Ultrasonography of the eyeball. What a radiologist needs to know

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Learning objectives

• Describe the technique of performing ultrasonography of the eyeball, the selection and configuration of the probe.

• Describe the study protocol.

• Identify ultrasonographically the different structures of the eyeball.

• Characterize the main pathologies of the eyeball evidenced by ocular ultrasound and Doppler ultrasound.
Background

Ultrasonography (US) of the ocular globe when performed by a trained examiner is a useful tool for the diagnosis of various entities of the ocular globe. It is a safe procedure that is performed in real time, it does not require sedation, it does not use radiation, and moreover, it is cheap and affordable.

The main indications result from the difficulty of examining ocular rear wall, when there is opacification of the transparent media, for example, by cataracts, hyphema, hypopyon, vitreous hemorrhage, extreme miosis, etc.

Contraindications to ultrasound of the eye are rare, the main contraindication is suspected rupture of the ocular globe in patients with trauma or who have recently had surgery, because it could cause extrusion of the contents of the ocular globe.

In these cases the modality of choice for the study is computed tomography. MRI is also useful, but ultrasound has better resolution of small lesions less than 2 mm deep.

ECHOGRAPHIC PROCEDURE

Contact lenses should be removed before the US technique. Patients are explained eye movements to be done with eyes closed. The use of a generous amount of gel is useful for improving the contact of the probe.

Probe Selection and Settings

Due to the superficial location of the eye, linear high-frequency transducers (7.5 to 13.0 MHz) must be used. In B mode, the gain setting is adjusted first for surface images (anterior chamber) and then to the deepest area (vitreous and posterior wall). Color Doppler is adjusted to lower speeds. The transducer pressure should be minimal to avoid collapse of anterior chamber, a precaution which is especially important in patients with traumatic eye injuries due to the risk of rupture. Thus, ultrasound is contraindicated in patients with traumatic injury and ocular eye suspected rupture.

Study Protocol
Axial images are acquired from the upper to the lower pole. Then sagittal images from the temporal to the nasal side. You must also obtain oblique images and dynamic images with smooth eye movements to represent echoes and vitreous lines.

Color Doppler represents the central artery of the retina, the posterior ciliary arteries, the retina layer and the parallel venous system.

ANATOMY OF THE EYE

The eye is located in the anterior region of the orbit near the lateral and superior walls. The wall of the ocular globe consists of three layers: the retina, or sensorineural inner surface; vascular uvea, comprising anterior to posterior, the iris, ciliary body, and choroid; and the cornea and sclera, which form the outer layer and support. The aqueous humor is contained in the anterior chamber between the cornea and the lens, and to a lesser extent, in the posterior chamber between the iris and the lens. The lens is supported by ciliary bodies and vitreous posteriorly, which fills the posterior segment.

The eye is divided into two segments: the previous segment, which contains the cornea, anterior chamber, lens, posterior chamber, iris and ciliary body; and the posterior segment containing the vitreous, retina, choroid and sclera.

The blood supply is mainly from the ophthalmic artery, which arises from the internal carotid artery and flows adjacent to the optic nerve. Its main branches are the central retinal artery which supplies the first two thirds of the retina and the posterior ciliary arteries, which supply the choroid, optic disc and the outer third of the retina. The major venous drainage occurs through the superior ophthalmic vein.

The structures of the eye are easily recognizable in ultrasound. The above structure is the cornea, shown as a thin line can sometimes be unidentifiable. The anterior segment comprising two anechoic areas: the anterior chamber (between the cornea and the lens) and the lens, with an anechoic structure thin anterior and posterior capsules. Hypoechoic ciliary bodies are on both sides of the lens. The vitreous is also seen as a posterior lens anechoic area. The rear wall (three layers) appears as a concave echogenic line, it is interrupted by the optical disk. Behind the ocular globe, retro-ocular fat appears hyperechoic and extra-ocular muscles appear hypoechoic. The central retinal artery, which supplies the retina, and the short posterior ciliary arteries are color Doppler, which also represents the layer of the retina and central retinal vein.
Fig. 1: Ocular anatomy.

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Fig. 2: Ocular anatomy. Image of normal ocular ultrasound.
Findings and procedure details

**PATHOLOGY US FINDINGS**

**SIZE AND MORPHOLOGICAL CHARACTERISTICS**

In adults the normal ocular anteroposterior diameter of the ocular globe is 22-25 mm.

High **myopia**, for a long time increases the ocular anteroposterior axis, sometimes with a thin wall, and often manifests with abnormal morphology, usually later, this is known as Staphyloma.

The **phthisis bulbi**, refers to a small, non functioning eye, and usually calcified, as a result of pathological conditions such as trauma, angiomatosis, noxas intrauterine infection, genetic disorders, and retinopathy of prematurity. With US, it is seen a small eye, usually with a calcified wall and hyperechoic fibrous tracts, with retinal detachment.

**Microphthalmos** is a congenitally small eye and it is mainly associated with coloboma caused by incomplete fusion of the optic cup; with US it can be observed as a defect on the optical disc and eye retro cyst.

**TRAUMA**

In patients with trauma, you can see abnormal morphological characteristics of the ocular globe as a result of an open trauma, with the extrusion of content or orbital hematoma compressing ocular globe.

In patients with orbital trauma, we should take special care when performing ultrasound, reducing pressure transducer to avoid breaking a wall of previously injured eye.

**ANTERIOR CHAMBER**

The blood in the anterior chamber (hyphema) is caused by the rupture of the vessels in the iris and ciliary body. In patients with hyphema, anterior chamber appears hyperechoic, but the main purpose of ultrasound is to exclude associated injuries. Differential diagnosis should be formed from the anterior lens subluxation, thereby decreasing the depth of the anterior chamber.
CONDITIONS OF THE LENS

Cataracts.- Cataracts are usually related with age, but can also be congenital or result from trauma or infection. On ophthalmoscopy, they look like a white reflection with an opaque lens, a fact which is known as leucocoria. On US, cataracts can demonstrate three different appearances: intralenticular echoes, increased thickness and echogenicity of the rear wall, or both. The main role of US is the evaluation of post-opaque lens structures.

Luxation.- The lens can be moved from its normal position, usually posterior and rarely lateral. The dislocation of the lens is caused by damage to the zonular fibers that keep the lens in place, and it can be seen in different conditions, such as those related to trauma and Marfan syndrome, which can be bilateral. There are two types of dislocations: partial dislocation (subluxation) and complete dislocation. In partial dislocation, a margin of the lens keeps its normal position behind the iris, while other angles are into the vitreous. The complete dislocation, the lens is in the dependent region of the vitreous and it is in an abnormal position on US. In patients with traumatic dislocation can be observed an echogenic lens (traumatic cataract) and hemorrhage.

Cataract patients are mainly treated with surgical removal of the lens, which leads to a postoperative condition of aphakia. In patients with aphakia, ciliary bodies are seen on ultrasound and CT, but the lens is absent. Some patients undergo placement of an artificial lens, a condition called pseudophakia. In these cases, ultrasound look like a flat or concave highly echogenic structure at the location of the lens.

IRIS AND CILIARY BODY CYSTS

The cysts of the iris and ciliary body appear as a round anechoic lesion. These lesions are usually asymptomatic, and may be congenital or related to trauma or eye surgery. The cysts of the iris and ciliary body should be distinguished from solid lesions that represent tumors.

VITREOUS CONDITIONS

The presence of echoes within the normal anechoic vitreous may result from entities such as the vitreous degeneration, hyalosis asteroid, bleeding, and infection.
Vitreous degenerates with age, with synergetic changes observed within the cortical and central gel. On US, vitreous degeneration is observed as small low-level echoes that move freely and are usually bilateral. Asteroid hyalosis is usually asymptomatic and it is often associated with systemic diseases such as hyperlipidemia, hypertension and diabetes mellitus.

Asteroid hyalosis is observed on ultrasound as asteroid bodies which appear as small vitreous opacities, consisting of calcium phosphate and lipid deposits. Small echoes are also observed, hyperechoic phones which are usually unilateral refractive result of calcified deposits.

Vitreous hemorrhage can be traumatic, spontaneous or related to tumor. Ultrasound is not only useful in the diagnosis of the disease, which is usually done in ophthalmoscopy, but mainly in excluding associated lesions (eg, tumors or detachment). The findings of vitreous hemorrhage on US differ depending on its age and extent: mild acute bleeding shows normal or slightly increased vitreous echogenicity, and in abundant bleeding, mobile, poorly defined hypoechoic echo or clots can be seen within the vitreous.

Absorption and reduced bleeding clots occur with healing, leading to increased echogenicity vitreous. The resolution can occur within 2-8 weeks, however, membranes are frequently seen. Initially, these membranes are short and moving, and then become rigid part and sometimes fixed to the back wall, usually outside the optical disk. When retinal detachment is present, the differential diagnosis is made based on the distance of the membranes of the papilla.

An infection in the vitreous is called vitritis, in which the vitreous hypo- or isoechoic is observed, that is a finding that may look like bleeding, however, the echoes are less mobile than bleeding. Membranes appear progressive organization.

**DETACHMENT**

**Retinal Detachment.**- Lines within the vitreous are indicative of different conditions, including retinal detachment, in which retinal pigmented layers are separated due to trauma, tumor or exudative processes. There are three types of retinal detachment, as the underlying mechanism: rhegmatogenous or tractional retinal tear; separation of the retina layer due to the traction of vitreous membranes; and exudative, in which the blood, fluid, or a lesion is present in the subretinal space.

The complete retinal detachment appears as an echogenic line to be fixed in the disc and extends to the ora serrata. An acute angle is formed with the typical shape of V, with the
vertex on the optical disc. The sharply detached retina is mobile, with the appearance of a "floating echogenic line". In chronic detachment line is thicker, very mobile, and retinal cysts as anechoic lesions may appear within the detachment.

In the presence of a retinal detachment, subretinal and vitreous space should always be examined as they may contain blood, fluid, exudative, or tumor, thus providing the cause of separation. That is not always possible to determine by ophthalmoscopy. The vitreous is anechoic to ultrasound, and blood may be anechoic or hypoechoic. Neoplasms occur as a solid mass. Retinal detachment may be partial when it is only a single region, in these cases, the echogenic line has different morphological characteristics, making diagnosis more difficult.

Proliferative membranes and new vessels develop in patients with diabetes, macular lesions or retinal ischemia and should be included in the differential diagnosis of partial detachment of the retina.

On US, proliferative membranes or irregularities appear as lines which can be difficult to distinguish from central retinal detachment.

**Choroidal detachment.**- It is caused by the accumulation of fluid (e.g., serous fluid or blood) in the potential suprachoroidal space, located between the choroid and sclera. Typically it is related to hypotonia due to the inflammatory conditions, trauma or surgery. The potential suprachoroidal space extends from the ora serrata to the optic disc, but the choroid is fixed to the sclera by vortex veins.

At US it appears as two thick convex and barely lines extending from the ciliary body to a point on both sides of the disc (vortex veins), creating an obtuse angle.

**Hyaloid detachment.**- It may be related to vitreous retraction and usually occurs in patients aged 45 to 65 years, but may occur earlier in patients with myopia. On ultrasound, the hyaloid detachment appears as a thin line across the optic nerve papilla.

**Retinosis.**- It involves a defect in the retina that can be congenital or related to trauma or inflammatory disease. At US, the retinal hole appears as a soft thin line, an aspect that can resemble a detached retina; however, in retinosis, the insertion is far from the papilla.

**POSTERIOR WALL MASSES**

Tumors of the rear wall arise from the vascular uvea, and appear as elevated posterior wall lesions of various sizes.
**Melanoma** is the most common primary ocular tumor. It arises from the choroid, and its clinical manifestations vary depending on the location: it can present with vitreous hemorrhage or cause defects in visual perimeter, and patients usually present with glaucoma when it is in the iris or defects accommodation when they are in the ciliary body. At US, small lesions are often seen as a hypoechoic mass with a smooth round without calcification. Doppler color, usually seen as vascular. The projection function is typical image of choroidal melanoma excavation. An excavation area on a small mass of the rear wall is indicative of melanoma, although this feature is not always present.

Eye **metastases** are most commonly from breast and lung tumors. At US, it appear as a mass of the rear wall and usually multiple, and they are usually flat or discoid or hyperechoic with an uneven surface. The differential diagnosis of metastasis is the same as for melanoma. Metastasis show greater flow than melanoma at Doppler.

**Nevi** are another rear wall tumor and they are seen as a pigmented tumor on direct examination. It usually appears as a flat mass with no Doppler-flow.

The **hemangioma** is a vascular malformation that can be isolated or multiple in patients with Sturge-Weber syndrome. It is most commonly found in the orbit, but can also occur in the ocular globe. At US, vascular lesions appear as hyperechoic mass not calcified, convex, homogeneous, usually in the temporal region without choroidal excavation. Multiple lesions may be present. The flow can be seen on Doppler, depending on the type of lesion present.

**PSEUDOMASSES**

Posterior wall masses at the ultrasound are not always related to tumors, and pitfalls may include subretinal hematoma resulting from proliferative membranes and granulomas in patients with granulomatous infection. Both lesions are usually heterogeneous, and neither demonstrates the Doppler flow. Monitoring of clinical findings and imaging are important for differential diagnosis. In the subretinal hematoma, fibrovascular preretinal membranes are observed with pathological neovascularization, which develop in patients with proliferative diabetic retinopathy or retinal ischemia macular lesions. They often rupture, leading to hemorrhaging.

At US, the subretinal hematoma is usually seen as a small lump under the line of the retina without associated lesions or small irregularities on the back wall.
Several infections such as retinitis exudative and granulomatous, can affect the entire globe, with different manifestations.

Granuloma appears as a mass of the rear wall of the peripheral retina or optic disc, and the differential diagnosis includes posterior wall tumors.

Its main causative pathological entities are tuberculosis and histoplasmosis in adults and toxocariasis in children.

CALCIFICATIONS

Calcified plaques in the optical disc are called drusen. They are usually bilateral and asymptomatic, but they can cause optic nerve atrophy. Optic nerve plaque is seen in ophthalmoscopy, typically with autofluorescence. At US it is seen as hyperechoic lesions in the optic disc with acoustic shadow. The presence of calcifications and its location are the clues to the diagnosis.

FOREIGN BODIES

In a penetrating trauma, foreign body enter through the cornea and can be located anywhere in the eye and orbit. At US, foreign bodies can be seen as echogenic dots. CT is useful for locating them (such as metal and wood) and associated injuries (such as fractures). RM also plays a role in some cases. Surgical material can also be seen.
Fig. 3: Myopia. Staphyloma (arrows), rear wall morphological alterations.

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Fig. 4: Full cataract left eye (arrows).

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Fig. 5: Traumatic cataract. Echogenicity and distortion of crystal morphology (arrow).

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**Fig. 6:** Subcapsular cataract in the right eye (arrow).

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**Fig. 7:** Cataract. Lens opacity (arrow).

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Fig. 8: Vitreous degeneration and retinal desprendimiento (arrow).

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Fig. 9: Vitreous degeneration. Linear echogenicity posterior chamber (arrows).
**Fig. 10:** Vitreous hemorrhage (arrow).

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**Fig. 11:** Vitreous hemorrhage (arrow).

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**Fig. 12:** Vitreous hemorrhage (arrow).

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Fig. 13: Vitreous hemorrhage (arrow).

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Fig. 14: Retinal detachment. Image tumor (arrow).

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Fig. 15: Retinal detachment. Image tumor (arrow).

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**Fig. 16:** Retinal detachment (arrows).

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Fig. 17: Retinal detachment (arrows).
**Fig. 18:** Retinal detachment (arrows).

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**Fig. 19**: Hyaloid detachment.

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**Fig. 20:** Ocular choroidal melanoma. Tumor thickening (arrow) in posterior choroidal excavation wall.

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Fig. 21: Ocular choroidal melanoma. Tumor thickening (arrow) in posterior wall with increased Doppler flow and choroidal excavation.

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**Fig. 22:** Metastasis of breast cancer. Image tumor in posterior wall with increased Doppler (arrow) flow.

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Fig. 23: Nevus. Rear wall tumor lesion (arrow).
**Fig. 24**: Foreign body injury. Drilling by wire (arrow).

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Fig. 25: Foreign body injury. Drilling by wire (arrow).

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• Using ultrasound eyeball we can describe findings that are not visible by ophthalmoscopy. So what is a vital and quick test to perform, especially when there is a "barrier" (blood, pus, calcium, foreign body, etc.) that doesn't allow observing the fundus.

• It's a harmless test that can be performed at the bedside of the patient so that you can make quick decisions in cases of emergency.
References