuries, ocular detachments, intraorbital foreign bodies, carotid cavernous fistula, and optic nerve injuries. We do not describe the wide variety of facial fractures that may involve the orbit, but we do discuss injuries to the orbital apex. Key imaging findings are illustrated, emphasized, and contrasted with imaging pitfalls and mimics that may be mistaken for posttraumatic lesions. A comprehensive imag-

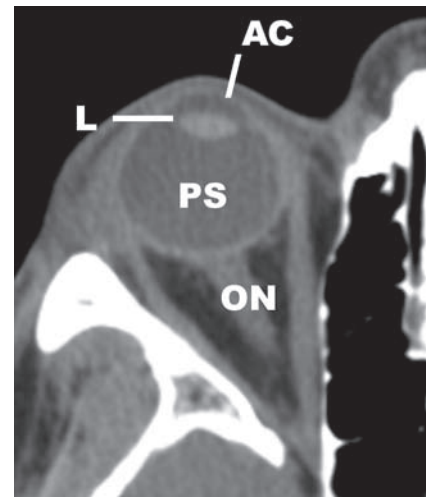
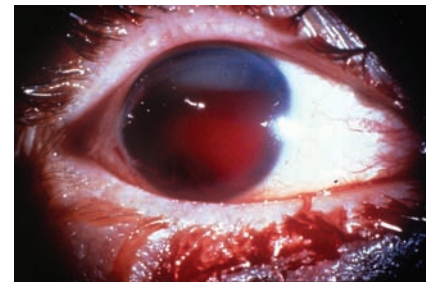


Figure 2. Unenhanced axial CT scan of a healthy 32-year-old man. *AC* = anterior chamber, *L* = lens, *ON* = optic nerve, *PS* = posterior segment (vitreous humor).

Figure 3. Photograph shows post-traumatic hyphema in a 25-year-old man.



ing “checklist” is also given to further aid the radiologist in accurately evaluating this challenging patient cohort.

Imaging Options

It is difficult to perform a physical examination on a severely injured patient. The eye may be swollen shut, rendering funduscopic examination impossible. The patient may be unable to cooperate or respond, making it difficult to evaluate for visual acuity or ocular movement. Radiographic examination of the orbits is rarely performed now. Radiography has a sensitivity of 64%–78% for a fracture (3), but it has very low sensitivity for soft-tissue injuries to the orbital contents. Ultrasonography (US) can be very useful for evaluating the globe and its contents; however, US is contraindicated if a ruptured globe is suspected. Magnetic resonance (MR) imaging may be difficult to perform emergently; it is contraindicated if there is a possibility that a metallic intraorbital foreign body is present. Using MR imaging for the initial evaluation of an orbital trauma is not recommended, although it may be very useful once the initial imaging has been performed. Computed tomography (CT)

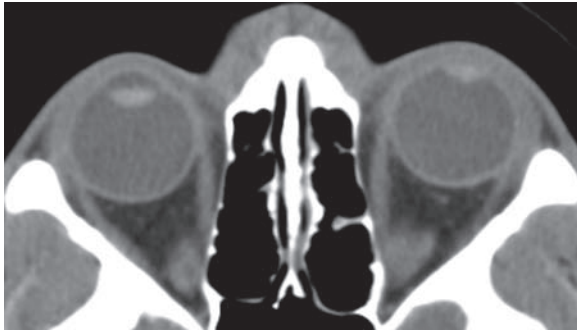


Figure 4. Corneal laceration in a 22-year-old man. Unenhanced axial CT scan shows decreased volume of the anterior chamber, a finding that confirms the diagnosis.

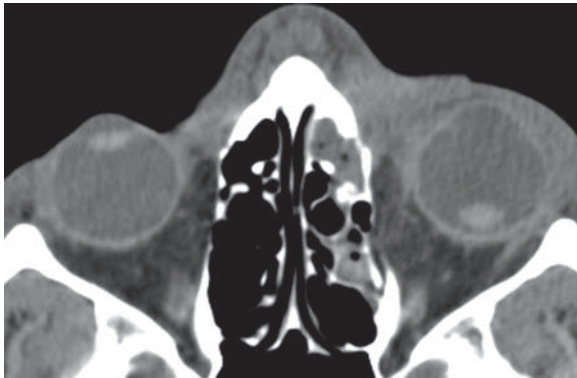


Figure 5. Unenhanced axial CT scan of a 29-year-old man shows complete subluxation of the lens.

is considered to be the imaging modality of choice in evaluating orbital trauma. The goal of optimized CT is to help the radiologist make an accurate diagnosis while limiting the amount of radiation exposure to the lens. **The best protocol is to obtain thin-section axial CT scans (0.625–1.25 mm, depending on the capabilities of the scanner), then to perform multiplanar reformation.** CT has been shown to be more accurate than radiography in detecting fractures. When fractures are present, three-dimensional reformation is a useful tool to guide treatment (4).

Anatomy

The orbit is a pyramidal space that is formed by seven bones. The globe lies in the anterior orbit; the globe and its contents are contained by three layers (Fig 1). The sclera and cornea form the fibrous outermost layer; the vascular uveal tract, including the ciliary body anteriorly and the choroid posteriorly, forms the middle layer; and the retina forms the innermost sensory layer. The lens is connected to the sclera by radially oriented zonular fibers. The lens divides the globe into an anterior segment, which contains the aqueous humor, and the posterior segment, which contains the more viscous vitreous humor (Fig 2). The

iris further subdivides the anterior segment into the anterior chamber and the posterior chamber. Posterior to the globe, the six extraocular muscles and their intermuscular fascial membranes form an intraorbital conical structure. Veins and lymphatics lie within the orbital fat of the muscle cone. Centrally, the optic nerve sheath passes from the posterior globe to the brain. The optic nerve sheath is an extension of the dura mater and contains the ophthalmic artery, the optic nerve, and small veins.

Anterior Chamber Injuries

Posttraumatic bleeding into the anterior chamber, or traumatic hyphema, is caused by the disruption of blood vessels in the iris or ciliary body. The blood extravasates into the anterior chamber, where a blood-fluid level is usually readily appreciated at clinical examination (Fig 3). CT images may show increased attenuation in the anterior chamber, but the primary role of imaging is to evaluate for other related injuries. Corneal lacerations are usually associated with a penetrating trauma. After a laceration, the iris may prolapse into the anterior chamber, thereby closing the defect. **On CT images, the key finding is decreased volume of the anterior chamber, which appears as a diminished anterior-posterior dimension compared to that of the normal globe (Fig 4).** Anterior subluxation of the lens is an important mimic of corneal laceration. To accurately diagnose a corneal laceration, the radiologist needs to not only assess the volume of the anterior chamber, but to also determine the position of the lens (5).

Injuries to the Lens

Blunt trauma to the eye results in deformation of the globe and typically displaces the cornea and anterior sclera posteriorly, with the globe expanding in a compensatory fashion in an equatorial direction. Deformation of the globe causes the zonular attachments that hold the lens in position to stretch and potentially tear; tearing of the zonular attachments may be either partial or complete. After a complete disruption, the lens may dislocate posteriorly or, less commonly, anteriorly. Posterior dislocations are more common, in part because the iris impedes anterior subluxation of the lens (6). After complete posterior subluxation, the lens usually lies within the dependent portion of the vitreous humor (Fig 5). If there is only partial disruption of the zonular fibers, the intact fibers retain one margin of the lens in its normal position just behind the iris while the remainder of the lens is angled posteriorly and projects into

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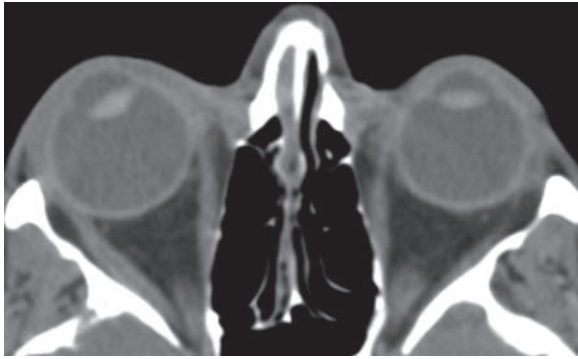


Figure 6. Unenhanced axial CT scan of a 49-year-old woman shows a partially dislocated lens.

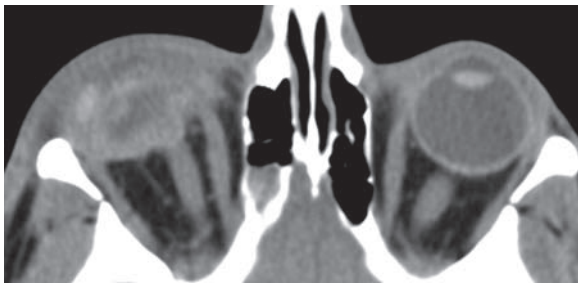


Figure 8. Ruptured globe in a 35-year-old man. Unenhanced axial CT scan shows extrusion of the lens.

the vitreous humor (Fig 6). The diagnosis of a displaced lens is usually made at clinical and ophthalmologic examination. CT images can readily show the displacement of the lens, as well as any associated injuries. Trauma is the most common cause of lens dislocation; it accounts for more than half of all cases. An important pitfall for the radiologist to avoid is that of the spontaneous dislocated lens. Nontraumatic lens dislocation may be associated with systemic connective tissue disorders, such as Marfan syndrome, Ehlers-Danlos syndrome, and homocystinuria (7). If the dislocation is bilateral, the radiologist should suspect an underlying systemic condition.

Open-Globe Injuries

A ruptured globe or an open-globe injury must be assessed in any patient who has suffered orbital trauma, because open-globe injuries are a major cause of blindness. In blunt traumas, ruptures are most common at the insertions of the intraocular muscles where the sclera is thinnest (1). If intraocular contents are visualized at clinical examination, a diagnosis of a ruptured globe can be obvious. Otherwise, CT scanning is the test of choice. In a group of patients with suspected orbital injuries studied between 1989 and

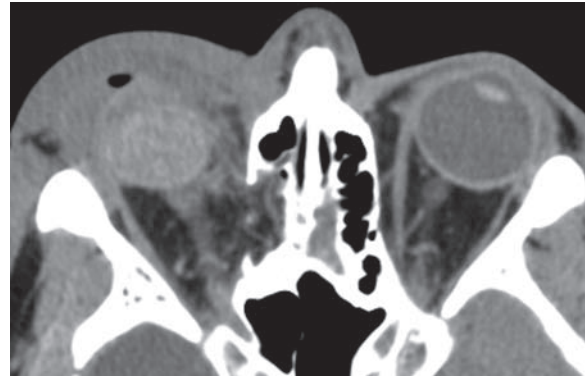


Figure 7. Ruptured globe in a 43-year-old man. Unenhanced axial CT scan shows the flat tire sign, which indicates an open-globe injury.

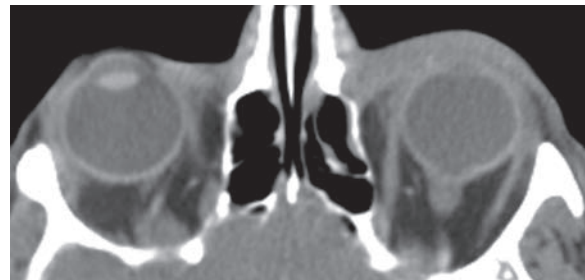


Figure 9. Congenital coloboma in a 53-year-old man who presented with decreased visual acuity. Unenhanced axial CT scan shows a deformity at the left optic nerve head.

1993, the sensitivity of CT for detecting open-globe injuries was found to be approximately 75% (8). In a subsequent study covering patients imaged between 1998 and 2003, the sensitivity was similar, at approximately 71% (9). Unfortunately, the sensitivity of CT for detecting clinically occult open-globe injuries varied from 56% to 68%, depending on the observer.

CT findings suggestive of an open-globe injury include a change in globe contour, an obvious loss of volume, the “flat tire” sign, scleral discontinuity, intraocular air, and intraocular foreign bodies (Figs 7, 8). There are several non-traumatic causes for an altered globe contour that may mimic an open-globe injury, including congenital deformities at the optic nerve head (eg, coloboma) and acquired contour deformities, which may involve any portion of the globe (eg, staphyloma) (Fig 9). A posttraumatic orbital hematoma may deform the globe, mimicking an open-globe injury (Fig 10). Traumatic rupture of the sclera may permit the vitreous to prolapse through the defect. Because of the decreased volume of the posterior segment, the lens can move posteriorly by a few millimeters, while the zonular attachments remain intact. Posterior move-

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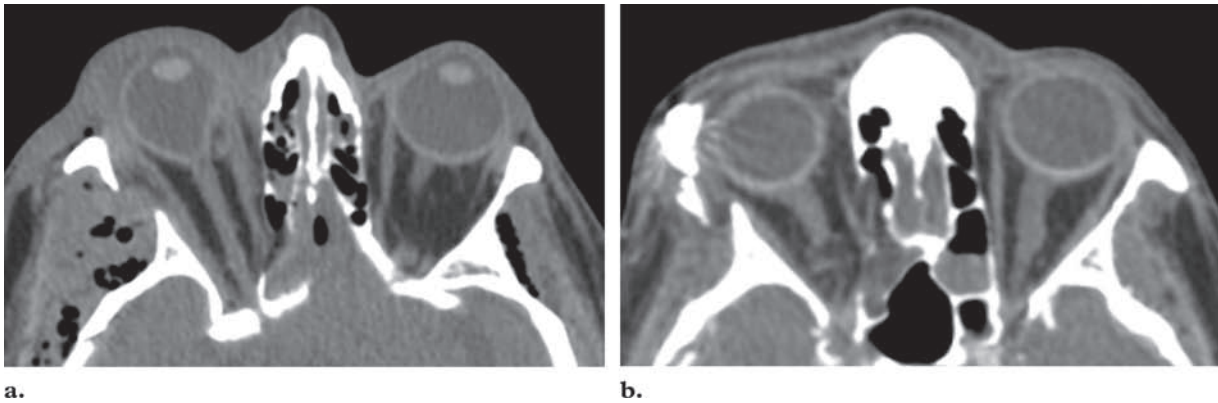


Figure 10. Globe deformity in a 58-year-old man with facial fractures. **(a)** Unenhanced axial CT scan shows deformity of the globe, but it is unclear if there is an open-globe injury. After the facial fractures were internally fixed and the soft-tissue swelling decreased, the globe appeared normal. **(b)** Unenhanced axial CT scan shows no open-globe injury, a finding that suggests that the globe deformity was secondary to posttraumatic hematoma and soft-tissue swelling, which subsequently resolved.

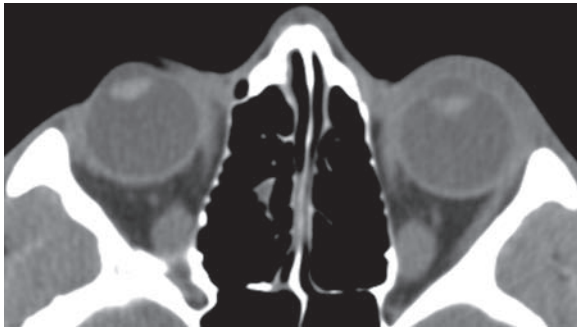


Figure 11. Open-globe injury in a 20-year-old man who presented with orbital trauma that may or may not have been an open-globe injury. Unenhanced axial CT scan shows increased depth of the anterior chamber, which helps confirm the diagnosis of an open-globe injury.



Figure 12. Mimic of open-globe injury in a 75-year-old man who presented with head trauma. Unenhanced axial CT scan shows gas within the globe, a finding that mimics an open-globe injury; the gas had been placed to treat a detached retina.

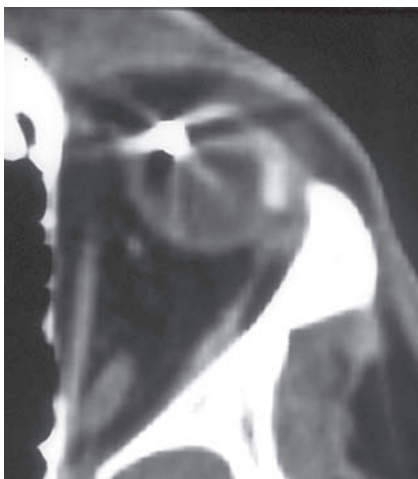
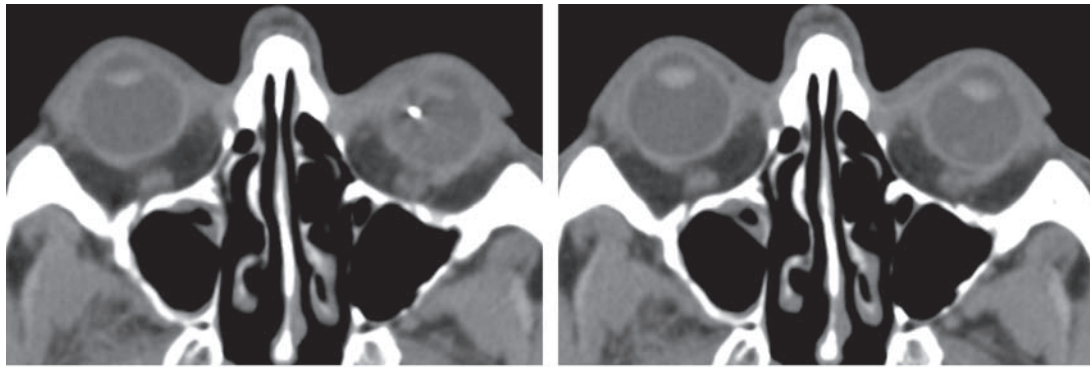


Figure 13. Mimic of open-globe injury in an 82-year-old man who presented with head trauma. Unenhanced axial CT scan shows metal adjacent to the globe, a finding that is a mimic for a penetrating injury. In this case, it is the metal “buckle” of a previously placed scleral band.

ment of the lens enlarges or deepens the anterior chamber. A deep anterior chamber has been described as a clinical finding in patients with a ruptured globe and can also be a useful clue on CT images (Fig 11) (10).

Radiologists must also be aware of several pitfalls that can complicate evaluation of a potentially ruptured globe. One treatment for retinal detachment is to inject perfluoropropane gas into the vitreous. On CT images, the intraocular gas tamponade shows no difference in attenuation from that of air (Fig 12). Because of this, the presence of low-attenuation areas within the globe may be misinterpreted as evidence for a penetrating trauma. Another treatment for retinal detachment is to place low-attenuation silicone sponges or a high-attenuation scleral band around the globe (Fig 13). These appliances indent the globe and may be mistaken for



a.

b.

Figure 14. Mimics of open-globe injury in a 28-year-old man who presented with a penetrating injury to the globe. (a) Unenhanced axial CT scan shows a 4–5-mm metallic foreign body inside the globe. (b) Unenhanced axial CT scan shows small dependent areas of attenuation, possibly vitreous hemorrhage, within the globe.

intraorbital air or an intraorbital foreign body in a trauma setting (Fig 14) (11). To avoid pitfalls, the radiologist should carefully scrutinize images for other signs of trauma, compare current images with previous ones, and correlate imaging findings with a good clinical history.

Ocular Detachments

The three layers of the globe can separate, thereby creating potential spaces between the layers. The retina is the inner, sensory layer of the globe. The retina is very firmly attached along its anterior margin, called the ora serrata, and posteriorly at the optic disc (Fig 15). The remainder of its surface is only loosely attached to the choroid. Retinal detachment occurs when the retina is separated from the choroid. Common causes of retinal detachment include both inflammatory and neoplastic etiologies. Retinal detachment may also occur secondary to trauma, particularly if there is a break in the retina, which can allow vitreous fluid to pass into the subretinal space. Collections of subretinal fluid assume a characteristic V-shaped configuration, with the apex at the optic disk and the extremities at the ora serrata (12,13). The presence of retinal hemorrhage in a child should raise concern for possible non-accidental trauma (Fig 16).

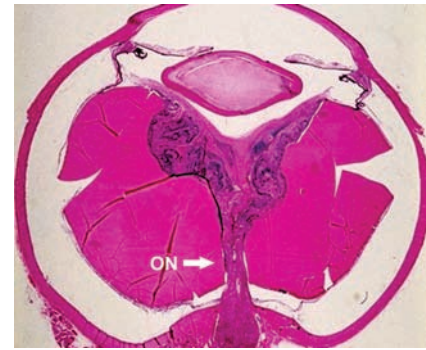


Figure 15. Photograph of a gross pathologic specimen (hematoxylin-eosin stain) shows a retinal detachment. Note the characteristic V-shaped configuration caused by tethering of the retina near the optic nerve head (arrow). ON = optic nerve.

The choroid is part of the middle layer of the globe. It extends from the optic nerve head to the ora serrata and is tethered to the sclera by arteries and veins, which supply this vascular layer. Choroidal detachments are caused by an accumulation of fluid in the potential suprachoroidal space that lies between the choroid and the sclera. Ocular hypotony is the underlying cause of choroidal detachment; hypotony may be the result of an inflammatory disease, accidental perforation, or surgery. Decreased ocular pressure results in decreased pressure in the suprachoroidal space. Transudate may accumulate in the suprachoroidal space, resulting in a serous choroidal detachment (Fig 17). If there is associated

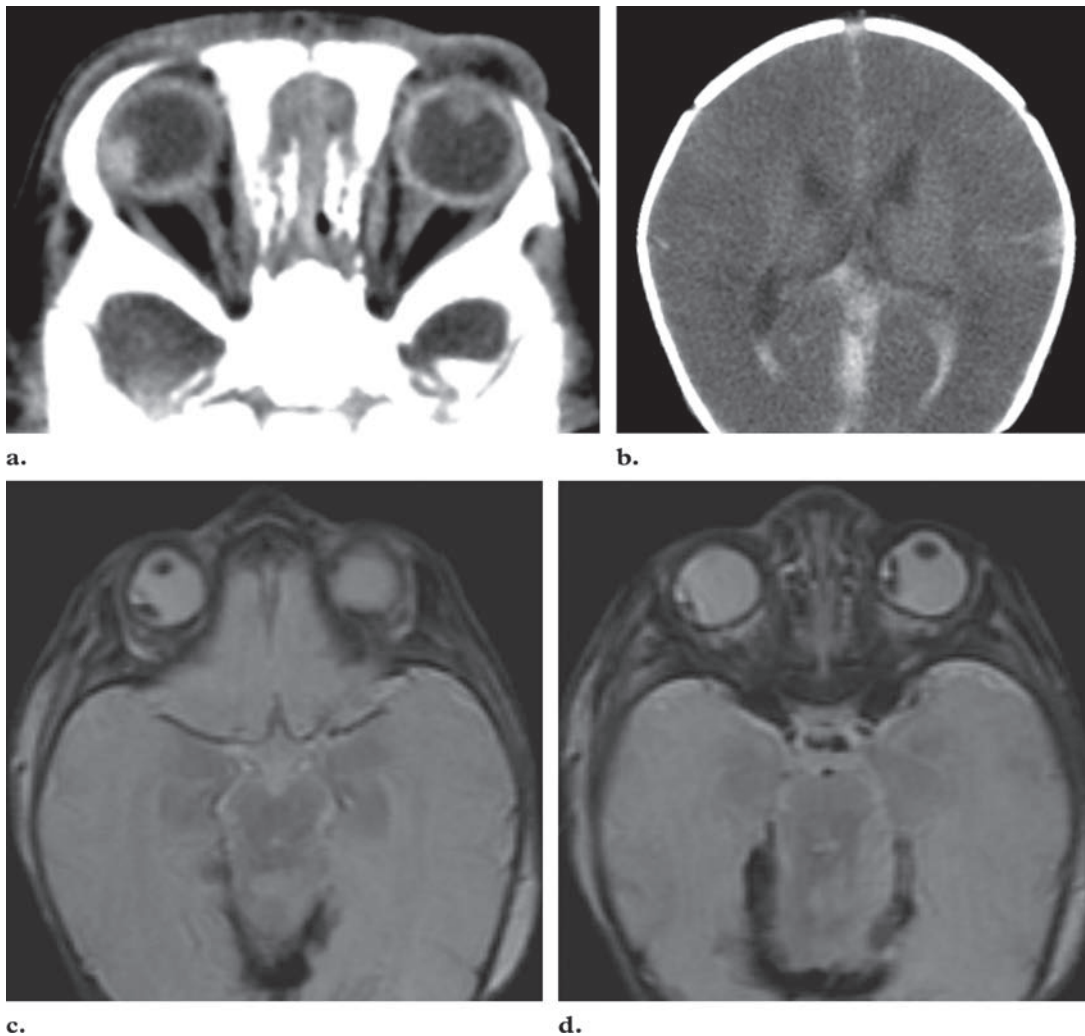


Figure 16. Retinal hemorrhage in a boy less than 1 year old who presented with trauma. **(a)** Unenhanced axial CT scan obtained at a caudal level shows bilateral retinal hemorrhage. **(b)** Unenhanced axial CT scan obtained at a cranial level shows traumatic brain injuries that include subdural hematomas, intraventricular blood, and subarachnoid hemorrhage. **(c, d)** Axial T2-weighted MR images (2500/100 [repetition time msec/echo time msec]) obtained at a cranial **(c)** and caudal **(d)** level show the hemorrhages more clearly. Note the fluid-fluid level in **d**.

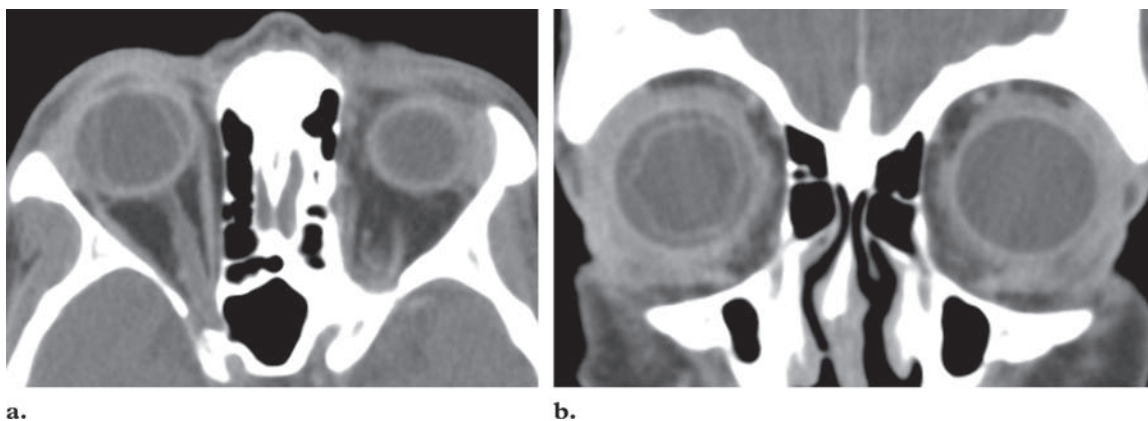


Figure 17. Unenhanced axial **(a)** and coronal **(b)** CT images of a 40-year-old woman show a right serous choroidal detachment secondary to ocular hypotony.

tearing of blood vessels, a hemorrhagic choroidal detachment may occur. Suprachoroidal fluid collections usually assume a biconvex or lentiform configuration that extends from the level of the vortex veins to the ora serrata (Fig 18) (12,14). Posttraumatic bleeding can also occur within the vitreous humor, or it may occur in the layer between the vitreous and the retina (Fig 19). A treatment for retinal detachment is to place silicone oil around the vitreous. Silicone oil has higher attenuation on CT images than vitreous does, and it may mimic a hemorrhage (11).

Intraorbital Foreign Bodies

The detection and localization of intraorbital foreign bodies is an important task for the radiologist. CT is sensitive and is usually the first imaging test performed. MR imaging may be of value, particularly for detecting nonmetallic foreign bodies. However, a metallic foreign body must be definitively ruled out before MR imaging is performed. Failure to detect a metallic foreign body before performing MR imaging may result in blindness. Fortunately, CT is a very sensitive imaging modality that can demonstrate metal fragments less than 1 mm in size. Potential false positives for metallic objects include previously placed surgical devices such as scleral bands. False negatives can be caused by eye or head movement during imaging.

Evaluation for nonmetallic foreign bodies is more problematic. In a study comparing CT, US, and MR imaging for the ability to demonstrate intraocular glass, CT was shown to be the most sensitive. Glass fragments of 1.5-mm diameter were detected 96% of the time, and 0.5-mm glass fragments were detected 48% of the time. Not only the size of the glass fragment, but also the type of glass and its location affect detection rates (15). Unfortunately, glass foreign bodies can still be missed. A recent case report describes a 4-mm glass intraorbital foreign body

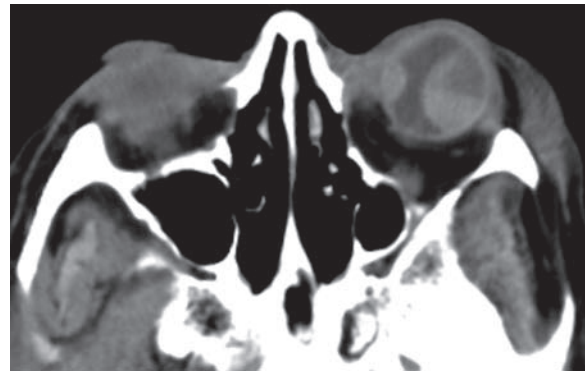


Figure 18. Unenhanced axial CT scan of an 84-year-old woman shows a posttraumatic, hemorrhagic choroidal detachment.

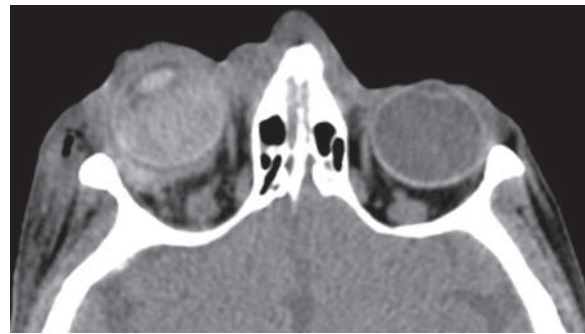


Figure 19. Unenhanced CT scan of an 81-year-old woman receiving anticoagulation therapy, who presented after a trauma, shows an extensive vitreous hemorrhage.

that was not identified at 1-mm collimation CT scanning (16).

Unlike metallic and glass foreign bodies, wooden foreign bodies usually appear hypodense (darker) on CT images; because of their low attenuation, they can be mistaken for air (17). The radiologist should suspect a wood or organic foreign body if the low-attenuation collection seen on CT images displays a geometric margin (18). The attenuation of wood can also change over time as the water content of the foreign body changes. Substantial increases in attenuation have been seen in experimental models after 1–5 days (19). MR imaging may dem-

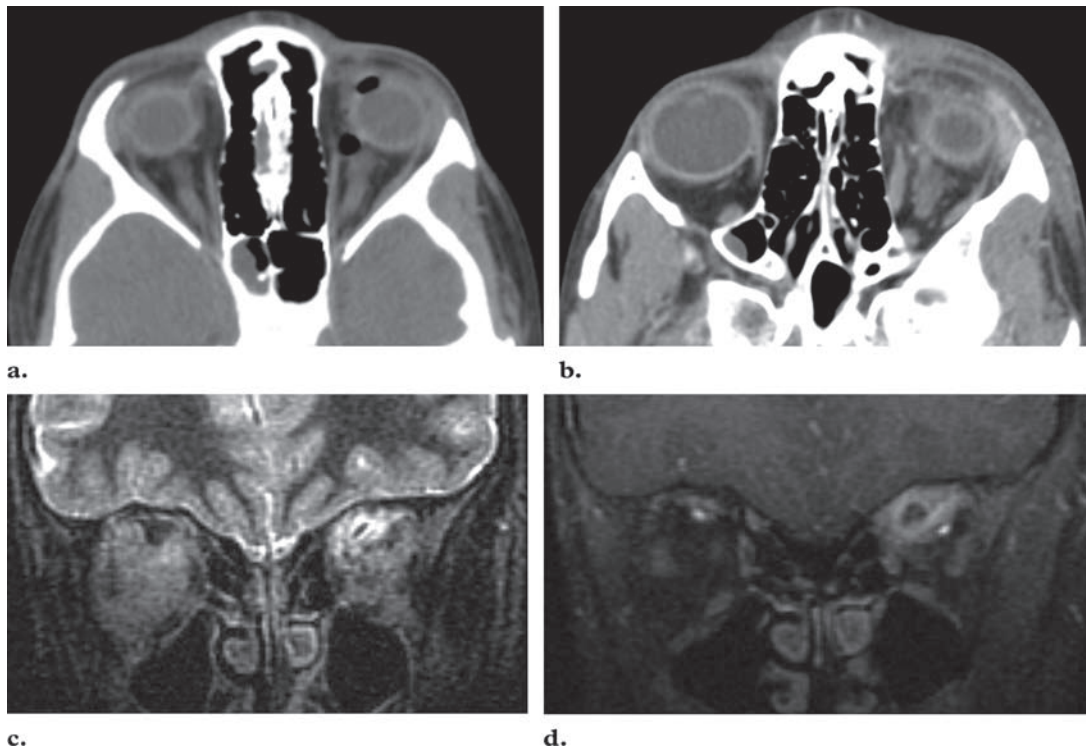


Figure 20. Penetrating injury from a tree branch in a 7-year-old boy. The branch was removed, and unenhanced CT was performed to evaluate for any remaining foreign bodies. **(a)** CT scan shows only a low-attenuation defect; no definite foreign body is seen. Three days later, the eye became infected, and contrast-enhanced CT was performed. **(b)** CT scan shows soft-tissue swelling and abnormal enhancement consistent with the infection, but no definite foreign body is seen. **(c, d)** Coronal unenhanced T2-weighted inversion recovery MR image (4167/110/100 [repetition time msec/echo time msec/inversion time msec]) **(c)** and coronal contrast-enhanced T1-weighted fat-saturated MR image (400/20) **(d)** show the infection surrounding a low-signal-intensity foreign body. The MR images were obtained on the same date as the CT images. During surgery, a small piece of wood was removed.

onstrate wooden foreign bodies in cases where CT results have been either negative or equivocal. My own experience is that T2-weighted or contrast material-enhanced MR imaging performed with fat suppression can demonstrate an intraorbital foreign body by enhancing the inflammatory response seen surrounding that foreign body (Fig 20).

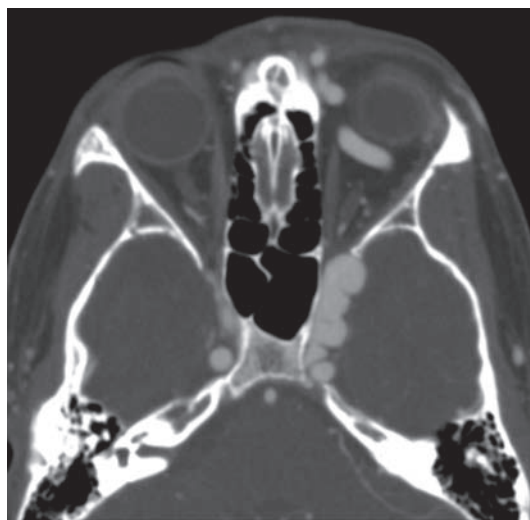
Carotid Cavernous Fistula

The presence of posttraumatic diplopia associated with proptosis and chemosis suggests a diagnosis of carotid cavernous fistula. Objective

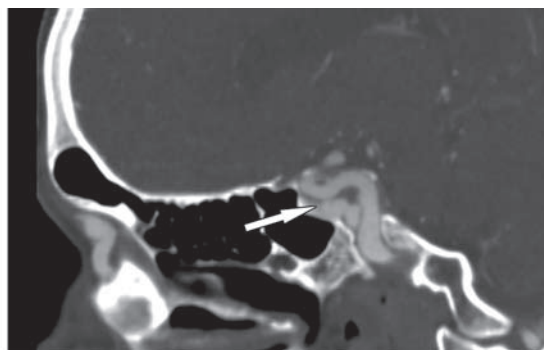
pulsatile tinnitus may also be present. A tear in the cavernous internal carotid artery allows arterial blood to enter the cavernous sinus, thereby increasing the sinus pressure and reversing the flow in the venous tributaries. Prominent anterior venous drainage results in arterialization of the conjunctiva (20). **On unenhanced CT scans of the orbit, a dilated superior ophthalmic vein is usually seen.** Isolated dilatation of the superior ophthalmic vein is a potential diagnostic pitfall; this finding has been reported in

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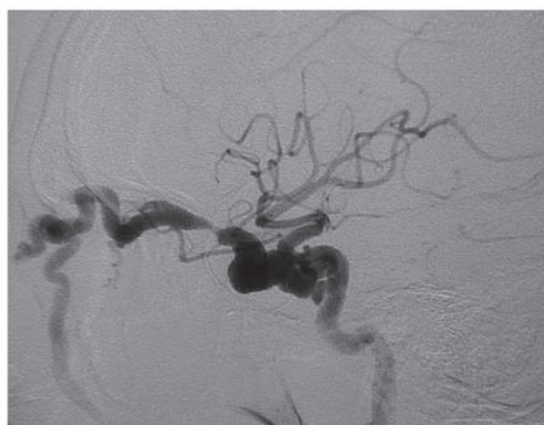
Figure 21. Carotid cavernous fistula in a 16-year-old boy who presented with exophthalmos and objective pulsatile tinnitus after trauma. **(a)** Axial CT angiogram shows dilatation of the periorbital veins and the left superior ophthalmic vein and a dilated left cavernous sinus. **(b)** Sagittal CT angiogram shows an apparent communication between the cavernous segment of the internal carotid artery and the cavernous sinus (arrow). **(c)** Lateral view from left internal carotid angiography shows the carotid cavernous fistula.



a.



b.



c.

multiple other conditions, including cavernous sinus thrombosis, venous varix, Graves disease, and as a normal venous variant. The diagnosis of carotid cavernous fistula can be confirmed with CT angiography, or more definitively with conventional angiography (21) (Fig 21).

Optic Nerve Injuries

Optic nerve injuries can result from either direct or indirect trauma. Rarely, a blunt orbital injury may fracture the optic canal and lacerate the optic nerve (Fig 22). More commonly, a definitive fracture is not found. In these cases, the optic nerve or its vascular supply is torn, thrombosed, or compressed (22). In patients with a rapid post-traumatic decrease in visual acuity, high-resolution CT of the orbital apex should be performed to evaluate for possible fracture and to guide surgical intervention. If there are no contraindications to MR imaging, T2 prolongation may be visualized as increased signal intensity in the injured optic nerve (18).

Image Evaluation Checklist

Given the demands on emergency department radiologists to evaluate a large number of images covering multiple organ systems in severely traumatized patients, a comprehensive checklist is useful for evaluating the orbit and its contents.



Figure 22. Optic nerve injury in a 33-year-old man who presented with multiple facial fractures and decreasing vision in his right eye. Axial unenhanced CT scan shows a right orbital apex fracture with a bone fragment impinging on the optic nerve.

1. Evaluate the bony orbit for fractures, and note any herniations of orbital contents. Pay particular attention to the orbital apex, where even a tiny fracture may be an indication for emergent surgery.

2. Evaluate the anterior chamber. Increased attenuation suggests a hyphema. Decreased depth suggests either a corneal laceration or anterior subluxation of the lens. Increased depth is associated with open-globe injuries.

3. Evaluate the position of the lens. Remember that the lens may be displaced, either anteriorly or posteriorly, and that it may be either completely or partially dislocated.

4. Evaluate the posterior segment of the globe. Look for bleeds or abnormal fluid collections. Try to localize the fluid collections, remembering the characteristic shape of fluid collections in a retinal or choroidal detachment. Also, evaluate for radiopaque or radiolucent foreign bodies. Remember that wooden foreign bodies can mimic air on CT scans.

5. Evaluate the ophthalmic veins and the optic nerve complex. If the ophthalmic veins are dilated, look for other signs of carotid cavernous fistula. The optic nerve may be transected, particularly in penetrating traumas. In blunt traumas, the key area to evaluate is the orbital apex.

Conclusions

Traumatized patients are usually initially evaluated with CT; typically, multiple organ systems are imaged. Careful evaluation of the orbit and its contents is important to overall patient outcome. In an Australian study, 16% of the major trauma patients had ocular or orbital trauma, and 55% of patients with injuries involving the face had ocular or orbital injuries (23). In a cohort of pediatric major trauma patients evaluated in the United States, approximately 8% of the children sustained an ocular injury (24). Ocular injuries have a major bearing on patient outcome. For example, of patients with a ruptured globe, 29% underwent enucleation, and an additional 29% had very poor visual acuity or no light perception (25).

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Imaging of Orbital Trauma

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The best protocol is to obtain thin-section axial CT scans (0.625–1.25 mm, depending on the capabilities of the scanner), then to perform multiplanar reformation.

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On CT images, the key finding is decreased volume of the anterior chamber, which appears as a diminished anterior-posterior dimension compared to that of the normal globe.

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CT findings suggestive of an open-globe injury include a change in globe contour, an obvious loss of volume, the “flat tire” sign, scleral discontinuity, intraocular air, and intraocular foreign bodies.

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Evaluation of nonmetallic foreign bodies is more problematic.

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On unenhanced CT scans of the orbit, a dilated superior ophthalmic vein is usually seen.