The advent of the ultrasound biomicroscope (UBM) has made high resolution imaging of the anterior segment possible, permitting reproducible imaging of the cross-sectional anterior chamber angle anatomy. This article gives an outline of normal anatomy, technique of UBM and reviews the various applications of the UBM for glaucoma and illustrates how it can be a useful tool in the management of various conditions.

**Keywords:** Anterior chamber angle, Gonioscopy, Ultrasound biomicroscopy.
Image Acquisition

In the Paradigm Instruments UBM, the probe is suspended from a gantry arm to minimize motion artifacts. Images are acquired with the patient lying supine (Fig. 1). Room illumination, fixation, and accommodative effort affect anterior segment anatomy and should be held constant, particularly when quantitative information is being gathered.

In the OTI (Ophthalmic Technologies, Toronto, Canada) device, the probe is small and light enough not to require a suspension arm. Scanning is performed with the patient in the supine position. A plastic eye cup of the appropriate size is inserted between the lids, holding methylcellulose or normal saline coupling medium (Figs 2 and 3).

This is uncomfortable and may potentially distort the eye anatomy and angle configuration. This requirement of globe contact renders this instrument minimally invasive and may make it impractical for many clinical situations, such as perforating ocular injuries or infective corneal perforations. In addition, a highly skilled operator is needed to obtain high quality images, and the learning curve of the technique is fairly steep. Also this is one technique, where it is preferable and at times may be mandatory for the treating physician to do the procedure himself, since it is imperative to image precisely the area of interest. The high magnification renders general scanning of little use. To maximize the detection of the reflected signal, the transducer should be oriented so that the scanning ultrasound beam strikes the target surface perpendicularly.

Clinical Applications

Before studying any imaging technique for disease pathology, it is important to know, what the normal eye looks like. The normal anterior segment can be imaged very well with the UBM and is illustrated below.

Cornea

For imaging the cornea from anterior to posterior (Fig. 4), the first echogenic line structure is the corneal epithelium (a). The next is the Bowman’s membrane (b). The stroma is minimally echogenic (c) and is then followed by another echogenic structure— the Descemet’s membrane (d).

The Normal Angle of the Anterior Chamber

The normal angle of the anterior chamber (Fig. 5) is seen as the junction between the cornea and sclera, where the iris root inserts into the ciliary body. The sclera is normally not as echoluscent as the cornea owing to the irregular arrangement of the collagen fibers. The junction between the cornea and sclera marks the anterior schwalbe’s line (a). The anterior-most part of the junction between the sclera and the ciliary body band is the scleral spur (b). Identification of the scleral spur is critical to angle assessment using the UBM. The scleral spur is the only
constant landmark allowing one to interpret UBM images in terms of the morphologic status of the anterior chamber angle and is the key for analyzing angle pathology. The area between the scleral spur and the anterior schwalbe’s line is the region identified as the trabecular meshwork (c) on the UBM.

Generally, in the normal eye, the iris has a roughly planar configuration with slight anterior bowing, and the anterior chamber angle is wide and clear. However, morphology of the anterior segment structures alter in response to a variety of physiologic stimuli such as accommodation and lighting. It is important to maintain a constant testing environment critical for longitudinal comparison.

**UBM in Glaucoma**

The major applications of the UBM in glaucoma can be summarized under the following headings:

1. Angle measurement-quantifying the angle
2. Pathophysiology of angle closure
   a. Pupillary block glaucoma
   b. Plateau iris
3. Pigmentary glaucoma
4. Pseudoxefoliation
5. Goniodysgenesis
6. ICE syndrome
7. Ocular trauma
   a. Angle recession
   b. Iridodialysis
   c. Cycloidalysis clefts
   d. Occult foreign bodies

**Angle Assessment**

UBM measurement of the angle structures may be influenced by variation in physiological variability. Failure to control accommodation and room illumination can alter the findings when using UBM. Direction of gaze can be standardized by placing markers on the ceiling to optimize orientation of the eye when measuring different quadrants. Other sources of variability are more difficult to control and this technique of angle assessment is inherently subjective in nature.

**Quantifying the Angle**

It is possible to use the UBM to quantify the width of the angle. It is important to understand some concepts of measurement inherent to the machine properties.

**Angle Measurement**

Pavlin et al. established various quantitative measurement parameters as standards (Fig. 6). The position of the scleral spur is used as a reference point for most of their parameters, because this is the only landmark that can be distinguished consistently in the anterior chamber angle region.

a. The angle-opening-distance (AOD): This is defined as the distance from the corneal endothelium to the anterior iris, perpendicular to a line drawn along the trabecular meshwork (TM), at a given distance from the scleral spur. This is measured at 250 μ (AOD 250), which consistently falls on the trabecular meshwork and 500 μ (AOD 500) from the scleral spur, which measures the angle opening anterior to the trabecular meshwork. The AOD reflects the amount of relative pupillary block in patients with occludable angles. The AOD 250 is a measure of the angle opening at the level of the posterior trabecular meshwork. AOD 500 is a measure of the angle opening at the level of the anterior Schwalbe’s line.

b. The Trabecular-ciliary process distance (TCPD): This is measured from a point on the trabecular meshwork, 500 μ anterior to the scleral spur, extended perpendicularly through the iris to the ciliary process. The TCPD defines the port through, which the iris must traverse and has implications as to the potential maximal angle opening, and defines the space available between the trabecular meshwork and ciliary process. It is a typical feature in an individual eye. It is the sum of three segments: the angle opening 500μ from the scleral spur, the thickness of the iris at that point, and the width of the ciliary sulcus. An anteriorly placed
The ciliary process can reduce the peripheral anterior chamber depth and make it susceptible to occlusion.

In a comparative study between UBM and gonioscopy, excellent correlation was found between gonioscopically quantified angles and those quantified by the UBM. There is actually no role of the UBM in quantifying the angle for diagnosing angle closure, but it is of immense help in qualifying the cause of a narrow angle.

**Pathophysiology of Angle Closure**

**Pupillary Block Glaucoma**

Relative pupillary block (Figs 7A and B) with aqueous pooling behind the iris can be easily recognized on the UBM. Laser iridotomy is the treatment of choice and adequacy of treatment can be confirmed easily by UBM.5-8

**Plateau Iris**

This entity is often difficult to diagnose clinically. The typical gonioscopic features include a comparatively flat iris plane compared to an obvious convexity in pupillary block, and a sharp drop-off of the iris in the periphery. Confirmatory signs include the “double hump” sign on indentation due to a prominent ciliary processes abutting the periphery of the iris against the trabecular meshwork. Often a plateau iris (Figs 8A to C) is suspected, when there is a persistency of symptoms or raised pressures despite a successful iridotomy. This entity can be beautifully diagnosed by UBM.9

In these cases, appropriate treatment is a laser peripheral iridoplasty. The UBM can show adequacy of treatment by demonstrating that the peripheral iris has been pulled away from the trabecular meshwork by the laser contraction burns.

**Angle-closure with Iridociliary Cysts**

Isolated iridociliary cysts are an uncommon cause of angle closure (Fig. 9). However, they must be suspected especially in young patients with closed angles and no other explainable cause. UBM is probably the only investigation, which can demonstrate them objectively.10

**Pigmentary Glaucoma**

Pigmentary glaucoma is now recognized to be caused by a concave iris configuration resulting in a “reverse pupillary block”, where the aqueous dams in from of the iris.11 This causes the iris to rub against the ciliary processes and zonules (Fig. 10A), resulting in pigment dispersion all over the anterior segment including the anterior lens surface, corneal endothelium and trabecular meshwork. With time, this pigment clogs the trabecular meshwork and causes raised pressures and eventually optic nerve head damage. Laser peripheral iridotomy serves to reverse this pathology and the iris flattens, thus relieving the reverse pupillary block (Fig. 10B).12
Pseudoexfoliation

Pseudoexfoliation is commonly thought to be a cause of secondary open-angle glaucoma. However, in certain situations, there may be angles may be closed. The broken zonules cause the lens to become more spherical and move forward (Fig. 11). In this condition, it leads to a secondary angle closure. Usually, by this time, there is significant cataract, and cataract removal would solve the problem. However, in case the lens is clear, a laser iridotomy works very well.

Goniodysgenesis

Goniodysgenesis was also known as mesodermal dysgenesis or anterior segment cleavage syndromes. Current terminology groups these disorders into the spectrum of the Axenfeld-Reiger anomaly. The common features are multiple iris processes, and higher insertion of the iris signifying improper recession of the iris during angle development (Figs 12A and B).

Iridocorneal Endothelial (ICE) Syndrome

This group of entities comprising Chandler’s syndrome, Cogen Reese syndrome and essential iris atrophy is characterized by a membrane, which grows on to the iris from the corneal endothelium, hence its name. The characteristic features include broad-based peripheral anterior synechiae, but the angle underlying is normal (Fig. 13).

Ocular Trauma

Angle Recession and Iridodialysis

A tear between the longitudinal and circular ciliary muscle can be easily demonstrated on the UBM. Likewise iridodialysis or separation of the iris from its root can be recognized (Fig. 14).

Cyclodialysis Clefts

Cyclodialysis clefts may be the cause of unexplained hypton following trauma. Often difficult to ascertain with gonioscopy, they may be detected by careful examination by the UBM. (Fig. 15).13
Occult Foreign Bodies

Foreign bodies lodged in the iris or ciliary body area can be extremely difficult to localize. The UBM can aid immensely by precisely localizing them to enable their removal with certainty (Fig. 16).14-16

Ciliochoroidal Detachment

Ciliochoroidal detachment can result in unexplained postoperative hypotony, which may remain undetected by conventional methods of investigations. The UBM, by imaging anterior to the pars p Alan a can pinpoint the cause easily (Fig. 17).

CONCLUSIONS

Ultrasound biomicroscopy technology has become an indispensable tool in qualitative and quantitative assessment of the anterior segment. It has clarified concepts in the pathophysiology of diseases such as pigment dispersion, plateau iris and pseudoexfoliation glaucoma. Future advancements including incorporation of doppler technology may further enhance the utility of the device in quantitative assessment of the anterior segment.

REFERENCES