OCULAR SONOGRAPHY: Supporting the ophthalmologist.

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Authors:  
- F. Pozo Piñón¹, A. Fernández Flórez², E. herrera romero¹, A. B. Barba Arce³, V. Fernández Lobo², Y. Lamprecht², E. Marín Diez², B. González Humara², P. Lastra Garcia-Barón², ¹Santander, Cantabria/ES, ²Santander/ES, ³Torrelavega, Cantabria/ES  
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Learning objectives

Explain the technique of ocular ultrasound, the main indications, and the advantages and disadvantages of its use.

Also we will review the anatomic characteristics of the eye and the orbit, the most frequent pathologies seen with ultrasound, and see what role it has in the ophthalmologic diagnosis.
Background

The use of ultrasound applied to ophthalmology was first described in 1956 by Mundt and Hughes through the use of ultrasound A. Since then, especially with the appearance of ultrasound B and the improvement of the probes, this technique has become essential in the diagnosis of intraocular pathology, becoming more important in those cases where the ophthalmologist evaluation can't be performed such as eyelid problems (severe edema, wound), corneal opacifications, hyphema, hypopyon, myosis, dense cataract, vitreous opacifications (hemorrhage).

There are three types of sonographic exploration: topographic, quantitative and kinetic. The topographic exploration informs us of the location, extension and shape of the lesion. The quantitative exploration gives information of the echogenicity, the internal structure, homogeneity/heterogeneity, and the degree of attenuation. With the kinetic exploration we assess the mobility and vascularization of the tissue.

Regarding the sonographic exploration methodology, there are basically two methods. The contact method in which the probe rests on the eyeball, being able to do it on the cornea or on the sclera. It can also be done by placing the probe on the eyelid, although this will cause a great attenuation of the beam, decreasing the quality of the image of the posterior structures. In the immersion method, the probe is immersed in saline or transducer gel, without being in direct contact with the eye. It is used to explore the anterior pole.

The basic positions in the ocular ultrasound are three: transverse, longitudinal and axial. The transverse with the probe on the sclera and the beam oriented tangentially to the corneal limbus, following the margin of the cornea. This examination gives us information on the lateral extent of the lesions. The longitudinal orientation with the probe on the sclera and the beam perpendicular to the corneal limbus, gives information of the anteroposterior extension of the lesions. The axial orientation with the probe centered on the cornea is used for the study of the optic nerve and the macula. It must be taken into account that in the transverse and longitudinal positions, the region of the posterior pole that appears on the screen corresponds to the contralateral of the place where we place the probe. That is, if we place the transducer on the temporal sclera we would be studying the nasal region and viceversa.

When we perform a contact ultrasound by directing the ultrasound wave through the probe, with an axial orientation, the first structure we observe is the posterior aspect of the lens. Next we can see an empty space corresponding to the vitreous and finally the posterior pole. If we use a lateral projection, with the probe in contact with the sclera,
we will avoid the attenuation of the ultrasound caused by the lens and we will be able to evaluate the posterior pole in greater detail.

Talking about the technique, the patient must be lying with his eyes closed; we use a large amount of conducting gel (immersion technique) and a highfrequency linear transducer (12-17 MHz). A careful scanning technique is critical to avoid anisotropy due to the curvilinear contours of the eye. To avoid this pitfall, the transducer may be gently placed along the anterior wall of the eye, with a minimum of pressure. In some cases, scanning the contralateral eye can be useful to compare the pathologic eye with the normal one.
Findings and procedure details

We have reviewed the images of ocular ultrasound from our hospital's database, taken from urgent and routine studies. Based on these images we wanted to review the principal characteristics of the anatomy of the eye visualized with ultrasound. In addition, we want to show the most common pathologies of the eye and the orbit in which the ultrasound can play an important role, either because of its good diagnostic value or because of the impossibility performing other studies, such as vitreous pathologies (vitreous opacities, vitreous hemorrhage, inflammatory processes or diabetic retinopathy), retinal pathologies (retinal detachment, posterior vitreous detachment and choroid detachment), tumors (melanoma, retinoblastoma, metastasis), or orbital pathologies (traumatisms or tumors).

Anatomy study (Fig. 1)

The eye ball is divided by the lens into two segments:

- **Anterior segment**: subdivided by the iris in anterior and posterior chamber. It includes the cornea, iris, cilliary body and lens. It contains a fluid called aqueous humor.
- **Posterior segment**: also contains more consistent fluid called vitreous humor.

The lens, aqueous humor, vitreous humor and the cornea are the transparent structures of the eye.

The eyeball wall is composed by three layers:

- **The external layer**: a fibrous layer that is very resistant and keeps the shape of the eye. It is formed by the sclera at the back and the cornea in the anterior part.
- **The intermediate layer**: the uveal tract is a vascular layer, divided in anterior part (iris and cilliary body) and posterior part (choroid).
- **The internal layer**: a neural layer, the retina, which contains different structures in its surface: macula, fovea and papilla or optic disk.

The structures of the eye are easily visible on ultrasound. The anterior structure is the cornea, shown as a thin line, it can sometimes be unidentifiable. The anterior segment comprises two anechoic areas: the anterior chamber (between the cornea and the iris) and the lens, an anechoic structure with thin anterior and posterior capsules. Cilliary bodies are on both sides of the lens shown as hypoechoic structures. The vitreous is seen as an anechoic region posterior to the lens. The posterior wall (three layers) appears as a concave echogenic line, interrupted by the optical disk.
Retinal Detachment

The retinal detachment is caused because of fluid accumulation between the neuroepithelium and the retinal pigment epithelium in the "subretinal" space. It can be seen as a high echogenicity thick membrane, from the optic disc to the ora serrata when the detachment is complete. It takes morphology in "V" in its early stages, "Y" or "T" when it evolves without treatment. May be mobile in the acute phase, becoming more rigid in cases of chronic detachments. Vascularization is detected with Doppler (arteriovenous flow). (Fig. 3-4)

Choroidal Detachment

The choroidal detachment presents as a high echogenicity thick membrane with a convex configuration. It forms an obtuse angle with the posterior wall not detached. Colour Doppler reveals arterial flow. (Fig. 3)

Posterior Vitreous Detachment

The detachment may be complete or incomplete. Incomplete detachment may present fixation areas to the posterior wall, being able to observe retinal traction. In complete detachment there is no relationship with the posterior wall. B-scan shows a thin membrane with very low echogenicity and sometimes it is necessary increasing the gain to see it. This membrane has a concave shape parallel to the posterior wall. With colour Doppler there is absence of flow, which differentiates it from retinal detachment. (Fig. 5-8)

Vitreous Hemorrhage

The most frequent causes are the rupture of sclerotic vessels, trauma, choroidal neovascularization, diabetic retinopathy and tumors.

There are several stages of hemorrhage showing different morphological characteristics. In early stages B-scan reveals very low echogenicity thin echoes, with considerable movements. In its evolution, opacities acquire medium echogenicity, with the same fluid movements. (Fig. 9)

Then they form high echogenicity fibrin clots, and may form thick membranes which move fluidly with eye movements at beginning, and after they become rigid and fixed to the posterior wall, being able to cause a retinal detachment.

Melanoma

They are tumors that affect the uveal tract (iris, cilliary body and choroid). Small tumors show middle and homogeneous echogenicity, a biconvex lens appearance and they have...
usually a regular outline. Larger tumors are lower-echogenicity lesions and can present
cystic areas representing areas of necrosis or hemorrhage. They are usually mushroom-
shaped and they have an irregular outline. These tumors present smooth attenuation. In
colour-Doppler scan they show evidence of perfusion in most instances. (Fig. 10-11)

It is frequently associated with retinal detachment, and occasionally with vitreous
hemorrhage.

**Orbital Lymphoma**

The orbital lymphomas can affect any structure of the orbit, such as the extrinsic ocular
muscles, the optic nerve, the lacrimal gland, the periosteum and the eyeball.

With the ultrasound they can be seen as single or multiple nodules, with unilateral
or bilateral affection, smooth or irregular margins, low echogenicity and relatively
homogeneous parenchyma. When we use the Colour-Doppler we can see the
vascularization of the tumor. (Fig. 12-13)

Both Hodgkin and No-Hodgkin lymphoma can affect the orbit, but the most frequently
seen is the Hodgkin type.
Fig. 1: US image of the ocular anatomy: 1. Cornea; 2. Anterior chamber; 3. Iris; 4. Lens; 5. Vitreous humor; 6. Retina

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<th>Topography</th>
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<td>Smooth and thick membrane. Without insertion in the optical disc. Either in the ora serrata or the ciliary body, with a domus form.</td>
<td>Smooth and thin membrane. With or without insertion in the optical disc.</td>
<td>Smooth membrane. Insertion from the optical disc to the ora serrata. &quot;V&quot; or &quot;Y&quot; form.</td>
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Summary of the differential diagnosis of the Choroid detachment, Posterior Vitreous detachment and the Retinal detachment, with the ultrasound characteristics.
Fig. 2: Table showing the differential diagnosis of the detachments (retinal detachment, choroidal detachment and posterior vitreous detachment).

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Fig. 3: Retinal detachment ("V" morphology layer, in touch with the retina) in association with choroidal detachment adjacent to the ciliary body.

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Fig. 4: Retinal detachment with the presence of Colour-Doppler inside the layer of the detachment.

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Fig. 5: Smooth and thin layer with a "U" morphology, without insertion in the optical disc.
**Fig. 6:** Smooth and thin layer with a "U" morphology, without insertion in the optical disc, and also showing absence of Colour-Doppler in the layer.

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Fig. 7: Posterior Vitreous Detachment after cataract surgery showing. Also, there is subvitreous hemorrhage.

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**Fig. 8:** Posterior Vitreous Detachment showing the absence of Colour-Doppler inside the detached layer, after cataract surgery showing. Also, there is subvitreous hemorrhage.

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**Fig. 9:** Vitreous hemorrhage: Hyperechoic material inside the vitreous humor with Colour-Doppler in the retina.

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**Fig. 10:** Choroid melanoma: Hyperechoic mass inside the vitreous humor, in contact with the retina.

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Fig. 11: Choroid melanoma: Hyperechoic mass inside the vitreous humor, with a "mushroom" morphology (typical of this entity), in contact with the retina with central vessels coming from the retina.

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**Fig. 12:** Orbital Lymphoma: Hyperechoic heterogeneous mass surrounding the eyeball, in a patient with a lymphomatous disease.

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Fig. 13: Orbital Lymphoma: Hyperechoic heterogeneous mass surrounding the eyeball, with important hyperemia in Colour-Doppler, in a patient with a lymphomatous disease.

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Conclusion

Ocular ultrasound is a complementary technique that is highly useful for the ophthalmologist in selected cases (especially in patients with opacity of the lens), given its rapidity, good cost-benefit ratio and absence of radiation with this study.
References