Imaging the Anterior Segment With OCT and UBM

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OPTICAL COHERENCE TOMOGRAPHY

Overview

Since its commercial introduction in 1996, the clinical applications of optical coherence tomography (OCT) have expanded continuously. After nearly a decade of exploration of OCT applications for use in the posterior segment, the first dedicated anterior segment OCT (AS-OCT) system debuted in 2005 (Visante OCT; Carl Zeiss Meditec, Inc.). AS-OCT uses a longer wavelength (approximately 1,300 nm) than posterior segment OCT (approximately 840 nm), which permits deeper penetration and can image from the cornea to the iris in one scan.

Preparation

Because AS-OCT is noncontact, the only preparation required for using the device is to clean the chin and forehead rests with alcohol prep pads and to enter patients' information.

Assessment of the Cornea and Anterior Chamber

The basic type of scan is low-resolution sulcus-to-sulcus, which provides clinicians with a comprehensive view of the entire anterior chamber. I recommend performing not only a single scan of the anterior segment (along one horizontal axis) but also dual (two axes) and quad (four axes) scans. High-resolution scans of the central cornea can also be performed, especially for quantitative assessments such as thickness measurements for LASIK flaps.

The OCT's signal is strongest when the scanning beam hits its target perpendicularly. Look for the center of the corneal surface, where the bright white lines appear horizontally together with a vertical white line (Figure 1). If these lines are not visible—even when the overall image is well aligned—adjust the scanner vertically by moving it slightly higher or lower as the scanning plane slices the target in an oblique fashion.

Assessment of the Angle

I recommend the high-resolution scan for optimal visualization of the anterior segment angle. Ask the patient to look sideways so that the nasal or temporal side of the limbus is fully exposed to the scanner. Because it is nearly impossible to install an effective external fixation light on AS-OCT scanners, you must work with patients to maximize the effect. The goal is to visualize the interface between the sclera and ciliary body as horizontally as possible (Figure 2). Because the scleral spur defines one end of the trabecular meshwork, the subjective assessment of the angle's opening totally relies on its location. To maximize the visibility of the scleral spur, ensure that the scanning beam hits the limbus' surface as perpendicularly as possible.

Sometimes, the Visante's image preview screen shows a distorted cornea no matter how you adjust

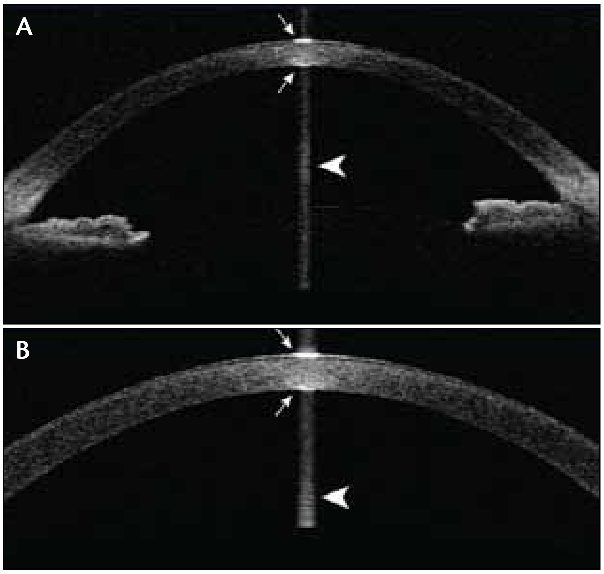

Figure 1. A low-resolution sulcus-to-sulcus AS-OCT scan (A) and a high-resolution scan of the central cornea (B). The two parallel bright white lines on the central cornea (white arrows) on both images indicate that the scanning beam is hitting the corneal surface perpendicularly. A vertical white line (arrowhead) is a reverberation artifact, another indication of the perpendicular incident angle.

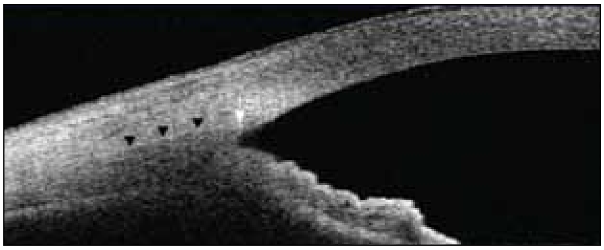

Figure 2. An AS-OCT scan of the anterior chamber angle. To make the angle structure clearly visible, the operator images the interface between the sclera and ciliary body (black arrowheads) as horizontally as possible by asking the patient to look sideways. The scleral spur (white arrow) is an important reference landmark in the angle, because it is where the trabecular meshwork starts.

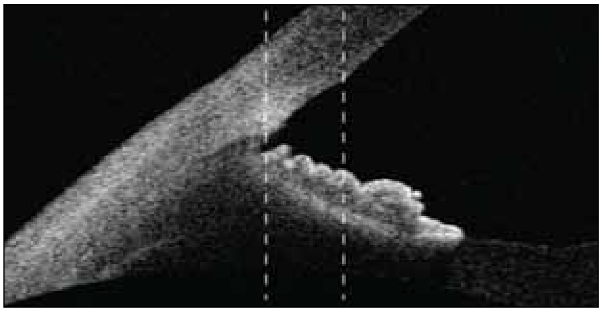

Figure 3. Changing the incident angle distorts the image of the anterior chamber angle of the same eye seen in Figure 2. The internal fixation target was used for this scan. Note that the angle appears much wider than in Figure 2 and that the corneal curvature between the two dashed lines is distorted.

the scanning location and angle (Figure 3). This is because the device's image-visualization engine is optimized for scanning the cornea instead of the angle, but you can still subjectively assess narrow-angle conditions. If angle occludability is the only clinical question, I suggest ignoring the distortion, but I do not recommend making a quantitative assessment of distorted images.

Spectral-Domain OCT

The software of two commercial posterior segment spectral-domain OCT (SD-OCT) devices (RTVue [Optovue Inc.] and Cirrus HD-OCT [Carl Zeiss Meditec, Inc.]) was recently upgraded to include imaging of the anterior segment. These all-in-one OCT systems image both the anterior and posterior segments. Moreover, they bring the benefits of SD-OCT technology to anterior segment imaging, namely faster scanning (26 kHz) and a higher axial resolution (approximately 5 µm). High resolution makes it possible for you to visualize not only the trabecular meshwork but also Schlemm canal (Figure 4). Despite the differences in OCT engines, you can directly apply the scanning techniques described earlier to scanning the anterior segment with SD-OCT. Because the wavelength of SD-OCT's light source is optimized for scanning the posterior segment, however, only the surface of the iris can be visualized (Figure 4).

ULTRASOUND BIOMICROSCOPY

Overview

In 1991, Pavlin et al introduced ultrasound biomicroscopy (UBM), a clinical application of high-frequency ultrasound. UBM uses a higher range of frequency (50-100 MHz) than conventional ultrasound (5-20 MHz), achieving a higher axial resolution (approximately 25 µm). Since its inception, UBM dominated the field of anterior segment imaging until 2005, when the first commercial AS-OCT unit was introduced.

Preparation

Most UBM devices use balloon-like disposable probe covers, which contain distilled water that serves as a coupling medium between a UBM probe and the eye (Figure 5A). Unlike the conventional plastic eyecup system, the probe cover system allows patients to be scanned in a variety of postures—supine, sitting, and even prone. For maximum maneuverability and probe stability, choose the supine position.

Do not completely fill the probe cover with distilled water. The balloon should look a bit saggy so that you can minimize the pressure on the eye when applying the probe to the corneal surface (Figure 5B and 5C).

After instilling an anesthetic drop, place the little finger of the hand holding the probe on the lower eyelid, and place the thumb or middle finger of your other hand on the upper eyelid (Figure 6). With one smooth synchronized rotating motion of both hands, gently place the probe (covered by a water-filled balloon) on the cornea while applying gentle but firm

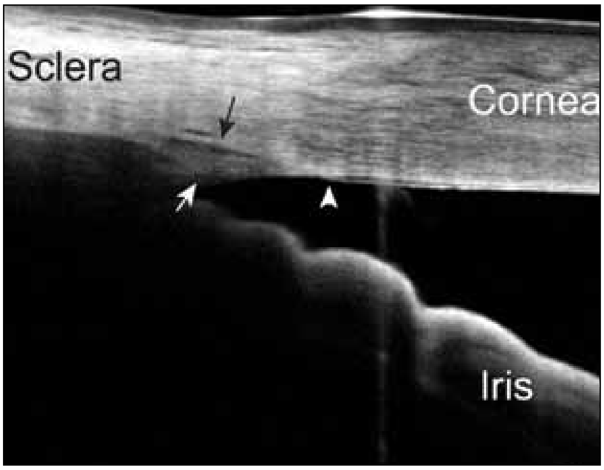

Figure 4. The high resolution of the RTVue allows visualization of the scleral spur (white arrow), Schwalbe line (white arrowhead), and Schlemm canal (black arrow). Due to poor penetration, however, only the surface of the iris can be seen.

Figure 5. The probe cover should not be fully filled with water to avoid the application of unnecessary pressure on the cornea (A). The anterior chamber angle image with no pressure applied to the cornea (B). Scan of the eye with a fully filled probe cover (C). Note that the angle is artificially widened (arrow) due to pressure on the cornea.

tension on both the upper and lower eyelids. Finally, place the index finger of the hand holding the upper eyelid to the side of the probe above the balloon. This way, the hand that is holding the probe rests rigidly on the patient's cheek, and you can control the probe with a delicate but precise motion with support from the index finger of the other hand. This method also gives you a sense of the probe's location in three-dimensional space, which is useful when you are performing UBM in a dark room (dark room provocative test for angle-closure glaucoma).

Probe Handling

The UBM probe is held freely in three-dimensional space, which makes it challenging for you to master 6 degrees of freedom (Figure 7). I always ask beginners to scan a plastic model eye to get a feel of each degree of freedom one by one. Use forward-back and left-right movements for coarse registration of the region of interest (ROI) in the center of the viewing screen. Adjust up-down for the vertical location of the ROI within the viewing screen. Up-down is the key movement to keep the ROI in focus. The focal plane is perpendicular to the scanning beam. Think of this as a horizontal band in the viewing screen. After registering the ROI to the optimal scanning location, use the other 3 degrees of freedom (pitch, yaw, and roll) to fine-tune the angle to be scanned to the ROI.

Scanning for Glaucoma Assessment

It is essential to provide clear images of the anterior chamber angle at any location in a uniform way so that the physician can easily compare one image to another. I recommend placing the scleral side on the left of the screen and the corneal side on the right (Figure 8). Ask the patient to look away from the ROI so that the angle in question is fully exposed to the probe. For example, if you want to scan the temporal angle (9 o'clock for the right eye), ask the patient to look to the nasal side (look to the left when the right eye is scanned). Alternatively, to scan the 1-o'clock region, ask the patient to look in the direction of 7 o'clock.

Scanning Tips

As with OCT, UBM also generates the strongest signal when the scanning beam hits its target perpendicularly. You therefore must carefully choose an incident angle depending on the structure of focus. For narrow angle cases, focus on the angle's structure, especially on the trabecular meshwork. Try imaging the cornea as horizontally as possible so that the scleral spur and Schwalbe line are visible (Figure 8B). On the other hand, for a case in which a tube is implanted behind

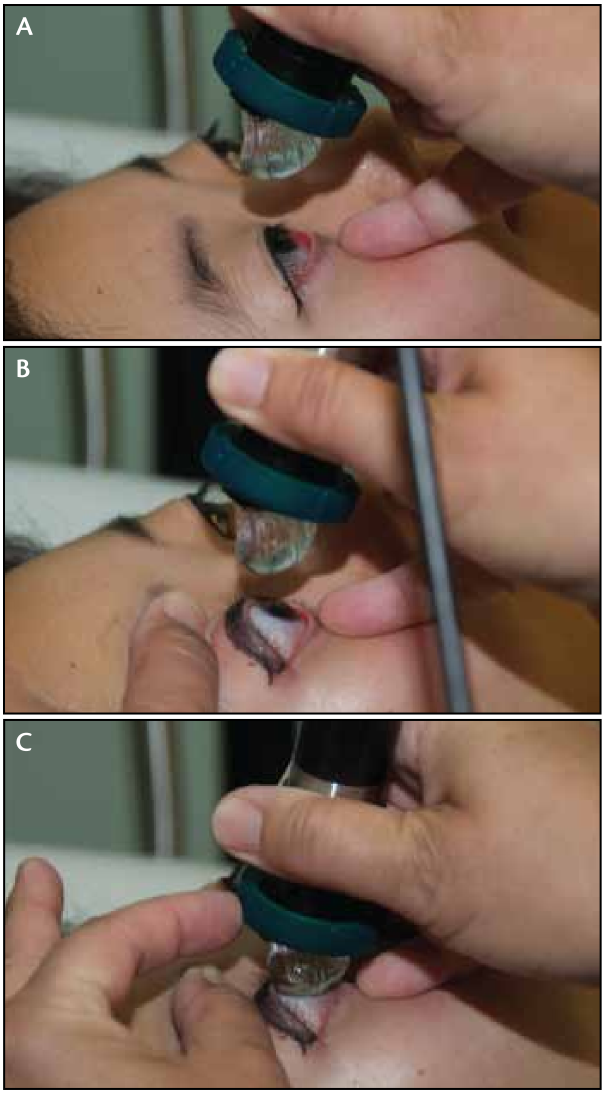

Figure 6. To handle the probe, the operator pulls down the lower eyelid with his or her little finger (A), retracts the upper eyelid with either his or her thumb or middle finger (B), and after touching the probe to the cornea, uses his or her index finger to delicately control the probe (C).

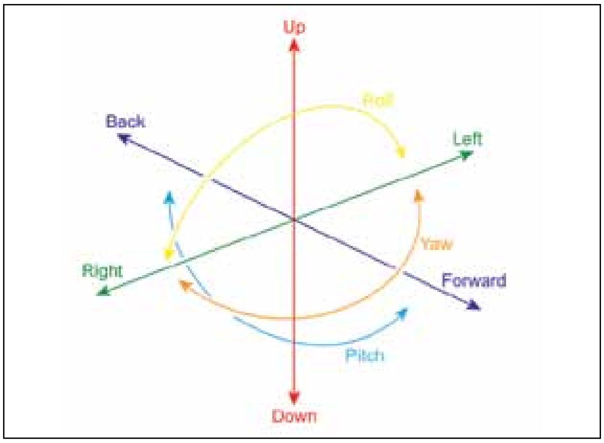

Figure 7. There are 6 degrees of freedom in the motion of a probe in three-dimensional space, namely the ability to move forward-backward, up-down, and left-right (translation in three perpendicular axes) combined with rotation in about three perpendicular axes (pitch, yaw, roll).

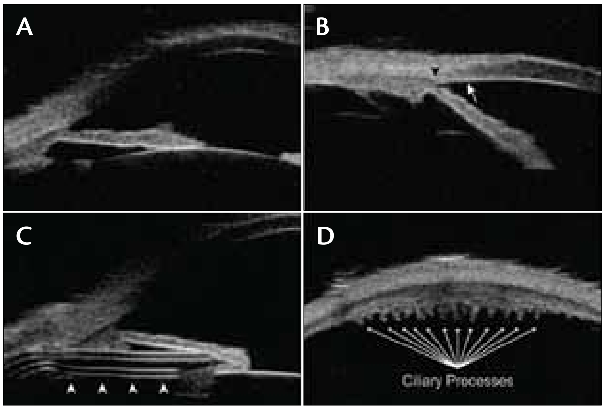

Figure 8. Sample UBM scans. On the iris, the borders of the iris, the surface of the lens, and the central cornea show high echogenicity where the structure is perpendicular to the scanning beam (A). In an optimized scan of the incident angle, the scleral spur (black arrowhead) and Schwalbe line (white arrow), which define both ends of the trabecular meshwork, are visible (B). The operator visualizes the entire length of a tube implanted behind the iris within the scanning window by placing the tube perpendicular to the scanning beam (C). Slicing parallel to the limbus reveals a group of ciliary processes in pars plicata (D).

the iris, image the iris as horizontally as possible so that the tube can be seen in full length within the scanning window (Figure 8C).

Scanning for Other Pathologies

UBM can also be used to assess tumors and cysts. Most cases require size and extent measurements. To demonstrate three-dimensional extent, image a longitudinal (parallel to the limbus) slice through the lesion in addition to a regular transverse (radial) slice. On healthy eyes, a group of ciliary processes can be visualized through the width of the scanning window on successful longitudinal scans (Figure 8D). ■