ULTRASOUND BIOMICROSCOPY FOR OPHTHALMOLOGY– AN OVERVIEW

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ABSTRACT

BACKGROUND

Ultrasound biomicroscopy (UBM) is a non-invasive procedure to visualise the structures of the anterior segment using high frequency ultrasound. Any abnormalities in the structures like the iris, ciliary body and zonules can be easily detected. In case of corneal oedema, the Descemet's membrane can be detected with UBM than the slit-lamp biomicroscopy. It plays a useful diagnostic tool in glaucoma. It differentiates between open and closed angle closure. It also helps in the diagnosis of plateau iris configuration and malignant glaucoma. Bleb status and tenon's cyst can be visualized by the UBM. It plays a major role to rule out angle recession or cyclodialysis cleft in cases of trauma. Zonular dialysis and iridodialysis as well as the integrity of the posterior capsule can be assessed with UBM. It is the only modality which can easily diagnose pars plannits or cyclitic membranes noninvasively. In cases of unexplained hypotony, it helps to diagnose ciliary body atrophy or traction on the ciliary body. This article is a short overview describing the indications and uses of anterior segment pathologies.

KEYWORDS

UBM, Ciliary Body Tumour, Iridodialysis, Glaucoma.

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BACKGROUND

Advances in the field of technology has led to develop an ideal imaging device that can visualise minute ocular structures in detail with perfect contrast in real time.

Ultrasound bio-microscopy (UBM) is a new imaging technique that uses high frequency ultrasound to produce images of the eye at near microscopic resolution. UBM provides high-resolution in vivo imaging of the anterior segment in a non-invasive fashion and can scan through opaque media. The tissues such as the cornea, iris, and sclera commonly seen using conventional methods (i.e. slit lamp method), as well as the structures including the ciliary body and zonule, previously hidden from clinical observation, can be imaged and their morphology assessed using the UBM.[1-3] Additionally, pathophysiological changes involving anterior segment architecture can also be evaluated qualitatively and quantitatively.

This paper describes the clinical applications of Ultrasound Biomicroscopy in Ophthalmology.

REVIEW OF LITERATURE

Technology- Ophthalmic ultrasound imaging is based on the emission of an acoustic pulse and reception of the pulse after it has been reflected off ocular tissues. It has been used in the form of A and B-scans for many decades. The use of a higher frequency transducer allows for a more detailed assessment of the anterior ocular structures than was available using traditional B-scan ultrasound. Although the resolution of the images are increased but the depth of penetration (to only 5 mm) is decreased. Lateral and axial resolutions are estimated to be 40 and 20 microns, respectively.

Ultrasound biomicroscopy (UBM) is a non-invasive technique used to visualize the anterior segment with the help of high frequency ultrasound transducer.[1] The anterior segment has a depth of 4-5 mm and the structures are close to each other so we require a higher frequency probe.[1] UBM (anterior segment ultrasonography) is performed with a 35 and 50 MHz probe. The resolution of 50 MHz probe is 40 microns and the depth of penetration is 4 mm.

History- Mundt and Hughes.[2] (A-scan) and Baum and Greenwood.[3] (B-scan) in the 1950s were the founders for use of ultrasound for diagnostic purposes in the eye.[4] The pioneer in the work for development of UBM goes to Dr. Charles Pavlin and Prof. Stuart Foster in 1989.[1] They developed three probes-50, 80, and 100 MHz for clinical trials and finally reached to a conclusion that a 50 MHz is an ideal compromise between depth and resolution to visualize the entire anterior segment.[1] Coleman et al. independently developed a UBM system emphasizing the processing of raw radiofrequency echo data acquired in sequential planes suitable for 3-D analysis, especially corneal biometric analysis.[5]

Technique- UBM is done with the patient in the supine position with the eye wide open. Since the piezoelectric

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crystal of the transducer is open and to prevent cornea injury, it should not come in direct contact with the eye. There is a special cup which fits in between the eyelids, to keep them open. The eye cup is filled with saline or sterile methylcellulose. The crystal of the transducer is placed in saline. This helps the transducer to remain approximately 2 mm. from the ocular surface thus prevents injury to the cornea and also helps as a fluid standoff. The eye is scanned in each clock hour from the centre of the cornea to the ora serrata.

NORMAL ANATOMY

Images produced by UBM are similar to the images produced under low power microscope with a resolution of 40 microns. The different ocular structures imaged from outer to inner are as follows:

a) Cornea- This is the first structure viewed on UBM. The layers of the cornea are well-differentiated. The first dense echogenic structure is the Bowman's membrane. The adjoining low, irregular reflective area is the stroma. Descemet's membrane is seen as a dense highly reflective line. Finally, the corneo-scleral junction can be differentiated because of the lower internal reflectivity of the cornea compared to the sclera.[1] (Figure 1)

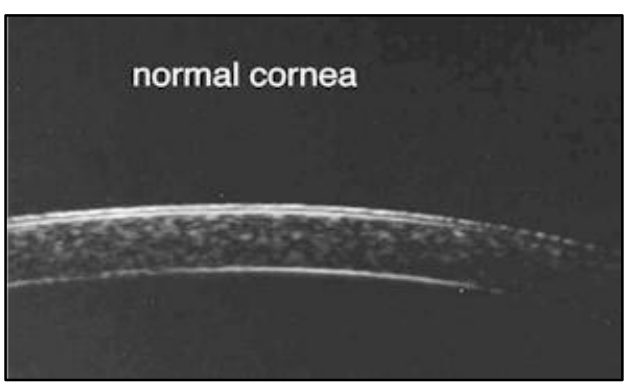

Figure 1. Cornea is the First Reflective Line Viewed by UBM

The next is Bowman's membrane. The distance between these two lines is the thickness of the corneal epithelium. The third reflective inner structure is the Descemet's/endothelium. The low reflective between the first and third line comprises the stroma.

b) Anterior Chamber (AC)- is seen as a low echogenic space between the cornea and the iris. Measurement of the AC is done from the posterior surface of the cornea to the anterior capsule. The normal AC depth is 2.5-3.0 mm.

c) Iris- is seen as a flat uniform echogenic area. The morphology of the iris and ciliary body which converge in the iris recess and finally insert into the scleral spur can be viewed in detail.[1] The area under the peripheral iris and above the ciliary processes is defined as the ciliary sulcus. The natural profile of the iris is straight in contrast to anterior bowing in pupillary block glaucoma and posterior bowing in pigment dispersion glaucoma.[1,6]

d) Angle of Anterior Chamber can be studied in a cross-section by orienting the probe in a radial fashion at the limbus. The most important landmark in the angle on UBM is the sclera spur. The scleral spur is seen as small echogenic dot when the line between the sclera and ciliary body is traced to the AC. The ciliary body can be clearly defined by UBM from the ciliary processes to the pars plana. The ciliary processes vary in appearances and configuration. The axial view of the ciliary processes is seen when taking a section of the angle. A transverse section through the ciliary processes helps to assess the individual processes better. The posterior ciliary body tapers off toward the para plana.[1,4] (Figure-2)

e) Anterior Zonular Surface can be consistently imaged by UBM. The zonules are seen as a medium reflective line extending from the ciliary processes to the lens surface.[1]

f) Peripheral retina and Pars Plana region can be visualized as far peripherally as the probe can be moved before eyecup prevents the movement of the transducer. The retina in this region is thin and generally is imaged as a single line that cannot be differentiated from the retinal pigment epithelium unless detached. The composite image of the anterior segment on UBM can be seen as a transverse section between one ora serrata to opposite oraserrata.[1,4,7]

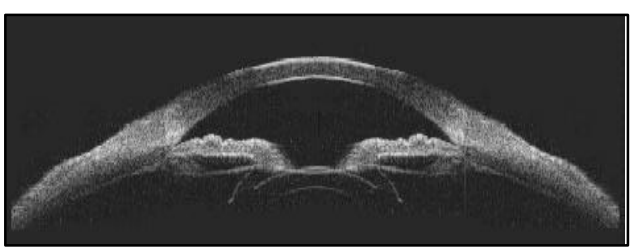

Figure 2. Composite Picture of the Anterior Chamber

Clinical Applications of UBM in various Ocular diseases

a) Glaucoma

The initial use of UBM started with the study of the angle structures. The exact configuration of the iris, ciliary body, and processes can be defined even in the presence of an opaque media. The angle can be quantified and the values can be followed up after treatment. It plays an important role in narrow angle glaucoma. The pathophysiology of narrow angle glaucoma can be well studied by identifying the four anatomical sites such as the iris (pupillary block), ciliary body (plateau iris), the lens (phacomorphic glaucoma) and the forces behind the lens. Pavlin et al[7] examined the anterior segment in glaucoma. The iris bombe pattern, the anterior displacement of the ciliary body and the posterior concavity of the iris helps to differentiate the types of glaucoma. (Figure 3, 4).

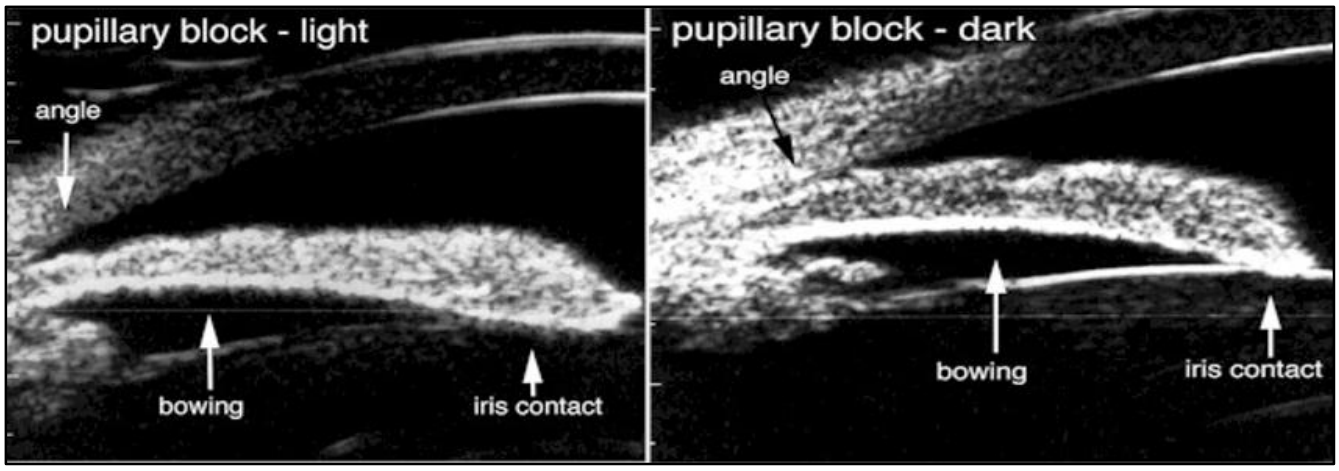

Figure 3, 4. Dilation of the Pupil Produces Angle Narrowing in Eyes with Pupillary Block by a Combination of Iris Thickening, and Anterior Iris Displacement as the Iris Tip Moves Towards the Root.[1]

UBM is a useful tool in guidance and evaluation in glaucoma surgery.[8] including evaluation of the bleb and Schlemm's canal in procedures such as deep sclerectomy and canaloplasty.[8-10] Ishikawa, Liebman and Ritch described further criteria in 2000, especially numeric descriptors of angle geometry.[11] These criteria are of importance in allowing definition of reproducible criteria for characterizing different glaucoma types. Marchini.[12,13] for instance, used UBM to biometrically compare different forms of angle closure glaucoma, and Sihota et al.[14] applied these criteria for comparing subtypes of primary angle closure glaucoma.

b) Uveitis- UBM is helpful in the study of anterior uveitis. The presence of pars planitis, supraciliary effusion, cyclitic membranes, and ciliary body detachments can be visualized on UBM.[1,7]

c) Trauma- Anterior segment trauma is usually associated with hyphema. In presence of hyphema, it is difficult to visualize the iris and lens. UBM is helpful to study the position of the lens, the status of the iris, ciliary body, and the configuration of the angle. Angle recession and cyclodialysis cleft can be evaluated on UBM.[1]

d) Opaque Media- In presence of dense corneal opacity, UBM is helpful to study the anatomy of the anterior segment before surgical intervention.[1] (Figure-5)

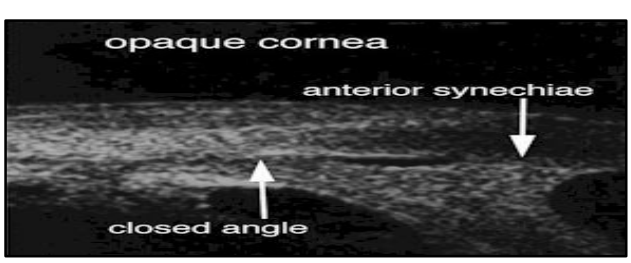

Figure 5. The State of the Anterior Chamber below Opaque Grafts can be Assessed, Including the State of the Angle, Anterior Synechiae and IOL Position

e) Tumours- Tumours of the anterior segment can be detected by UBM. This also helps to identify the extent and dimensions of the tumour. It helps to quantify the characteristics of the tumour.[1]

f) Scleritis- UBM helps to differentiate scleritis from episcleritis and also helps to differentiate the various types of scleritis, mainly the necrotizing types. It is also helpful to study the extent of scleritis and to rule out the involvement of the ciliary body and choroid.[1]

Different Clinical Scenario with UBM

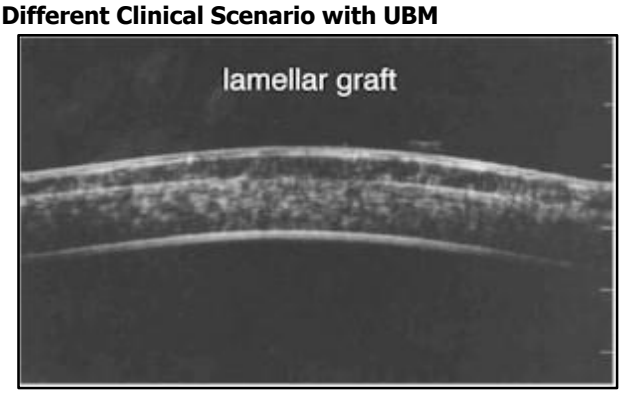

Figure 6. The Depth of the Lamellae in the Stroma can be Imaged, along with Abnormalities at the Interface Such as Epithelial in-Growth

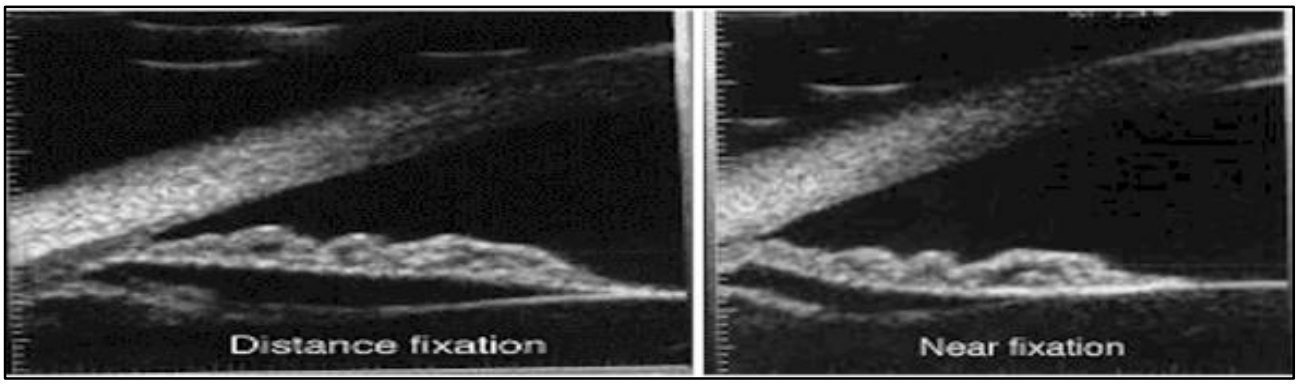

Figure 7 and 8. Angle Variation in Different Fixation Distance

The anterior chamber depth can be quantified with the help of UBM. This is useful in different types of glaucoma. The standard measurements include the angle opening distance (AOD), the perpendicular distance between the trabecular meshwork at a point 500 um anterior to the scleral spur, and the iris.[14]

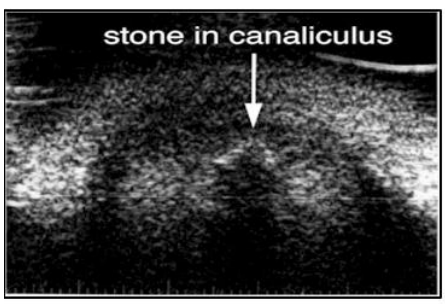

Figure 9. Detection of Stone in the Canaliculus

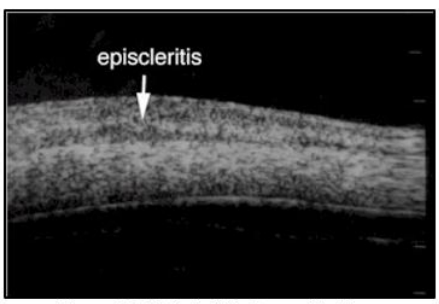

Figure 10. Episcleritis Generally Shows Thickening of the Episcleral Tissues without Involvement of the Sclera Itself

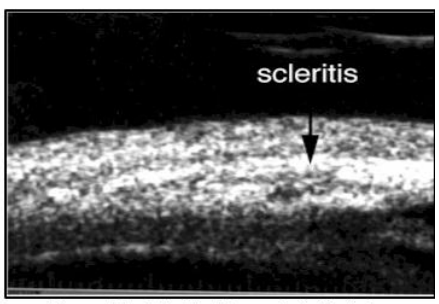

Figure 11. Scleritis Shows Relatively Low Reflective Regions within the Sclera Likely Representing Oedema and Inflammatory Infiltrates

IRIS

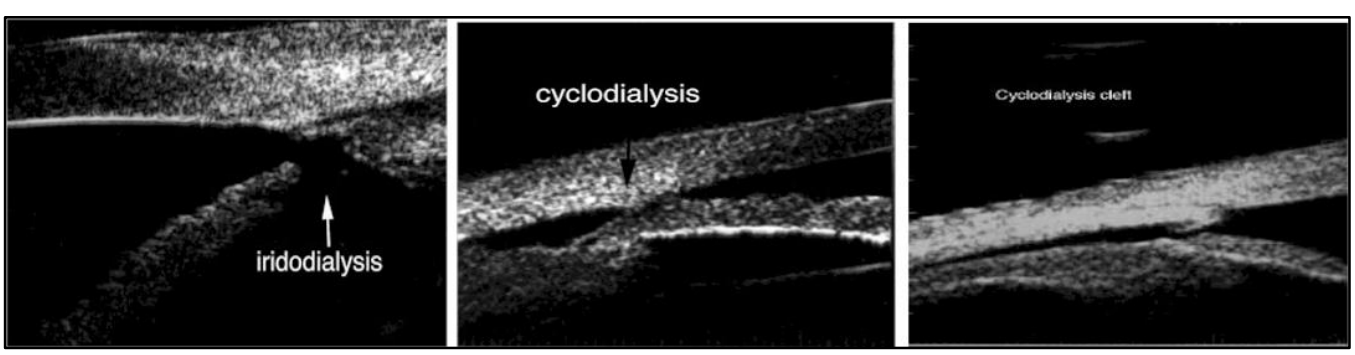

Figure 12, 13 and 14. UBM defines the Presence and Location of clefts very accurately. Clefts are usually Accompanied by 360 Degrees of Supraciliary Fluid.[1,8]

Zonules

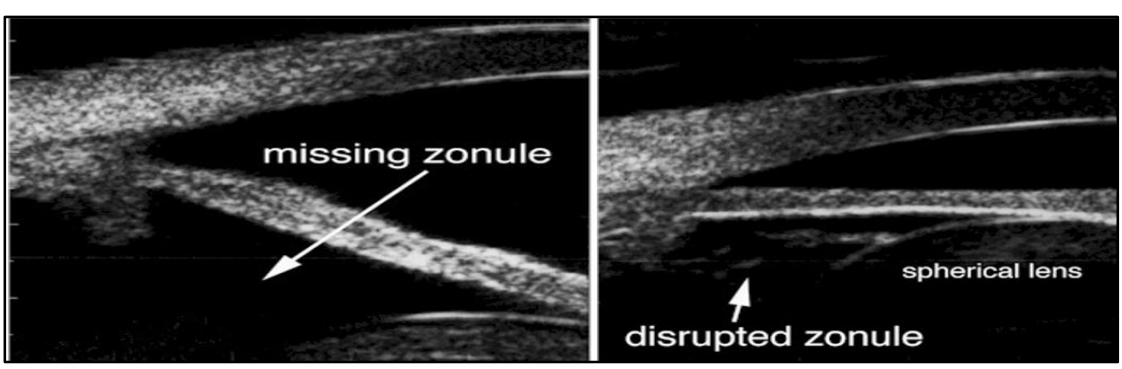

Figure 15 and 16. The Anterior Zonule Can Normally be Clearly Imaged. Disruption will Result in Absent Zonules, Increased Lens Sphericity, and Increased Distance of the Lens Margin from the Ciliary body Source.[1,15]

Tumor

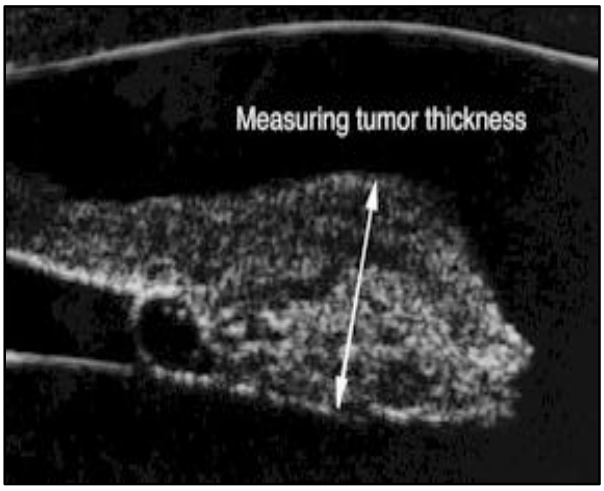

Figure 17. UBM adds the Element of Depth to the Assessment and follow up of Anterior Segment Tumours Technique is Similar to Measuring Posterior Segment Tumours i.e. Freeze an Image that Passes Perpendicularly through the Greatest Thickness of the Tumour, and use the Callipers to Measure the Greatest Thickness Relative to the long Axis of the Tumour.[16]

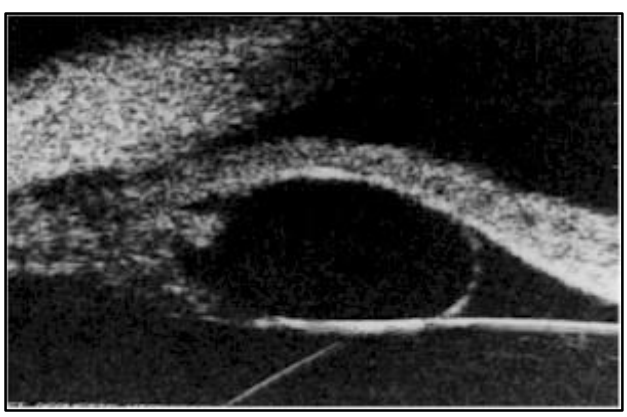

Figure 18. The Most Common Clinical Presentation of an Irido-Ciliary Cyst is a Peripheral Iris Elevation - the Typical UBM finding of a Thin Walled Structure with no Internal Reflectivity is Diagnostic.[1,7]

UBM	AS-OCT
Ultrasound	Infrared
50 MHZ	1310 nm
Gel/water bath	Non-contact
Cannot be used in perforated injuries	Can be used
Skilled operator	Skilled operator not required
Can be used for visualizing ciliary body and plateau iris	Cannot be used
Inexpensive	Very expensive

Table 1. Difference between UBM and Anterior Segment Optical Coherence Tomography (AS-OCT)

Limitations

Depth is one of the most important limitations of UBM. The structures deeper than 4 mm from the surface cannot be visualized by UBM. The other limitation of UBM is that it cannot be performed in presence of an open corneal or sclera wound.

CONCLUSION

Anterior segment diseases are well visualized by direct examination techniques. UBM plays a role in specific conditions. In cases of scleritis, it helps in differentiation of scleritis from episcleritis and helps in early detection of scleral necrosis.

In anterior segment tumours and tumor-like conditions, UBM helps to study the depth of the lesion and to delineate the layer of origin of tumor. This further helps in treatment planning of the patients. In glaucoma, it plays a role in differentiating various types of angle closure glaucoma and postoperative evaluation. In trauma, it helps to determine the extent of trauma to different anterior segment structure.

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