Ocular trauma is a major cause of blindness worldwide and oculo-orbital trauma is one of the pathologies that require urgent radiological studies. Traumatic pathology of the orbit is often seen in the polytraumatized patients and can result in a wide spectrum of tissue lesions of the globe, optic nerve and adnexa, ranging from the relatively superficial to vision threatening. Depending on the imaging findings and the radiological assessment, the patient may be assumed to require surgical treatment as in cases of intraorbital or intraocular foreign bodies, eye compression by hematomas or fractures with muscle entrapment etc.

However as it is the case with all trauma cases, it is the systemic stability which takes precedence over any other including eye injuries. ABC of trauma management is the primary aim in all cases. In selected cases of head injury and eye injuries, it the Computerized Tomography scan (CT scan), which is the primary imaging modality of choice to rule out life threatening injuries.

Apart from the systemic injuries, there can be multiple ocular injuries which need localization with imaging for proper management. 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 1,2.

The journey of imaging of effects of trauma on eyes and its surroundings has started with ubiquitous X rays leading on to recent Ultrasound Biomicroscopy (UBM). We will cover this journey by covering the general principles and then going on to specifics.

When evaluating a patient with an orbital injury, following should be assessed:

(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.

The radiological assessment of oculo-orbital trauma includes a global assessment of multiple structures and their potential injuries. Assessing traumatic ocular injuries is an important challenge and this assessment is even more difficult when there are injuries involving multiple organs which may even be life threatening. Imaging and evaluation of such injuries should always take precedence before specific ocular imaging.

The first and the foremost among imaging has and always be a readily available plain radiograph.

**Plain Radiography (X-Ray)**

Plain radiography has 64-78% of sensitivity for orbital fractures but this value is much lower for soft tissue injuries assessment. Radiography is the also the first-step for metallic...
Evolution: Evolution of Imaging Modalities in Ocular Trauma

Intraocular foreign body (IOFB) due to its accessibility and low cost (Figure 1).

There are many methods of localization of IOFBs using X-rays. For direct localization two exposures at right angle (AP and lateral views) are taken. For lateral view the affected side is towards the film with infra-orbital line at right angles to the film. The AP view or nose-chin position allows good view of maxillary region since the bony shadow of petrous temporal bone is excluded. Whereas in localization in relation to rotation of globe the head and the X-ray remain fixed, while the eye moves in different directions, straight gaze, up and down. The position of the IOFB is calculated from the direction and the amount of displacement referred to the centre of rotation of the globe.

Plain radiography is no longer considered an adequate modality for evaluation of ocular trauma however in today’s setting, plain film x-ray has a documentary and medico-legal role and also in our country due to paucity of sophisticated equipments, it has a role.

Limbal Ring

For localization of metallic foreign bodies a metallic ring made of either silver or steel of suitable diameter is sutured to the limbus. X-rays are taken in lateral position, in the straight gaze, up and down gaze. An AP view is also taken. The limbal ring is imaged as a straight line corresponding to the limbus. Three such lines will be seen corresponding to the three positions of the eyeball (Figure 2). The position and movement of the IOFB in correspondence to the limbal ring is then used to localize the IOFB. This method is rarely employed nowadays and is more of a historical significance.

X-Ray With Contact Lens

The same principle of limbal ring can be used by placing a contact lens with radio opaque markers over the cornea and then taking radiographs in different gazes to localize the radio opaque foreign body. The advantage of contact lens is that it is non invasive, no sutures are needed and ease of technique.

Ophthalmic Ultrasound (USG) AB Scan

Ultrasound is an acoustic wave that consists of an oscillation of particles within a medium. Diagnostic ophthalmic ultrasonography (Amplitude modulated scanning) was first reported in 1956 by Mundt and Hughes B scan was introduced in ophthalmic practice by Baum and Greenwood in 1958. For more than three decades,
B-scan ultrasonography has played a key role as a valuable diagnostic imaging device in the field of Ophthalmology. It is a modality of imaging which is as ubiquitous as X-Ray, however ophthalmic USG is different than the standard probes as it operates at higher frequencies of approximate 10 MHz. It is useful for evaluating the eyeball measure, layers and contents. It is non-invasive, inexpensive, non-ionizing and easily performed imaging technique. It is 98% sensitive in detecting IOFBs in appropriate clinical settings (Figure 3). When ophthalmoscopic evaluation is limited or not possible due to media opacity, ophthalmic ultrasound AB scan helps in identifying:

- Retinal detachment
- Posterior vitreous separation
- Vitreous hemorrhage and opacities (Figure 4)
- Choroidal detachment (can differentiate between serous and hemorrhagic)
- Areas of vitreoretinal adhesions
- Choroidal and scleral ruptures
- Retinal/ Vitreous incarceration
- IOFBs, both radiolucent and radio-opaque
- Dislocated lens (Figure 5)

It is relatively contraindicated in presence of open globe injury to avoid further trauma to the globe due to contact.

In addition it does not allow the assessment of all orbital components.

**Features on USG**

**A scan**

- IOFB shows steeply rising wide echo spike seen. It is noted along the baseline between the initial spike and ocular wall spike. The reflectivity of the lesion spike is extremely high (100%) which persists on low gain.
- The distance between the IOFB and the adjacent sclera is accurately measured at lower system sensitivity.
- Sound attenuation is very strong with IOFB.

**B scan**

- IOFB appears acoustically opaque contrasting with the acoustically clear vitreous. It remains displayed even when the system sensitivity is decreased by 20-30 db.
- Localization of the IOFB in different quadrants can be determined. The proximity to adjacent intraocular tissues is evaluated.
- Mobility of the IOFB can be assessed. Topographic and kinetic echography will show if the FB is adherent to the retina or if it is floating in the vitreous.
- With IOFB, sound attenuation is very strong. The IOFB causes shadowing of the ocular and orbital tissues behind it as it totally reflects the sound beams preventing its propagation within tissues behind it.
- Associated intraocular damage like vitreous haemorrhage, vitreous bands, fibrosis, retinal detachment, choroidal detachment and even scleral entry wounds can be assessed.

Echography provides excellent images of eye and in the hands of an experienced echographer can provide a reliable...
and detailed information about the ocular and orbital structures. When ophthalmoscopic evaluation is limited or not possible echography is useful. Ophthalmic ultrasound has several practical advantages compared with CT and MRI. The equipment needed to perform echography is easily transportable when necessary, making it one of the most efficient and rapid means of diagnostic imaging in many different settings.

Computed Tomography (CT) Scan

CT was invented in 1972 by British engineer Godfrey Hounsfield of EMI Laboratories, England and by South Africa-born physicist Allan Cormack of Tufts University, Massachusetts. Hounsfield and Cormack were later awarded the Nobel Peace Prize for their contributions to medicine and science. Introduction of CT scan has changed the evaluation and management of ocular trauma and shifted the focus from X-Ray and USG. It is considered the best imaging technique in oculo-orbital trauma because it assesses the intracranial, facial and ocular structures (Figure 6). In addition it is an available imaging option in most of the emergency services in main hospitals.

One of 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. CT is also 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 hypotony with no clinical evidence of anterior perforation, CT helps to evaluate the posterior segment. 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. 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 hypo attenuating structures that can be confused for air bubbles (Figure 7,8,9,10).

Magnetic Resonance Imaging (MRI)

Imaging the eye with magnetic resonance imaging (MRI) had proved difficult due to the eye’s propensity to move involuntarily over typical imaging timescales, obscuring the fine structure in the eye due to the resulting motion
artefacts. However, advances in MRI technology help to mitigate such drawbacks, enabling the acquisition of high spatiotemporal resolution images with a variety of contrast mechanisms. MRI as a imaging modality has come up in a big way as it delineates and differentiates tissues better than a CT scan. However it does not delineates bones which are better seen with CT scan. Also emergency MRI is not always available in most of the emergency services. It is not recommended for oculo-orbital trauma as a modality for initial evaluation. MRI is also more susceptible to motion artefact than other imaging modalities.

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 intra-orbital metallic foreign body is suspected. MRI imaging is also the best option for detecting non-metallic materials inside the globe and the orbit when CT fails to find them and excludes metallic foreign bodies. MRI must be done to assess optic nerve injury if suspected which is expressed by T2 high intensity signal.

Ultrasound Biomicroscopy (UBM)

The inability of conventional USG to visualize the anterior segment and give high resolution images led to shift towards alternate imaging modalities which could be small and operable by ophthalmologists leading to less reliance on radiologists. The first practical UBM system for imaging of the eye was developed by Foster and Pavlin in the early 1990s. Ultrasound biomicroscopy systems are suitable for imaging of virtually all anterior segment anatomy and pathology, including the cornea, iridocorneal angle, anterior chamber, iris, ciliary body and lens.

It is an imaging technique that uses high frequency (50 MHZ) sound waves to produce high resolution, cross-sectional images of anterior segment to a depth of around 5 mm. It is portable and operable by Ophthalmologists. It can visualize and produce high resolution images of anterior chamber, angle, iris, lens, zonules and IOLs.

In cases of trauma, it can also visualize angle recession, cycloodialysis, zonular dialysis, hyphema, scleral laceration, and lenticular foreign bodies. Another advantage of UBM is that images are real time and mobility of various structures can also be visualized. High frequency (50 MHZ) ultrasound can also show appearance of foreign body, surrounding tissue, exact location, size and the nature of IOFB much better than conventional low frequency (10 MHZ) ultrasound. UBM is also useful for detection and localization of small superficial non-metallic foreign bodies that are usually missed on CT and conventional USG (Figure 11).

Various Injuries and their Radiological Evaluation

Anterior Chamber Injuries

Usually these injuries are evident however in polytrauma cases when ocular evaluation is not possible, CT scan is invaluable for systemic as well as ocular evaluation. Posttraumatic bleeding into the anterior chamber, or traumatic hyphema, is caused by the disruption of blood vessels in the iris or ciliary body. 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. 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.
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. The diagnosis of a displaced lens is usually made at clinical and ophthalmologic examination. However if clinical examination is not possible due to any reason, imaging is required. USG can pick up a posterior dislocated lens whereas UBM can display any subtle zonular injury as well as mild subluxation. CT images can readily show the displacement of the lens, as well as any associated injuries.

Open-Globe Injuries

An open-globe injury must be assessed on priority clinically and imaged to quantify the extent of the damage in any patient who has suffered orbital trauma, because these 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. If intraocular contents extrusion are visualized at clinical examination, a diagnosis of a ruptured globe can be obvious.

In subtle cases where clinically diagnosis is difficult, CT scanning is the test of choice. 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.

A posttraumatic orbital hematoma may deform the globe, mimicking an open-globe injury. Traumatic rupture of the sclera may permit the vitreous to prolapsed 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 movement 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. However presence of tamponading gases and buckle after a retinal surgery may give impression of gas in vitreous and indentation on CT scan which may lead to a false impression of an open globe.

Contact procedures like USG should be avoided in such scenarios to prevent further injury to the eye.

Ocular Detachments

Retinal detachment (RD) may 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. Choroidal Detachments (CD) 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. If there is associated 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. The detachment are best picked up on USG A-B Scans, which can differentiate between RD, CD and PVD.

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 non-metallic 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 enhancement of intraocular injuries. 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. Unfortunately, glass foreign bodies can still be missed. Unlike metallic and glass foreign bodies, wooden foreign bodies usually appear hypoattenuating on CT images; because of their low attenuation, they can be mistaken for air. The clinician should suspect a wood or organic foreign body if the low-attenuation collection seen on CT images displays a geometric margin. The attenuation of wood can also change over time as the water content of the foreign body changes. MR imaging may demonstrate wooden foreign bodies in cases where CT results have been either negative or equivocal.

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...
Ocular Trauma

venous tributaries. Prominent anterior venous drainage results in arterialization of the conjunctiva. On unenhanced CT scans of the orbit, a dilated superior ophthalmic vein is usually seen. The diagnosis of carotid cavernous fistula can be confirmed with CT angiography, or more definitively with conventional angiography.

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. More commonly, a definitive fracture is not found. In these cases, the optic nerve or its vascular supply is torn, thrombosed, or compressed. In patients with a rapid posttraumatic 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 which gives a more specific and definitive diagnosis.

Conclusion

Imaging in ocular trauma has traversed a long journey from plain radiographs to high end imaging modalities and judicious use of these radiological investigations is necessary depending on the resources available in conjunction with a good clinical evaluation of the patient and the suspected injury to achieve an optimal end result.

References

2. J.P. Salazar P. Herrera, D. Armario Bel, P. Coscojuela. Imaging of oculo-orbital trauma: more than meets the radiologist’s eye. Poster No.: C-1769; Congress: ECR 2012; Barcelona/ES.