Original article:

Ultrasound evaluation of the posterior segment of the eye: A pictorial essay

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Abstract:

Imaging of the eye has undergone tremendous progress; however ultrasonography (US) still forms an integral part of ocular imaging. Superficial location of the eyes, different reflective characteristics of various ocular media and availability of good resolution ultrasound probes, enhance the diagnostic accuracy of ophthalmic ultrasound. US evaluation of the eye is fast, easy and involves no ionizing radiation, making it an ideal initial investigation. It provides ophthalmologists insights into the hidden areas, such as when the ocular media are opaque. This pictorial essay elaborates upon the US appearances of diverse posterior segment pathologies, with emphasis on key points to help clinch the diagnosis.

Key words: Ultrasonography, posterior segment diseases, retinal detachment, retinoblastoma, choroidal melanoma

Introduction:

Ocular imaging forms an integral part of routine clinical practice. Superficial location of the eyes, different reflective characteristics of various ocular media and availability of good resolution ultrasound probes, make ultrasound the initial radiological investigation in numerous disorders, especially of the posterior segment (1, 2). US evaluation of the eye is fast, easy and involves no ionizing radiation.

We hereby present a pictorial essay to portray the characteristic appearances of posterior segment diseases on ultrasound and acquaint the radiologists and the ophthalmologists with the same.

Material and methods:

A high resolution 7.5-10 MHz or higher linear array transducer is used for the ocular ultrasound in Radiology departments. It is performed with closed-eyelid technique, using the standard water-soluble ultrasound gel. Large amount of gel is required to create a standoff, for anterior segment evaluation. Ocular examination is performed in both the sagittal and transverse planes, in various positions of gaze. 'Dynamic scanning technique' is employed to evaluate echoes and membranes in the posterior segment, where the patient is asked to move the eye in various directions of gaze, while the probe is held stationary.

Very high frequency ultrasound (35-50MHz) or ultrasound bio-microscopy (UBM) is now used to evaluate the anterior segment pathologies like glaucoma, foreign bodies, trauma, cysts and neoplasms (3). UBM also provides biometric information regarding anterior segment structures, including the cornea and the anterior and posterior chambers.

Normal anatomy (Figure 1) (4-6):

'Eye' is anatomically divided into anterior segment and posterior segment by the lens. The anterior segment is further divided into

anterior and posterior chamber by the iris. Anterior segment is seen as an anechoic semicircular zone, anterior to the lens. Lens appears as a biconvex anechoic structure, with an echogenic capsule. Posterior segment includes vitreous humour, retina, choroid and optic disc. Vitreous is anechoic and clear. The ocular coat is histologically made of three layers- sclera, choroid and the retina. On US, choroid and retina are perceived as a single layer in the normal eye. Sclera is the highly reflective outermost layer. Optic nerve is seen in the retro-bulbar region as a liner hypoechoic structure, amidst the hyperechoic retro-bulbar fat.

The commonly encountered diseases of the posterior segment are hereby discussed.

I] Vitreous humour

1. **Vitreous hemorrhage**
2. **-**Vitreous hemorrhage can occur due to trauma, inflammatory diseases, vascular disorders, metabolic diseases like diabetic retinopathy, tumors etc. (4-6).

   It presents as sub-hyaloid (Figure 2) or intragel hemorrhage. On US, acute intragel hemorrhage is seen as small mobile vitreous echoes (Figure 3), which show after-movements on dynamic scan. As it becomes chronic, it is seen as organized echogenic areas (Figure 4) with restricted mobility on dynamic scan. It can form multiple vitreous bands, with points of attachment to the retina. These need to be evaluated, since they can lead to tractional retinal detachment.

3. **Posterior Vitreous detachment (PVD) -** It refers to separation of cortical vitreous from the retina, posterior to the vitreous base, due to gel liquefaction and collection of fluid in the sub-vitreal space. PVD with vitreous liquefaction is commonly noted in old individuals, aphakics and myopes (4-6).

   On US, it is seen as reduced volume of vitreous gel with multiple linear and granular echogenic foci within the vitreous. Thin flimsy membrane of the detached vitreous is generally seen posteriorly, at high gain settings (Figure 5). It characteristically shows after movements on dynamic scan.

4. **Asteroid hyalosis-**It is characterized by the presence of multiple tiny opacities within the vitreous (Figure 6) composed of hydroxylapatite, which is composed of calcium and phosphates or phospholipids (7).It is seen in elderly, mainly in patients with diabetes and hypercholesterolemia.

   On US, it is seen as tiny echogenic foci within the vitreous, usually unilateral; and is unaffected by gravity. A clear anechoic zone is generally seen between the retracted vitreous and the retina (8).

   In contrast, synchysis scintillans is usually bilateral and seen in younger age group. It is seen as highly refractile bodies within vitreous (composed of cholesterol crystals), but sink due to gravity (8). (Table 1)

5. **Persistent hyperplastic primary vitreous (PHPV) -** It is a congenital developmental anomaly due to failure of the embryological primary vitreous and hyaloid vasculature to regress (4-6). It is usually unilateral. Bilateral lesions should raise the suspicion of a systemic or syndromic cause.

   PHPV can be either anterior or posterior type. Anterior PHPV patients are not routinely imaged; however, the findings

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described are shallow anterior chamber and small, irregular lens with cataract. Some cases may show a persistent hyaloid artery (9).

Posterior PHPV may present with microphthalmia, with a fibrotic band seen extending from the lens to the optic disc (remnant of Cloquet's canal which carries the hyaloid artery). Blood flow is sometimes detected in the band due to the persistent hyaloid artery (Figure 7). PHPV may be associated with retinal detachment.

II] Retina

1. Retinal detachment (RD) – It is the separation of neuro-sensory retina from the underlying pigment epithelium, which is seen as a 'U' or 'V' shaped echogenic membrane, with the apex attached to the optic disc posteriorly, and the ora serrata anteriorly (Figure 8).

Retina is supplied by the central retinal artery, with its larger branches traversing through the layer of retinal nerve fibres. Thus detection of blood flow on Colour doppler in a membranous structure in the posterior segment, helps the diagnosis of RD (Table 2).

RD can be classified in various ways-

- Based on etiology-
  - Primary or Rhegmatogeneous
  - Secondary- Tractional or Exudative
- Based on configuration:
  - Open funnel
  - Closed funnel.

Open (Figure 9) or closed funnel (Figure 10) – This describes the configuration of the retinal detachment. RD in the acute state is generally 'open funnel'. However, as it becomes chronic, the configuration changes to 'closed funnel'. This has both therapeutic and prognostic implications.

2. Retinopathy of prematurity or retro-lental fibroplasia (Terry's syndrome) - It usually affects premature and low birth weight infants, generally having received oxygen therapy (4-6). This leads to disorganized growth of retinal vessels from periphery, leading to dense fibrosis in the anterior vitreous.

It is a bilateral condition, which reveals dense retro-lental membranes on US. It is generally associated with retinal detachment. The growth of the globe is usually retarded leading to micro-ophthalmia. Calcification is rare, however may be seen in few advanced cases. Calcification in a micro-ophthalmic eye goes less in favor of RB, however few cases have been reported of RB with PHPV or ROP (Figure 11).

3. Retinoblastoma- Retinoblastoma (RB) is the most common primary intraocular malignancy of childhood (4-6). Clinically, it presents with leukocoria and strabismus. It is usually unilateral, however can be bilateral. Bilateral RB should arouse a suspicion of associated pineal gland tumor (trilateral RB) and supra-sellar tumor (quadrilateral retinoblastoma) (10).

RB can present with three types of growth patterns - endophytic, plaque like and exophytic. On US, endophytic type presents as a solid heterogeneous mass projecting into the vitreous chamber (Figure 12). RB commonly shows calcification within (75%) (6, 10).Exophytic RB begins in the outer retinal layers and grows in the subretinal space. This may lead to non rhegmatogenous RD with subretinal exudate. Diffuse infiltrative growth of RB sometimes mimicks inflammatory

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conditions of the eye. It presents with RD,diffuse nodular thickening of the retina and non specific hyperechogenicity of the vitreous (11).

Cross sectional imaging is used to confirm the diagnosis, assess the extent of the tumor and detect any associated intracranial primitive neuroectodermal tumor.

On CT, retinoblastoma appears hyperdense on plain scan and shows moderate post contrast enhancement. CT has high sensitivity and specificity for detection of calcification in RB. On MRI, the tumor appears slightly hyperintense to vitreous on T1W images, hypointense on T2W images and shows restricted diffusion on DWI with low ADC values. The calcified areas appear as hypointense foci within the tumour on gradient-echo images. The tumour shows moderate to marked enhancement (12-14).

III] Choroid

1.Choroidal detachment (CD)-On US, choroidal detachment appears as a 'C' or 'reverse C' shaped echogenic membrane in the posterior segment, with the anterior attachment at the ciliary body and posterior attachment at the exit of the vortex veins (Figure 13). The location of the anterior and the posterior attachment helps in differentiating RD and CD (Table 3). Severe cases lead to large elevations of the choroids, which may come in contact within the vitreous cavity. This is called as the 'Kissing choroidals' (Figure 14).

2. **Choroidal melanoma**- It is the commonest primary intraocular tumor in adults. It arises from the choroid and ciliary body (uveal tissue), commonly posterior to the equator (4-6).

On US, it is seen as a hyperechoic lesion with convex morphology, due to restriction of growth by Bruch's membrane. Mushroom or collar-button shape of the lesion is seen when the tumor breaks through the Bruch's membrane and extends into the subretinal space and the vitreous (Figure 15 A). It shows a hyperechoic rim, which is composed of the retina and peripheral vessels. US may also reveal associated marginal retinal elevation. Scleral erosions or extraocular extension of tumor into the orbital fat may also be detected. Colour Doppler shows tumor vascularity (Figure 15 B), however, all tumors are not vascular.

MRI is more sensitive in detecting extra-ocular and perineural spread. The tumor appears hyperintense on T1W images and hypointense on T2W images (due to the melanin pigment) and shows moderate post contrast enhancement.

IV] Miscellaneous

1. Endophthalmitis -Endophthalmitis implies infection of the internal coats of the eye ie. uveal tissue and retina (6). US findings reported in endophthalmitis include mobile vitreous echoes or vitreous membranes; diffuse homogenous or nodular thickening of the ocular coats with few hypoechoic areas within suggestive of edema, sub-Tenon fluid and exudative RD or CD (Figure 16) (15). Kohanim et al. (16) found that positive findings may be confirmatory in cases with high clinical suspicion; however ocular ultrasound alone cannot be used to prove or to exclude the diagnosis of endophthalmitis.

2. Intraocular foreign bodies (IOFB)- It is a common occurrence post ocular trauma and a major cause of blindness. US is a fast, accessible modality to assess the presence, type and location of the foreign body. It can be

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used to detect both radio-opaque and radiolucent IOFBs.

IOFBs are identified by their bright echogenic appearance, with shadowing or reverberation artifacts usually seen in the vitreous (Figure 17). US can also detect associated vitreous hemorrhage, RD and globe rupture.

3. Lens subluxation/ Dislocation into the posterior chamber- Traumatic or non-traumatic subluxation / dislocation of the lens can be accurately detected on US. Lens can be seen attached to one of the ends of the ciliary body by the zonules (subluxation) or completely detached, with abnormal location in the vitreous (dislocated) (Figure 18).

4. Ocular Cysticercosis- The larval form of pork tapeworm, Taenia solium, causes ocular cysticercosis. Ocular involvement includes cysts in the eyelids, extraocular muscles, conjunctiva, anterior chamber, vitreous, retina, uveal tissue, and optic nerve (17).

On US, cysticercosis is seen as a cystic lesion with an eccentric echogenic nodule that represents the scolex (Figure 19). They have to be differentiated from retinal macrocysts. These are associated with long-standing retinal detachment, especially of the traumatic type (18). They arise from the outer plexiform layer of the retina. The characteristic scolex of the cysticercus is not seen (Figure 20).

Conclusion:

USG is an excellent primary diagnostic modality, which can aid in diagnosing a broad spectrum of posterior segment disorders. Every radiologist should be aware of the imaging features of the frequently encountered posterior segment pathologies, which can be optimally diagnosed with USG. This would not only hasten the management of the patients, but also prevent further unnecessary imaging.

Table 1: Differences between ‘Asteroid hyalosis’ and ‘Synchisis scintillans’.

Asteroid hyalosis	**Synchisis scintillans**
Usually unilateral	Usually bilateral
Tiny echogenic foci in the vitreous unaffected by gravity. There is a clear anechoic zone between the retracted vitreous and the retina	Tiny echogenic foci in the vitreous, which sink due to gravity

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Table 2: Differences between 'Retinal detachment' and 'Posterior vitreous detachment'

Retinal detachment	**Posterior vitreous detachment**
A thicker uniform membrane in the posterior segment showing no movement on dynamic scan	A thin flimsy undulating membrane showing after movements on dynamic scan
Always attached to the disc	May or may not be attached to the disc
Central retinal artery and its branches are seen traversing through it	The membrane shows no internal vascularity

Table 3: Differences between 'Retinal detachment' and 'Choroidal detachment'

Retinal detachment	**Choroidal detachment**
The echogenic membrane is attached to the optic disc posteriorly and the ora serrata anteriorly	The echogenic membrane is attached to the vortex vein exit posteriorly and the ciliary body anteriorly
Central retinal artery and its branches are seen traversing through it	The membrane shows no internal vascularity

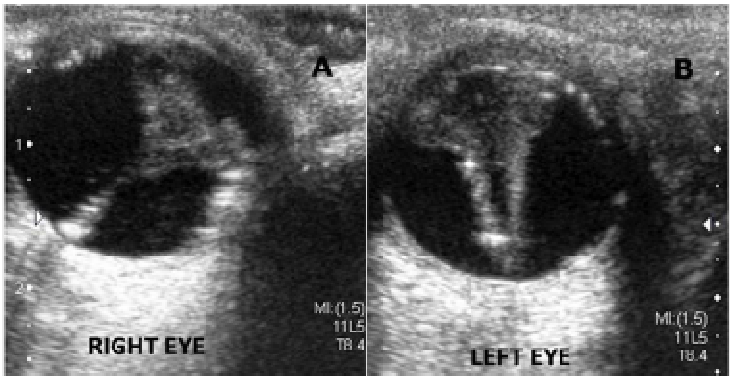

Figure 11: US of an infant with premature birth, treated with oxygen therapy reveals dense retrolental membranes with closed funnel RD in both the eyes (A and B) suggestive of retinopathy of prematurity.

Figure 12: US of a 2 year old boy with leukocoria reveals an endophytically growing soft tissue mass in the posterior segment, with foci of calcification within (arrow) suggestive of retinoblastoma

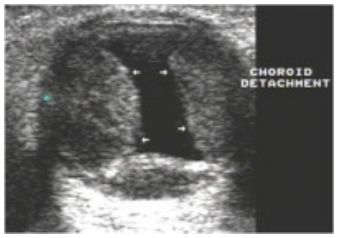

Figure 13: US reveals echogenic membranes in the posterior segment, with the anterior attachment at the ciliary body and posterior attachment at the exit of the vortex veins suggestive of choroidal detachment.

Figure 14: US revealschoroidal detachment with the membranes contacting in the posterior segment. This is termed as 'Kissing choroidals'.

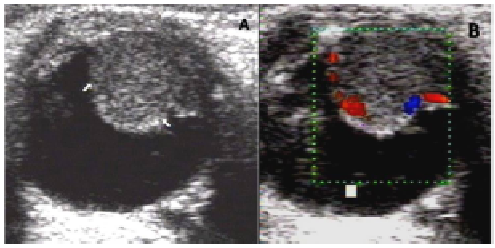

Figure 15: US reveals (A) a mushroom shaped hypoechoic mass arising from the choroid showing a hyperechoic rim (arrows) in an elderly patient (B) which shows vascularity on Color Doppler- suggestive of choroidal melanoma.

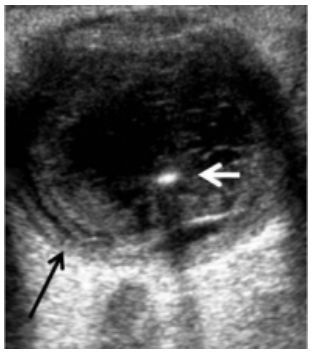

Figure 16: US reveals vitreous echoes and membranes with diffuse thickening of the chorioretinal layer (black arrow) suggestive of endophthalmitis. An echogenic foreign body (white arrow) with posterior acoustic shadowing is seen, which was the cause of endophthalmitis in this case.

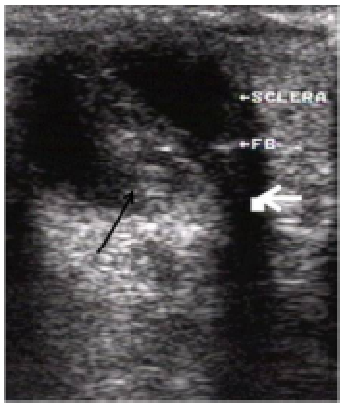

Figure 17: US reveals an echogenic foreign body (FB) in the posterior segment with characteristic posterior acoustic shadowing (white arrow). Vitreous hemorrhage is noted along the track of the foreign body (black arrow).

Figure 18: US reveals dislocated lens (arrow) in the vitreous cavity.

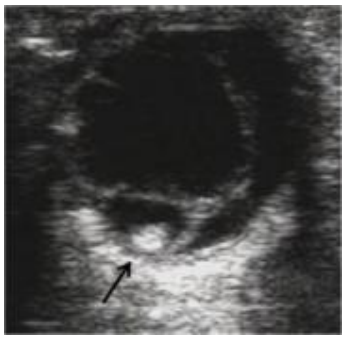

Figure 19: US reveals RD with a well defined cystic lesion in the retina (arrow) showing an echogenic eccentric focus suggestive of retinal cysticercosis.

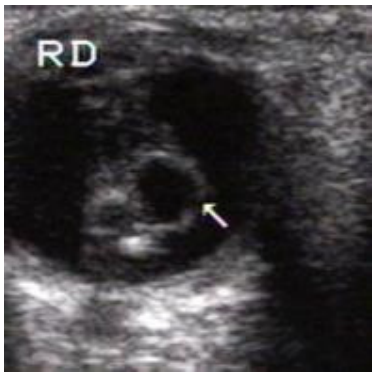

Figure 20: US reveals closed funnel RD with a well defined cystic lesion in the retina (arrow). It shows no echogenic eccentric focus suggestive of retinal macrocyst.

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