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A Review of the Diagnostic Modalities in Ocular and Orbital Trauma in Developing Countries

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Abstract: Ocular and Orbital trauma has become common nowadays. The determination of the extent of trauma to the eye and the orbit, with their precise localization is crucial to the successful management of the patients. The different methods which are used include plain X-ray film, computed tomographic scan(CT scan) , Ultrasonography, Magnatic Resonance is quite Imaging (MRI) ,Anterior Segment OCT (AS-OCT), and Ultrasound Biomicroscopy (UBM). AS-OCT and UBM are less commonly available in developing countries. Sometimes, a number of modalities are used together to obtain maximum information, for optimum management.

Keywords: Ocular trauma, Orbital trauma, intraocular foreign body (IOFB), intraorbital foreign body, Computed Tomography Scan (CT Scan), Magnetic Resonance Imaging (MRI), Anterior segment OCT, Ultrasound Biomicroscopy (UBM).

Introduction:

This is an age of speed and mechanization and so, ocular trauma is quite common. In the United States, upto three percent of all emergency department visits, were due to ocular trauma in one study (1). Imaging is an important diagnostic modality, which has seen significant increase in usage in the past two decades (2)(3).

Imaging plays an important role in the diagnosis and management of ocular trauma. In addition to plain X-ray film and computed tomography (CT) scan, Ultrasonography (USG), Magnetic Resonance Imaging (MRI), are commonly used. Ultrasound Biomicroscopy (UBM), and Anterior Segment Optical Cohorence Tomography (AS-OCT) are recently used modalities which may not be readly available in developing countries, less invasive but expensive technique are available in evaluating open globe injuries, like Fundus Autofluorescence, Spectral Domain OCT and AS-OCT.

Aim of the Review: The Ophthalmologist must know when to order a test. What test is to be ordered and how to interprete the test results. This results in cost effectiveness and better patient outcomes, in developing countries. These tests supplement the information. By various ophthalmological procedures in the assessment of ocular and orbital trauma (4). Thus knowledge about these procedures is beneficial to the ophthalmologist and results in optimum patient

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management. The diagnostics modalities commonly available in developing countries are covered in this review, with brief descriptions of other useful, but costly and less available modalities.

Different Imaging Modalities:

Plain X-ray films:

These films can be used to identify orbital fractures as well as radio-opaque intra ocular foreign body (IOFB) or orbital foreign body (Figure 1). They are often used to look for a metallic foreign body in the eye or orbit prior to a MRI scan. Plain X-ray have a 70% to 90% sensitivity for radio opaque objects while 0 to 40% sensitivity for radiolucent objects. However, its advantage is that it can delineate multiple intraocular or intraorbital foreign bodies better than an CT scan. This is the cheapest and most readily available option in developing countries. This may be implemented by other views like limbal ring and so on.

Computed Tomographic Scan (CT Scan):

In the acute ocular trauma setting, CT scan is the investigation of choice CT scan is available is most district hospitals, in India and this can cater to the patients who are referred here from the primary care setting. Thus, this is the primary technique of imaging used for ocular and orbital trauma evaluation.

The advantages are:

a. Three dimentional viewing of orbital bones and soft tissues of the orbit as well as ocular structures, when used without contrast.
b. It can be used to evaluate a large variety of trauma related pathology.
c. Radiographic cuts of 0.5mm to 2.0 mm through the orbit detect bony fractures.
d. Radiographic cuts of 1.0 mm are performed in suspected traumatic optic neuropathy (optic canal cuts). There are to be suspected in two-wheeler road traffic accidents with injury to temporal region of the scalp.
e. Similar cuts are also performed for dected intraocular and intraorbital foreign bodies to detect their location, size, and composition. The composition can be estimated by measuring their Hounsfield units. The minimal detectable size varies according to their composition: smaller for metals, larger for nonmetals.
f. Helical Computed tomography allows for better evaluation of intraocular foreign bodies in lesser time, lesser radiation exposed and lesser motion artefacts. Glass intraocular foreign bodies are best detected by this method, particularly in case of drivers and pilots.

   In a CT scan of the eye and orbit, the following points are to be evaluated by the Ophthalmologist:

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i. Bony orbit is checked for fractures, herniated orbital contents and orbital apex.
ii. Anterior Chamber: opacity, abnormal fluid collection and depth.
iii. Crystalline Lens: Subluxation or dislocations.
iv. Artificial Lens (Intra ocular lens) in post operative cases, suffering from injuries: subluxations or dislocations.
v. Posterior segment for bleeding, abnormal fluid collection and radiopaque or radiolucent foreign bodies.
vi. Ophthalmic vein, optic nerve complex and related structures, for any disruptions and haemorrhages.

The different pathologies which can be detected and evaluated by CT Scan are:

A. Orbital Pathology:

CT scan is the investigation of choice for accurate detection of orbital fracture and associate soft tissue injuries. Fracture occurs more commonly in the floor and medial walls, as they are thinner. However, any orbital bone may be fractured in severe trauma.

Blowout fracture (Figure-2) occurs when a blunt trauma caused by a circular object more than 4mm in diameter (closed first or cricket ball) which strikes the orbit from the front. This increases the intra orbital pressure and herniation of intraorbital contents occur in the adjacent maxillary sinus. CT scan can identify involved bones, projection of bony fragment and degree of extraocular muscle injury or displacement. Haemorrhage into the maxillary sinus may be seen as a fluid level in the dependent part.

Emphysema of eyelid and orbits may be seen as dark shadows on a white background. Enophthalmos may occur when a large part of the intraocular contents are herniated into the maxillary sinus. This is detected as the “tear drop” sign in the maxillary sinus (Figure -3). If the enophthalmos is more than 2mm then the orbital floor fracture is more than 50% and usually must be repaired surgically. However, if these patients are managed by observation alone, good results may be seen in some cases. (5)

The CT scan is particularly helpful in entrapment of muscle seen in paediatric patients with a “trapdoor” fracture where the fractured bone springs back into place impinging on the muscle. The extraocular muscle stimulation leads to activation of oculocardiac reflex, with normal appearing eyes, diplopia, bradycardia, nausea and vomiting. There is rounding of muscle shape with displacement through fracture site into the adjacent maxillary sinus best demonstrated by sagittal and coronal section on CT scan (6).The fracture must be repaired immediately to save child̓s life. CT scan may reveal a fracture in the orbital roof due to severe trauma. Pneumocephalus is seen as a dark area in white brain substance. Intracranial heamatoma is seen as dense white areas in brain substance, cerebrospinal fluid leaks and tear of duramater may be seen. These cases must be evaluated and managed by a neurosurgical team (6).

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B. Retrobulber Haemorrhage:

This can occur following ocular trauma and consist of collection of blood in the orbit. Small haemorrhage may occur in mild to moderate trauma and retrobulber injection. They usually heal by themselves. In Ophthalmology practice, there are cases of retrobulber haemorrhage, following retrobulber injection, or rarely, peribulber injections. Again, most of these cases heal spontaneously on conservative management, without compromising the optic nerve. Larger haemorrhage can cause rise in intraorbital pressure in the confined orbital space resulting in an orbital compartment syndrome. The intraocular pressure is raised and there is a relative afferent papillary defect. There is proptosis, resistance to retro pulsion and decrease visual acuity due to optic nerve compression, in severe cases. CT scan can identify orbital haemorrhage, particularly those adjacent to bony fractures. CT scan can also identify orbital compartment syndrome, by revealing proptosis, optic nerve stretching (loss of sinusoidal pattern of the optic nerve) and tenting of the posterior globe contour. These cases need urgent orbital decompression by surgery.

C. Foreign Bodies:

CT scan is the investigation of choice for detecting intraocular foreign body (IOFB). (Figure-4) and intraocular foreign bodies. These are usally metallic substance or may be glass foreign bodies. Organic materials such as wood are difficult to detect on CT. However, the dense inflammatory reaction surrounding such foreign bodies may be seen as a dense opacity on CT scan giving an idea about its location.

D. Open Globe Injury:

CT scan is done, if the posterior segment is not visualized and there is a suspected occult globe rupture or laceration or metallic IOFB. (7,8).

CT findings of an open globe injury are:

1. A change in globe contour
2. Presence of intraocular air
3. Presence of blood
4. Presence of intraocular foreign bodies
5. Presence of flat tyre sign (9)

   In a posterior perforation, a deep anterior chamber is seen. Vitreous haemorrhage, choroidal detachment or retinal detachment may be seen. Intraocular air may be seen in the injured eye prior to surgery. So, clinical correlation of CT findings is essential (9). A post traumatic orbital haematoma may be deforming the globe, mimicking open globe injury and so, clinical correlation is required here also (9). Open globe injury must be repaired surgically within 24 hours of occurrence of trauma. The positive predictive values of CT scan detecting open globe injuries ranged from 86% to 100%, but negative predictive values ranged from 42% to 50%, in one study (2). This means that CT scan can detect open globe injuries with higher accuracy and

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false negatives in such detection ranged from 42% to 50% only. Another study of 125 patients of open globe injury found that results of imaging did not influence of management decisions in these patients (10).

E. Anterior segment trauma:

The dislocated crystalline lens can be visualized on CT scan. Depending on the extent of breakage of zonules, the lens may be displaced forward into the anterior chamber, backward into the vitreous and mild positional alteration, if only a few zonules are broken. If the lens dislocation is bilateral, a search should be made for systemic conditions like Marfan's syndrome or homocystinuria (9). Hyphaema can be visualized as increased attenuation in the anterior chamber (6). Anterior lens subluxation can mimic a corneal laceration, so the anterior chamber volume should be assessed (9). If the anterior chamber is shallow, it signifies corneal laceration.

F. Detachment of Retina and Choroid:

Retinal detachment, after blunt trauma, can be detected by CT scan. The CT image shows a thin V shaped hyper attenuation within the globe. The apex of the 'V' is attached to the optic disc and the two extremities are attached anteriorly to the ora serrata. CT scan can also reveal choroidal detachment as two thin convexities curving into the vitreous cavity, but these convexities may or may not touch each other. If they do touch, then the image is called "kissing choroidela". Choroidal detachment may be caused by ocular hypotony, particularly after cataract surgery (9). Ophthalmologists prefer to use B-Scan ultrasonography to detect these conditions accurately.

CT Angiography (CTA)

CTA is useful for diagnosing intracranial vascular pathology, including aneurysms. In patients of ocular trauma, CTA is very useful in detecting carotid cavernous fistula (Figure-5). If the unenhanced CT image is used a dilated superior ophthalmic vein, enlarged cavernous sinus and enlarged extraocular muscles may be visible. The fistula can be directly visualized on CTA. This helps in the management of the patient, by helping in the closure of the fistula.

Magnetic Resonance Imaging (MRI)

The diagnostic modality has been used to diagnose orbital and periorbital tumours and for characterizing optic nerve disorders over the past two decades (11). However, MRI is not used frequently or routinely in evaluating patients of ocular trauma. It is contraindicated when there is a suspicion of metallic IOFB (Figure-6). This is because, the foreign body may get heated up and may also be displaced, causing further ocular damage (12). The scanning time is relatively longer and patient should lie still to prevent motion artefact (11). MRI is compatible with metals like platinum, titanium,tantalum and ferromagnetic metals, having a size below 0.5 mm. So, IOFB and intraorbital foreign bodies made of these materials may be detected, as their displacement is negligible. MRI is useful in detecting radiolucent nonmetallic intraocular and intraorbital foreign bodies, (Figure-7), once CT has ruled out metallic IOFB . If muscle injury occurs or there is presence of small wooden or inorganic intraocular or intraorbital foreign bodies, MRI provides a more detailed view than CT scan. Initially, MRI was difficult to perform in claustrophobic patients. However, the open grantry system has made it possible to do MRI in these patients, even in the developing countries.

Ultrasonography (USG)

USG is a quick, noninvasive and cost-effective imaging technique for ocular assessment. The USG B scan is used to assess intraocular structure when the view to these structure are obscured by hazy ocular media like hyphaema and vitreous haemorrhage. USG B scan can clearly visualize ocular pathology like crystalline lens dislocation (Figure- 8), vitreous haemorrhage, retinal detachment, intraocular foreign bodies, scleral rupture and damage to extraocular muscles. A high frequency probe (7.5 to 10 MHz) is used to evaluate rapidly, many intraorbital structure (13). It can be sensitive upto 98% to detect intraocular foreign bodies with vitreous haemorrhage or retinal detachment. Intraorbital foreign bodies or blood may also be detected with high frequency USG probes. However, in case of orbit, ophthalmologists prefer the CT and MRI over USG, particularly for non-metallic intraorbital foreign bodies.

The B scan USG probe has to be applied over a coupling fluid over the skin of eyelids, with the eyes remaining shut, USG should be deferred if a ruptured globe is confirmed clinically, or the patient is very unco-operative (7). This is because, pressure on the closed eyelids may lead to rise of intraocular pressure and extrusion of intraocular contents. This may lead to severe and irreparable visual loss. Infection may be introduced in the eye from outside, resulting in endophthalmitis and panophthalmitis. The USG images demonstrated a 100 percent sensitivity and 97 percent specificity in detecting various traumatic eye conditions, in one study (14). B scan USG may miss small, wooden or organic foreign bodies. The presence of gas bubbles may give rise to false positive result (12). The various ocular pathologies, which may be detected by USG are:

a. **Retinal Detachment (R.D):** The USG B scan image shows a bright continuous free-floating membrane within the vitreous humor. If the retinal detachment is total (funnel R.D) (Figure -9) it may have a triangle shape with posterior attachment at the optic disc and anterior attachment at the ora serrata. Many retrospective and prospective studies have revealed that ultrasonography performed by emergency physician can accurately detect retinal detachment in the emergency room itself (15). Thus, B scan USG differenciates patients who need urgent ophthalmologic consultation from those who may be seen in the Outpatient department later on. If retinal detachment is seen on B scan USG, then it has to be evaluated urgently by the on-duty Ophthalmologist. In many cases, urgent surgery is required to optimize visual outcomes.
b. **Carotid cavernous fistula:** A dilated superior ophthalmic vein may be seen on USG as a echoic superior orbital mass. In a colour Doppler study is done, then high velocity

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turbulent flow is seen within the mass (7). However, best visualization as well as confirmation of dilated superior ophthalmic vein is seen on CT angiography.

c. **Intra ocular foreign bodies:** These are well detected as a dense white hyperechoic mass within the contour of the globe. Associated vitreous haemorrhage, retinal detachment and gliosis are well visualized.
d. **Intra orbital foreign bodies:** These may be detected using high frequency probes. Orbital haemorrhage can be visualized as a dark mass in the surrounding white background. Foreign bodies appear hyperechoic and their precise location is obtained, thus facilitating their removal.
e. **Vitreous haemorrhage:** This is seen as multiple vitreous opacities on USG B scan, within the vitreous cavity, giving echoes on A-scan USG, in the composite USG scan.
f. **Posterior vitreous detachment (PVD):** This is seen as an hyperechoic segment membrane like mass in the posterior of the eye having high reflectivity. It is not attached to the optic disc. It is seen in many patients of blunt ocular trauma.

Ultrasound Biomicroscopy (UBM):

This diagnostic technique uses high frequency transducer (35 to 75 MHz) to provide in vivo imaging of the anterior segment of the eye. The axial resolution is 30 to 70 micrometer and the penetration depth of the ultrasound beam in 2 to 7 mm. Tissue contact is needed through fluid coupling medium. The image acquisition time is relatively slow and the quantitative analysis is manual. This method can be used to image the structures surrounding the posterior chamber, which are normally hidden from clinical observation. The anatomical relationship of these structures can be assessed. UBM can be used to investigate both the normal structures, as well as diseased structures in many areas of ophthalmology, particularly anterior segment trauma and their sequelae, like uveitis, glaucoma and membrane and cyst formation. Initial studies with UBM were primarily qualitative, but later on quantitative studies have become much more common (16). Three-dimensional analysis of UBM images are still not available widely. UBM can well delineated traumatic cyclodialysis clefts and the accompanying supra ciliary effusion which is found frequently. Traumatic iridoschisis are well diagnosed by UBM. Significant correlation has been found in the measurement of anterior chamber angles by UBM and gonioscopy, particularly after blunt ocular trauma (17). Thus, UBM may be used with accuracy to assess anterior chamber angles in the scenario of blunt ocular trauma with opaque media.

Anterior Segment Optical Coherence Tomography (AS-OCT):

This method uses infrared light instead of ultrasound and transmits signals of shorter wavelength (820 to 1310 nm). This produces images of high resolution. The axial resolution in 5 to 15µm. The image resolution is higher than UBM (18). The imaging is non-contact and so may be profitable utilized in cases of ocular trauma where contact with instruments may cause herniation of intra ocular contents or introduction

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of infection inside the eye leading to total loss of vision. Dynamic relationships between angle wall, iris and lens can be assessed in patients of ocular trauma. The images are real time limbus to limbus cross sectional images. The scan speed is faster, so eye movement artefacts are reduced. There is software for automatic measurement of corneal and anterior chamber parameters. Ciliary body is visualized rarely due to pigmented posterior layer of iris which blocks light transmission. The image width is 15 -16 mm. It is more useful in the quantitative analysis of the anterior chamber than UBM. If compared with gonioscopy, there is significant correlation in the measurements of the anterior chamber angle (19).

Cornea and the angle structures are less distorted during AS-OCT, as it is a non-contact method. So, it avoids artefacts induced by in advertent pressure on the cornea, during gonioscopy or a limbal tissues with the eye cup during UBM. It can differentiate between appositional closure of the angle from syneachial closure due to trauma and traumatic uveitis (20). AS-OCT is ideal in assessing iridocorneal angle and anterior chamber in patients suffering from blunt trauma to the eye. In patients having acute hyphaema, gonioscopy may lead to rebleed. The corneal clarity is often compromised in cases of blunt trauma, and thus, in this situation, AS-OCT is superior in assessing the anterior segment of the eye. AS-OCT can be used to assess a cyclodialysis cleft, which can occur after blunt trauma. In this situation, the longitudinal muscle fibres of ciliary muscle are separated from the sclera spur. The aqueous outflow is increased and there is ocular hypotony. AS-OCT can delineate this separation, including the exact location and extent of the disinsertion. AS-OCT also gives high resolution images, which may be used for surgical planning.

Discussion:

Imaging has become an essential diagnostic tool for the assessment of ocular and orbital trauma. CT scan is the modality of choice formost cases of ocular trauma including IOFB. CT angiography is useful in cases of carotid cavernous fistula. USG B scan can be used to obtain cross sectional images of the eye ball and clearly delineates subluxated or dislocated lenses, retinal detachment, IOFB and posterior vitreous detachment. UBM adds a lot of information about the iris, ciliary body and iridocorneal angles. This is useful if trauma has rendered the eye opaque.

MRI may be useful for small, non-metallic intra ocular foreign bodies, intra orbital foreign bodies or bony orbital fractures which are delineated well. However, it is unsuitable for metallic foreign bodies and claustrophobic patients in resource poor settings. AS-OCT is noninvasive, and so, it is useful in cases of open globe injuries and in cases where the anterior segment cannot be visualized due to opaque media. It avoids rise of intra ocular pressure and introduction of infection while giving excellent clarity of images and also quantitative information.

Thus, many of these procedures may have to be used singly or severally to obtain maximum information for optimum patient management. Newer techniques like

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Fundus Auto Fluorescence and Spectral Domain OCT, especially enhanced depth Spectral Domain OCT are available in select centres in the country and are not in wide use at present. They can provide more information about metabolic activity of Retinal Pigment Epithelial Cells and anatomical changes in traumatic maculopathy (22). They thus allow visual prognostication, in patients of ocular trauma. This prognostication may be improved with more information obtained from electrophysiological tests like Eletroretinogram (ERG), Visual Evoked Potential (VEP) and Electro Oculogram (EOG). This improves the quality of patient follow up (22).

Finally, it must be borne in mind that extensive use and misuse of imaging tools can lead to exposure to unnecessary radiation, incidentalomas, increased patient anxiety and wasted resources (23).

Conclusion:

The Ophthalmologist and the emergency physician must understand the indications of each imaging study. They should be aware of their advantages and drawbacks. They should communicate with the radiologist ensuring that the minimum number of tests yield the maximum information for optimum patient outcomes. The developing world has progressed from limbal ring X-ray, Sweet's technique and crude orbital USG to more advanced diagnostic modalities. Imaging plays a key role in decision making and sorts out the cases which need emergency management including surgery, from those that can be seen later in the outpatient department. Thus, the streamlined use of imaging services can be vision saving as well as lifesaving. Finally, it must be remembered that extensive and unnecessary use, including misuse of imaging modalities may cause serious physical, mental and economical harm to the patient , in developing countries.

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Conflict of interest: None declared.

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Figure:1
Intraorbital foreign body X-ray view

Figure:2.
Blow out fracture on right orbital floor

Figure:3.
Tear drop sign on orbit

Figure:4
Intraocular foreign body [IOFB] on CT view

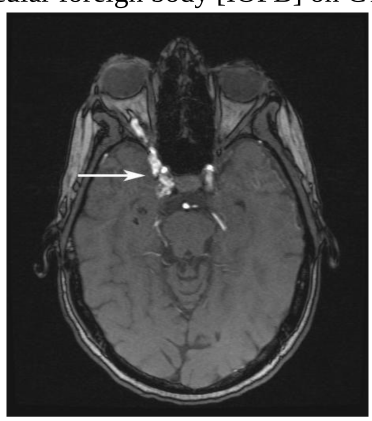

Figure:5
Carotid Cavernous Fistula on CT Scan view

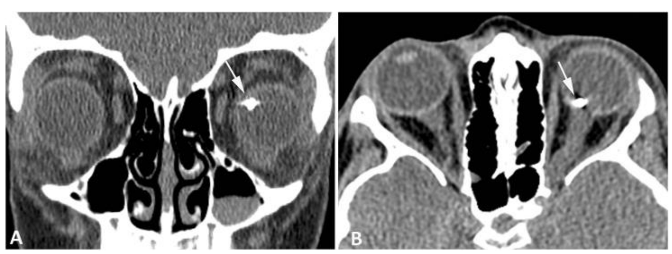

Figure:6

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Metallic intraocular foreign body [IOFB] on MRI view

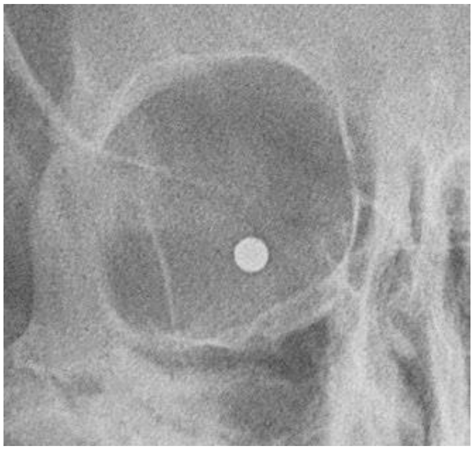

Figure:7

Intraorbital foreign body on MRI view

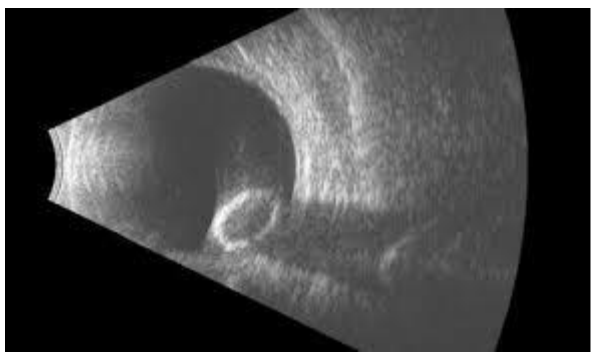

Figure:8

Crystalline lens dislocation on USG view

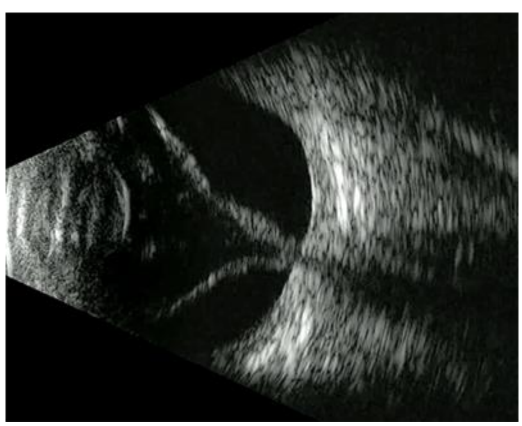

Figure:9 Retinal Detachment on USG view