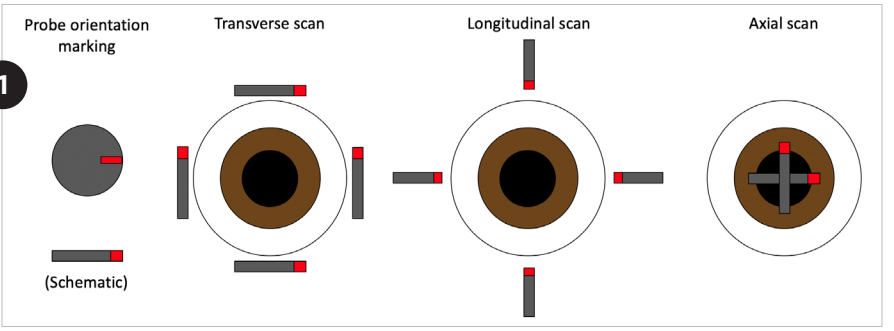
Using Ultrasound in Intraocular Diagnosis Part 1: Image Acquisition

Ophthalmic ultrasound is an important tool in the ophthalmologist's diagnostic arsenal. It provides a noninvasive method of visualizing ocular structures and pathology not otherwise easily seen on direct examination; it can also be useful in further differentiating visualized pathologies.

There are three commonly used types of ophthalmic ultrasound: A-scan, B-scan, and ultrasound biomicroscopy (UBM), which employ ultrasound frequencies of 8 MHz, 10 MHz, and 35-100 MHz, respectively. An A-scan (or amplitude scan) produces a single sound beam that creates a one-dimensional image with spikes corresponding to different tissue densities. In comparison, a B-scan (or brightness scan) provides two-dimensional cross-sectional imaging of the eye, with higher-amplitude reflections appearing as brighter points in the image. Finally, UBM utilizes a significantly higher frequency to provide high-resolution cross-sectional imaging of only the anterior segment of the eye.[1]

OCT employs a similar mechanism to create images by analyzing reflections off ocular structures such as the retina, optic nerve, or anterior segment. However, it uses near-infrared light rather than sound waves.

This two-part series on ophthalmic ultrasound focuses on the use of A- and B-scans in the diagnosis of ocular disease. Because the diagnostic utility of a scan depends on how it is captured, Part 1 presents the fundamentals of image acquisition and orientation. Next month, Part 2 will discuss how to interpret the scans to distinguish between important intraocular conditions.



SCHEMATIC. *Probe orientation for various scans.*

Gain Control

Gain control, along with scan orientation, is one of the principal aspects of B-scan acquisition. Gain control adjusts the signal intensity and sensitivity of the scan. Higher gain levels (80-90 dB) allow for the detection of more subtle structures such as the posterior hyaloid, vitreous opacities, or small foreign bodies. However, this comes at the expense of increased noise, which may complicate interpretation. Lower gain levels (60-70 dB) can emphasize stronger signals (i.e., from more highly reflective structures such as disc drusen) at the expense of missing weaker signals and decreasing the depth of penetration.

Scan Orientation

To help orient the examiner, B-scan probes have a marker near the tip of the probe that corresponds to the top of the imaged plane. The position of the marker in relation to the eye determines whether the scan is transverse, longitudinal, or axial in orientation (Fig. 1).

Transverse scans. Used to image each quadrant of the eye, transverse scans enable the examiner to evaluate a large area of the posterior segment. They are also used to determine the lateral extent of a lesion. Transverse scans are identified by clock hours, with superior and inferior scans designated as T12 and T6, respectively, and nasal and temporal scans as T3 or T9, depending on which eye is examined.

During each scan, the patient looks in the direction of the quadrant being imaged with the probe axis placed parallel to the limbus opposite to the quadrant of interest. The probe marker should always be oriented superiorly or nasally by convention: nasally for T6 and T12, and superiorly for T3 and T9 (Fig. 2). For example, if the superior quadrant is to be examined (T12), the

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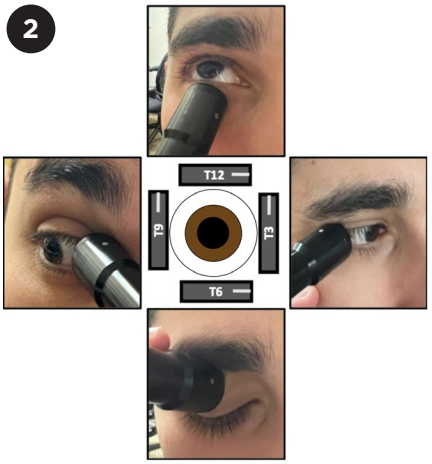


TRANSVERSE SCAN. *Probe orientation, right eye. Note that the probe marker (white dot) is oriented superiorly for T3 and T9 and nasally for T6 and T12.*

patient looks superiorly and the probe is placed at the inferior limbus, with the marker oriented nasally. Transverse scans typically show the optic nerve in the center of the fundus (Fig. 3, top left).

When performing a transverse scan, the examiner should first identify the optic nerve. The examiner then sweeps the probe along the contour of the globe posteriorly from the limbus to the fornix in order to image the entire quadrant from posterior to anterior. Within each clock hour, a probe placed closer to the limbus will image the regions posterior to the equator. In contrast, the more anterior retina and ora serrata can be imaged when the probe is placed close to the fornix, which is a useful orientation to help identify retinal tears.[1] The estimated location imaged is typically labeled as follows: posterior pole (P), posterior to the equator (PE), equator posterior (EP), equator (E), equator anterior (EA), ora serrata (O), and ciliary body (CB).

Longitudinal scans. Longitudinal scans are useful in assessing the anterior-posterior extent of a lesion. This scan orientation is designated by the clock hour being imaged (e.g., L3, L6, L9, L12). The patient looks in the direction of the meridian being imaged, and the probe is placed adjacent to the opposite limbus.

In longitudinal scans, the probe axis is oriented perpendicular to the limbus, with the marker on the probe pointing to the center of the cornea. For example, to image L12, the patient gaze should be directed superiorly. The probe should be placed at the inferior limbus with the probe marker directed superiorly. The corresponding image should show the optic nerve at the bottom and anterior periphery at the top (Fig. 3, top right). Oblique longitudinal orientations can also be used, depending on the location of the lesion of interest.

Axial scans. Axial scans are used to easily assess the posterior pole of the eye. For these scans, the probe is centered on the cornea with the patient in primary gaze. When the probe axis is oriented horizontally, this scan provides a nice view of both the optic nerve and the macula. However, the diagnostic utility of this orientation is limited, as axial scans send the signal directly through the cornea and lens, leading to lower resolution or even artifact in pseudophakic patients.

Macular scans. There are four standard macular scans: HMAC (horizontal), VMAC (vertical), TMAC (transverse), and LMAC (longitudinal). Macular scans are particularly useful in assessing the status of the macula in a retinal detachment.

HMAC is an axial scan with the probe placed on the apex of the cornea and the probe marker placed nasally (3 or 9 o'clock). The macula will be at the center of the scan with the optic nerve just above it (Fig. 3, bottom left).

VMAC is obtained with a similar method but with the probe marker placed at the 12 o'clock meridian. The nerve will not be visible in this scan.

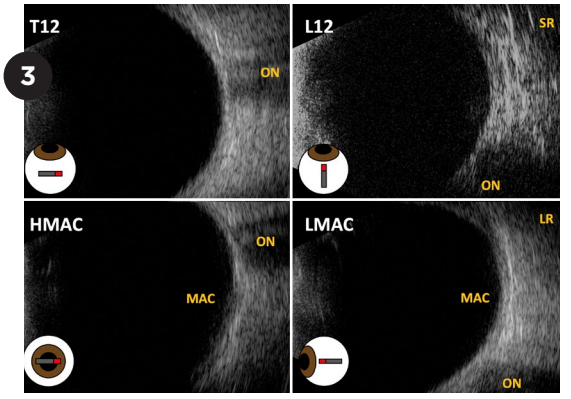
TMAC is obtained by having the patient fixate slightly temporally. The probe is placed on the nasal sclera with the marker pointing to 12 o'clock. The nerve will not be visible in this scan, either. TMAC allows for a vertical scan through the macula while bypassing the lens in order to avoid reverberation artifact.

Finally, LMAC is obtained by having the patient fixate slightly temporally. The probe is placed just posterior to the nasal limbus with the marker pointing temporally (3 or 9 o'clock). The optic nerve will be seen at the bottom of the scan, with the macula in the middle and the lateral rectus muscle seen inserting into the globe at the top of the scan (Fig. 3, bottom right). LMAC provides a horizontal scan through the macula while bypassing the lens.

Steps in Performing a B-Scan

Although the sequence of image acquisition may vary between examiners, it is important to have a consistent approach for all patients. On initial examination, gain should be set to high (80-90 dB) but can be lowered depending on the clinical context. It is also useful to turn on the A-scan overlay, which can aid in interpretation.

Because air is highly reflective on



REPRESENTATIVE SCANS OF RIGHT EYE. *The direction of gaze of the right eye and orientation of the probe marker are shown in the left lower corner of each image. (Top left) Transverse scan taken with patient looking superiorly (T12): the optic nerve (ON) is seen roughly in the center of the fundus. (Top right) Longitudinal scan taken with patient looking superiorly (L12): the optic nerve is seen at the bottom of the image and the superior rectus muscle (SR) is seen coursing through the orbit at the top of the image. (Bottom left) HMAC: the macula (MAC) is located at the center of the fundus with the optic nerve visible just above it. (Bottom right) LMAC: the macula is located at the center of the fundus with the optic nerve below it. The lateral rectus (LR) is seen coursing through the orbit at the top of the image.*

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ultrasound, a coupling agent must be placed on the probe prior to obtaining a scan. Only hydroxypropyl methylcellulose ophthalmic gels should be used as coupling agents, as standard general-purpose ultrasound gels may contain chemicals that could be harmful in direct contact to the eye.[2] In general, B-scan should be obtained directly on the eye (after application of topical anesthetic). Otherwise, it can be difficult for the patient and examiner to confirm the exact position of gaze when the eyes are closed. Additionally, the ultrasound signal is attenuated when passing through eyelid tissue.

The exception to this is in cases of trauma or in pediatric patients, where it is preferred to place the probe over the closed eyelid. In cases of potential globe perforation, even gentle ultrasound should be used with caution, and other imaging modalities such as CT scan should be considered to further evaluate the globe.

Start with a horizontal axial view (i.e., with the patient in primary gaze) to obtain an initial impression of the posterior segment. Then perform transverse scans (as described above) in the following order: superior, inferior, nasal, and temporal. Finally, obtain an LMAC scan.

For certain pathologies, dynamic scans can also be useful to assess tissue movement. To do this, the patient moves their eye back and forth while the examiner visualizes the tissue of interest. This technique is particularly useful in differentiating posterior vitreous detachments, retinal detachments, and choroidal detachments. The distinguishing features of these pathologies will be discussed in Part 2.

1 Silverman RH. *Clin Ophthalmol.* 2016;10:1865-1875.
2 Kendall CJ et al. *Neuroimaging Clin N Am.* 2015; 25(3):327-365.

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