Brief overview about Ultrasound Biomicroscopy use after Pars Plana Vitrectomy

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Abstract

Background: Pars plana vitrectomy (PPV) is a surgical technique originally introduced by Robert Machemer in 1971. The pars plana approach to the vitreous cavity allows access to the posterior segment to treat many vitreoretinal diseases. A successful vitrectomy can restore vision and improve the quality of life in patients suffering from many vitreoretinal diseases. However, the procedure can also be associated with complications. Although the chances are low when performed correctly, these complications can cause severe patient morbidity and blindness. Therefore, it is essential that clinicians have thorough knowledge regarding the topic, understand the procedure, when to use it, how to perform it, and post-operative management. A silicone oil (SO) is any liquid polymerized siloxane with organic side chains. The most important member is polydimethylsiloxane. These polymers are of commercial interest because of their relatively high thermal stability, lubricating, and dielectric properties. Ultrasound biomicroscopy (UBM) was first developed by Pavlin's group in Canada over 30 years ago. Instead of using the 10 MHz most widely used in ophthalmic diagnostic ultrasound, UBM uses ultrasound frequencies in the 50 to 100 MHz range, allowing examination of living subsurface ocular tissues at very high resolution**.** UBM has found widespread usage as a method of imaging much ocular pathology, from adnexal, conjunctiva, scleral, corneal, anterior chamber to anterior vitreous and retina. However, its major contribution has been to the understanding of the structure of the anterior segment, particularly in glaucoma.

Keywords: Ultrasound Biomicroscopy, Pars Plana Vitrectomy

Introduction

Pars plana vitrectomy (PPV) is a surgical technique originally introduced by Robert Machemer in 1971. The pars plana approach to the vitreous cavity allows access to the posterior segment to treat many vitreoretinal diseases. A successful vitrectomy can restore vision and improve the quality of life in patients suffering from many vitreoretinal diseases. However, the procedure can also be associated with complications. Although the chances are low when performed correctly, these complications can cause severe patient morbidity and blindness. Therefore, it is essential that clinicians have thorough knowledge regarding the topic, understand the procedure, when to use it, how to perform it, and post-operative management **(1)**.

Anatomy and Physiology

The retina is a neurosensory structure in the posterior segment of the eye that sends visual information to the optic nerve. It contains neurons, glial cells, and blood vessels. At a histological level, the retina consists of many layers. The inner limiting membrane separates the vitreous from the retina. Starting from inner to outer, the layers are the internal limiting membrane, nerve fiber layer, the ganglion cell layer, inner plexiform, inner nuclear, outer plexiform, outer nuclear, external limiting membrane, inner and outer segments of the photoreceptors, and the retinal pigment epithelial layer **(2)**.

The vitreous is a gel filling the vitreous cavity and is adherent to the retina at focal points throughout the posterior cortical vitreous. Vitreous liquefaction occurs over time and can lead to vitreous detachment. A vitreous detachment

from the retinal surface can lead to retinal tears and breaks, which can precede rhegmatogenous retinal detachment(RD). This gel has to be removed during PPV so that any blood or products obstructing the visual axis can be cleared, and the retina can, therefore, be accessed. This cavity is replaced by normal saline infusion during the procedure. The choroid is a vascularized structure that provides structural support to the retina and blood supply to the outer retinal layers **(3)**.

Most of the blood supply to the inner retina comes from the central retinal artery, which branches of the ophthalmic artery that, in turn, comes from the internal carotid artery. The ophthalmic artery also gives rise to the long and short posterior ciliary arteries. The long ciliary arteries supply medial and lateral horizontal parts of the choroid. The short ciliary arteries supply the posterior part of the optic disc at the level of the choroid. Terminal branches of the short ciliary arteries provide additional blood supply to Bruch's membrane and outer retina. The veins of the retina follow the blood supply and drain into the central retinal vein. The retina does not contain lymphatic vessels **(4).**

In PPV, vitreous cavity access is through the pars plana. This landmark is chosen for PPV due to the convenient access to the vitreous while causing minimal ocular trauma. Furthermore, the pars plana does not serve a sensory function and has no involvement in producing aqueous or vitreous humor, which is important since the eye needs to endogenously replace the vitreous humor removed during PPV **(3)**.

Indications

One of the most common indications for a PPV is when there is pathology that opacifies the vitreous such as non-clearing vitreous hemorrhage **(4).**

Vitrectomy is also performed for rhegmatogenous RD.The fluid causes a separation of the layers of the neurosensory retina. If the macula is still attached, known as 'mac-on,' the surgery is more emergent to restore good visual acuity. If the detachment also involves the macula, it is known as a 'mac-off' RD. The surgery will be less emergent, and the visual prognosis is worse. Intraocular tamponade can be achieved with air, gas, or silicone oil (SO) to prevent re-detachment until the chorioretinal adhesion becomes established around the breaks **(5)**.

PPV can also help relieve tractional forces on the retina that distort vision. Epiretinal membranes can be idiopathic in origin or occur secondarily to a variety of conditions such as retinal vascular disease, uveitis, laser therapy, or retinal breaks (**6)**.

Macular holes occur when there is a tear or break in the macula. Macular holes can occur due to a variety of diseases, including diabetic retinopathy and trauma, but most commonly occur due to aging when the vitreous tugs on the retina and mechanically causes a break or opening in the macula. PPV with a peel of the internal limiting membrane is appropriate for most macular holes.Vitreomacular traction can also occur spontaneously or in fibrovascular diseases that cause retinal scarring. Two common examples are sickle cell and diabetic retinopathy. These are acquired retinal diseases that can cause significant retinal non-perfusion. As both of these diseases progress, the ischemic retina causes angiogenesis and fibrovascular proliferation. In these cases, PPV with the removal of the scar tissue causing traction is necessary **(7)**.

PPV can also be done to remove a submacular hemorrhage that affects vision. The hemorrhage itself can cause photoreceptor dysfunction through chemicals in the blood and/or mechanical forces on the photoreceptors that can even disrupt connections between them. If left untreated, retinal scarring with irreversible vision loss can occur. Initial surgical approaches included removal of subretinal hemorrhages, but this was associated with significant complications. Since then, approaches have focused on displacement rather than removal. PPV is needed when there is significant ocular trauma affecting the vitreous or retina. As stated before, PPV will be needed if trauma causes vitreous hemorrhage. PPV is most certainly necessary when there is an intraocular foreign body. Other traumatic pathology repaired by PPV includes retinal detachments, retinal breaks or tears, and even later post-traumatic endophthalmitis **(4).**

PPV is an option for diseases that cause intraocular inflammation. The most common type of pathology is endophthalmitis, a serious intraocular infection that can rapidly progress to blindness. Typically, systemic and intravitreal antibiotics are the treatment for bacterial endophthalmitis. A similar approach with antifungal therapy is the initial therapy for fungal endophthalmitis. However, if these measures fail or patients present with poor visual acuity at baseline, then PPV must be done for source control of the infection. PPV can also serve as a diagnostic procedure, such as in cases of unknown or persistent intraocular inflammation after appropriate laboratory testing. The surgery can sometimes be useful for implantation of intraocular agents such as ganciclovir or fluocinolone implants. Ganciclovir implants have been used in cases of cytomegalovirus infection in HIV patients. Fluocinolone implants are used for idiopathic posterior uveitis or some refractory uveitis following the exclusion of infections. Other less common but possible indications of PPV include the retrieval of retained lens fragments after phacoemulsification, endoresection of intraocular tumors, tumor biopsies and gene therapy **(8)**.

Contraindications

There are no true contraindications to PPV. Like most intraocular surgical procedures, the risk to patients with significant systemic co-morbidities may be the only contraindication to some elective procedures. However, for urgent indications of PPV to prevent permanent visual loss, a thorough evaluation by the anesthesiologist with appropriate preoperative clearance by specialty is indicated. The only published relative contraindication to PPV appears to be related to the diagnostic intervention for intraocular tumors for the fear of dissemination **(9)**.

Technique

The procedure is performable under general anesthesia. Anesthesia is also possible via a peri or retrobulbar block. The patient should be draped in a sterile manner, just as with any surgical procedure. An eyelid speculum should be placed to keep the eye open. Trocar and cannulas are introduced through conjunctiva and sclera at the 2 o'clock, 10 o'clock, and inferotemporal regions, around 3-4 mm from the corneal limbus **(10).**

The infusion cannula gets inserted in the cannula inferotemporally. Visualization is most commonly through a non-contact wide-field system. However, in some macular pathology, a contact lens is placed on the cornea to visualize the fundus **(4).**

The parameters should be set on the vitrectomy machine based on the instruments used and the surgeon's preference. The core vitreous is removed. When removing vitreous near the posterior pole, a posterior vitreous detachment (PVD) may need to be induced if the posterior hyaloid is still attached to the macula and optic nerve. Steroids can help with visualization if this is difficult. The peripheral vitreous is removable, but care must be made to avoid damage to the posterior lens in phakic patients. Scleral indentation is a technique used to help with visualization of the peripheral retina **(11)**.

PPV is a common choice for a non-clearing vitreous hemorrhage. In this case, the vitrectomy removes the blood that is obstructing the visual axis. In the case of retinal vascular diseases causing neovascularization, additional interventions like pan-retinal photocoagulation or intravitreal anti-VEGF injections will be necessary **(4).**

PPV is also an option for retinal detachments. The ensuing steps differ based on the type of detachment. For rhegmatogenous retinal detachment, subretinal fluid is removed to flatten the retina. Any retinal breaks or tears that caused the detachment must be sealed with laser, cryotherapy, and gas or silicone added for tamponade to keep the retina attached until chorioretinal adhesion takes place. In the case of tractional retinal detachments, fibrovascular membranes causing traction require removal by delamination or segmentation. In the case of PPV performed for endophthalmitis, the vitrectomy helps with source control in aggressive infections where antibiotic penetrance alone is insufficient. A vitreous biopsy is also needed to culture the infectious agent and determine sensitivities to antibiotics or anti-fungal medications **(12)**.

When performed for a dropped lens during cataract surgery, the crystalline lens carefully gets removed. A new lens is placed, if possible, according to the remaining capsular support. If not, intraocular lenses can be sclerally fixated, or an anterior chamber lens can get implanted **(4).**

If performing PPV for a diagnostic sampling of an ocular tumor, then the tumor can be sampled following removal of the vitreous. This process typically occurs by fine-needle aspiration **(10).**

Finally, once all of the therapeutic interventions of the vitrectomy have taken place, the operating surgeon can remove the cannulas. The instruments should be removed from inside the eye. Any vitreous that prolapses outside the sclerotomy sites can be cut with the vitrectomy probe or Westcott scissors. The incisions are most commonly closed with polyglactin sutures if needed, but plain gut sutures are also an option **(13)**.

Complications

There are many complications of PPV. Some of these can cause serious morbidity to the patient, including blindness. Just as with any surgical procedure, infection or hemorrhage can occur anywhere **(4).**

In the early post-op period, a sudden rise in intraocular pressure may occur. The increase in intraocular pressure can cause irreversible damage to the optic nerve and thus cause blindness. PPV can also cause corneal epithelial defects in the early post-op period, which can result in tearing, blurry vision, and photophobia. A vitreous or choroidal hemorrhage may occur that needs further operative intervention. Additional early vascular complications include central retinal artery occlusion or cystoid macular edema. During surgery, iatrogenic retinal breaks or tears can occur that predispose to retinal detachment **(10).**

Patients can develop endophthalmitis after days to weeks after PPV. Patients can also develop iris neovascularization and neovascular glaucoma, which is more likely in disease states like diabetic retinopathy, which is believed to occur through the spread of angiogenic agents to the anterior chamber. The rise in intraocular pressure can cause irreversible vision loss **(4).**

In the late post-op period, patients can develop cataracts. Cataracts can affect vision and may need operative intervention. PPV is associated with narrowing of the anterior chamber and secondary glaucoma if gas and silicone oil are used without appropriate positioning or in the absence of a peripheral iridectomy (**14)**.

Silicone oil :

A silicone oil (SO) is any liquid polymerized siloxane with organic side chains. The most important member is polydimethylsiloxane. These polymers are of commercial interest because of their relatively high thermal stability, lubricating, and dielectric properties **(15)**.

Physical properties:

The following 4 physical parameters helps SO to be effective as an internal tamponade **(16)**:

(1) Specific Gravity (SG). This explains why an intraocular tamponade sinks or floats in aqueous humor. Any substances with an SG of 1 are neutrally buoyant in water, those with SG greater than 1 are denser than water and so will sink in it, and those with an SG of less than 1 are less dense than water and so will float. The specific gravity of aqueous humor and vitreous humor is a little higher than that of water (SG 1.00). Since the specific gravity of silicone oils in comparison is a little lower (0.97), they float in vitreous cavity.

(2) Buoyancy. An intraocular bubble of tamponade agent is acted upon by two opposing forces: buoyancy (upward force) and the gravity on the bubble (downward force). Archimedes' principle indicates that the upward buoyant force that is exerted on a body immersed in a fluid, whether fully or partially submerged, is equal to the weight of the fluid that the body displaces. For silicone oil, the "pressing" force is relatively small, as the specific gravity is close to that of aqueous humor. The force is greatest with air or gas, as the specific gravity is very low at 0.001.

(3) Surface Tension. It is the interaction that occurs at the surface of two substances involved together. Surface tension is a physical rating of the difference between the intermolecular force of the two liquids and it is responsible for the shape of liquid bubbles. Therefore, a substance with a high interfacial tension will have a greater tendency to stay as one large bubble without dispersion into small bubbles. Gas or air has the highest interfacial tension against water (around 80 mN/m), whereas perfluorocarbon liquids (PFCLs) and silicone oils have a lower interfacial tension, around 40–45 mN/m and 35 mN/m, respectively.

(4) Viscosity. The viscosity is the physical property of a fluid which measures its resistance to gradual deformation by shear stress. The tendency of a substance to emulsify and disperse into droplets over time is also dependent on its viscosity. The less viscous a substance, the lower the energy that is required to disperse a large bubble of the substance into small droplets. Silicone oils have a high viscosity (1.000–5.000 cs) and, once dispersed, the small droplets will tend to recoalesce back as a large bubble.

Medical Use:

Silicone oils have been used as a vitreous fluid substitute to treat difficult cases of retinal detachment, such as those complicated with proliferative vitreo-retinopathy, large retinal tears, and penetrating ocular trauma (**14)**.

Indications

The most frequent indication for use of SO is rhegmatogenous RD (RRD) with established proliferative vitreoretinopathy (PVR) and RRD with a high risk of developing PVR such as giant tears, signs of uveitis or preoperative choroidal detachment **(17)**.

Silicone oil is also used to treat RRD where it is impossible or not desirable to do effective retinopexy (e.g. macular hole RRD) and RRD with extensive posterior breaks. Other common indications include PDR unable to undergo primary laser retinopexy due to chronic RD, schisis or oedema, exudative RD caused by intraocular tumour Idiopathic large macular holes, although less common, are also to be treated by SO tamponade. SO could also be considered as a better choice as a short-term tamponade for patients with difficulty of maintaining a prescribed head position or the need of air or high-altitude travel **(17)**.

Complications:

A variety of complications particularly relating to longer term tamponade have been reported with variable incidences. These include cataract formation, glaucoma due to a variety of causes, chiefly emulsification (up to 13%), keratopathy due to emulsification with chronic endothelial contact (up to 10%) and,

controversially, a reduction in choroidal thickness, which may be related to the long-term intraocular pressure effects **(18)**.

Migration of SO, both intraocular (between the anterior chamber and vitreous chamber in phakic eyes or subretinal migration) and extraocular (through sclerostomies or perforation sites), have also been reported. There have also been sporadic reports of abnormal SO adherence to the retina called 'sticky SO' noted at the time of removal, which is most likely related to remnants of perfluorocarbon liquids, and perfluorooctane in particular. Silicone oil-related visual loss (SORVL) has also provoked concerns in the use of SO. Silicone oil-related visual loss (SORVL) can be defined as profound visual loss (>2 Snellen lines) during SO tamponade or, more typically at the time of SO removal without any apparent explanation. The duration of SO tamponade may also be a risk factor for SORVL, and early oil removal is increasingly advocated in appropriate cases with cases being rare with short-term tamponade of 8 weeks or less **(19)**.

Correlation of the timing of SO removal and retinal redetachment

Considerable experience has shown that the duration of oil tamponade does not affect final anatomical success. However, a slightly higher retinal redetachment rate was reported with the tamponade duration <3 months, probably relating to PVR. Proliferative vitreoretinopathy (PVR) has a median onset of 2 months following surgery, and typically, SO is left in place until this period has elapsed before removal **(17)**.

Ultrasound biomicroscopy (UBM) was first developed by Pavlin's group in Canada over 30 years ago. Instead of using the 10 MHz most widely used in ophthalmic diagnostic ultrasound, UBM uses ultrasound frequencies in the 50 to 100 MHz range, allowing examination of living subsurface ocular tissues at very high resolution. UBM has found widespread usage as a method of imaging much ocular pathology, from adnexal, conjunctiva, scleral, corneal, anterior chamber to anterior vitreous and retina. However, its major contribution has been to the understanding of the structure of the anterior segment, particularly in glaucoma **(20)**.

Ultrasound Biomicroscopy:

The first clinical model and prototype was developed in the late 1980s, and the first clinical images were taken in March 1990. In cooperation with Pavlin, Zeiss-Humphrey Inc (San Leandro, CA, USA) developed the first commercial model (Model 840) of the UBM in 1994. analysis. The newest model is the P60 workstation (Paradigm Ins. US). The development of UBM equipment was made possible by advances in transducer, high-frequency signal processing and precise motion control technology. The principal components of UBM are shown in **(21).**

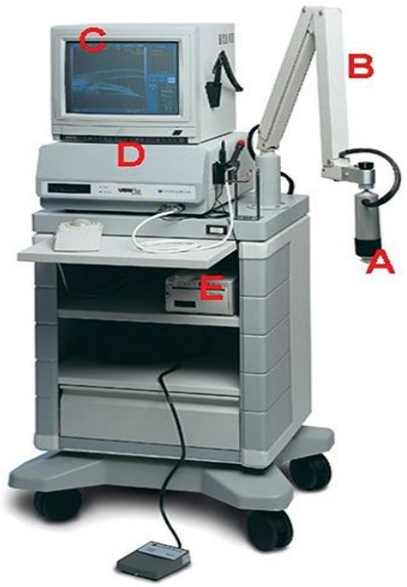

Fig. (1): The current UBM—P45 workstation (Paradigm Medical Industries, UT, USA). A: Ultrasound transducer and probe; B: Articulated arm; C: Computer monitor; D: Main processing unit; E: Printer **(21).**

The transducer is the critical component. By moving a transducer linearly over a 5 mm image field, sonographic data are generated along each of 512 lines (8 micron between lines). The signal is amplified in proportion to the depth from which it originated using so called 'time-gain compensation'. After signal processing, ultrasound data can be converted from analog to digital format and transferred to a high-speed scan converter, and eventually displayed on a video computer **(21).**

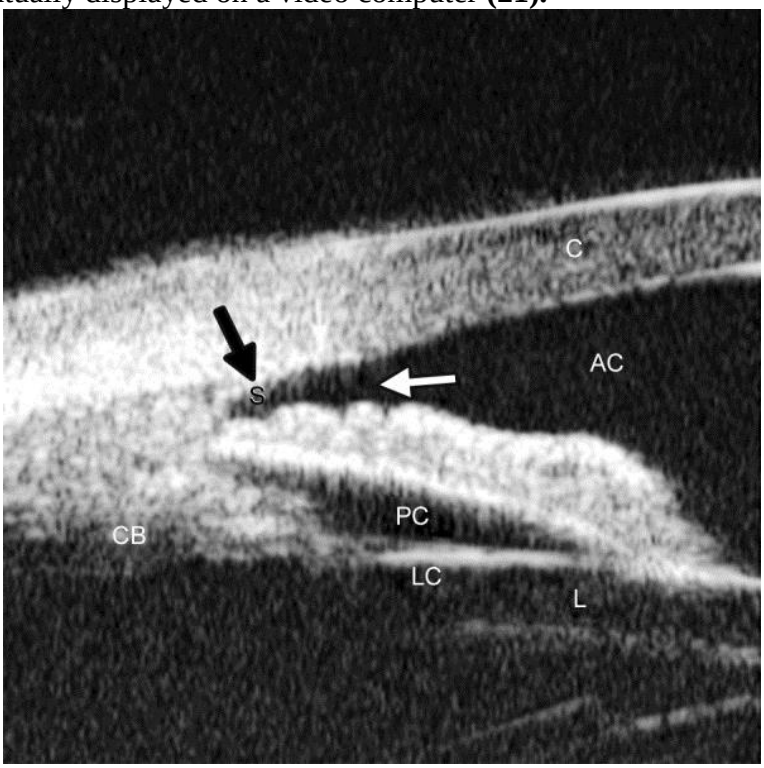

Fig. (2): Illustration of major anatomical landmarks in UBM images (C: Cornea; AC: Anterior chamber; S: Scleral spur; CB: Ciliary body; PC: Posterior chamber; LC: Lens capsule; L: Lens). The black arrow shows the most important landmark for drainage angle measurement**—** scleral spur **(21).**

According to the principles of ultrasound physics, image quality is dependent on the frequency of the ultrasound, the ratio of the focal length to the transducer diameter (f-number) and the length of the pulse. Higher frequency and shorter focal length are usually associated with higher resolution of the images but poorer penetration **(21).**

Measurement accuracy of the imaging system is dependent on the lateral and axial resolution, the stability of mechanical motion and the pixel size of the image. The lateral resolution (transverse to the direction of pulse propagation) depends on the distribution of ultrasound in the field of the transducer, which has a width at half maximum given by the product of the wavelength and the f-number. Therefore, a transducer of 80 MHz and f 2.2 has poorer resolution than 80 MHz/f 1.2. The 80 MHz/f 2.2 can capture the resolution of 50 microns **(22).**

The axial accuracy (resolution) is determined by the speed of sound in the various tissues, for example, 1542 m/s in the iris to 1620 m/s in the sclera. There are two terms describing the axial accuracy: 'Instrument axial resolution' and 'measurement precision'. Instrument axial resolution is the instrument's capability to distinguish two surfaces when they are brought closer and closer together. 'Measurement precision' can be significantly better than axial resolution in some special conditions, such as when the two planar interfaces are well resolved and parallel, e.g., the anterior and posterior surfaces of the cornea **(23)**.

Examination Technique:

The UBM examination technique is similar to B-mode ultrasound. Transducer direction and manipulation of the probe is guided by looking at the image on the screen. Major differences include an oscillating probe without a covering, the use of a water bath and the finer movements required **(21)**.

The patient is examined in a supine position facing the ceiling. After topical anesthesia, a specially-designed eyecup (22 to 24 mm diameter) is used to separate the eyelids and form a water bath environment. This is filled with a viscous, coupling fluid such as methylcellulose (1-2.5%). Some examiners use normal saline to fill the cup after sealing the interface between the eye and the base of the cup with 2.5% methylcellulose **(22).**

Images are stored in an electronic format on a computer attached to the device (**21)**.

Quantitative Measurement of UBM in Angle Assessment

UBM has proved to be a great asset in the study of AC angle. Radially-orientated images through the limbus provide a cross-sectional view of the anterior chamber angle. The corneoscleral junction and scleral spur can be distinguished in the majority of cases **(21)**.

The quantitative analysis of UBM images in the study of angle-closure usually addresses three specific issues: Quantifying the angle width by measurement of either linear distance or geometric angle, and the measurement of area between iris and trabecular meshwork **(22).**

Additional measurements of iris thickness and contour as well as the relationship between iris and ciliary body may also be made.

1. Angle Width Quantified by Linear Distance

The most commonly used index of angle width is the angle-opening distance (AOD). The scleral spur is identified and a point on the internal wall of the corneoscleral plane at a given distance from the scleral spur (most often either 250 or 500 microns) is identified. From this point anterior to the scleral spur, a line perpendicular to the plane of trabecular surface is extended to meet the surface of the iris. The length of this line gives the AOD, termed AOD 250, 500 or 750, dependent on the distance from the scleral spur. AOD at 500 microns was reported to be 347 ± 181 microns in normal eyes **(23)**.

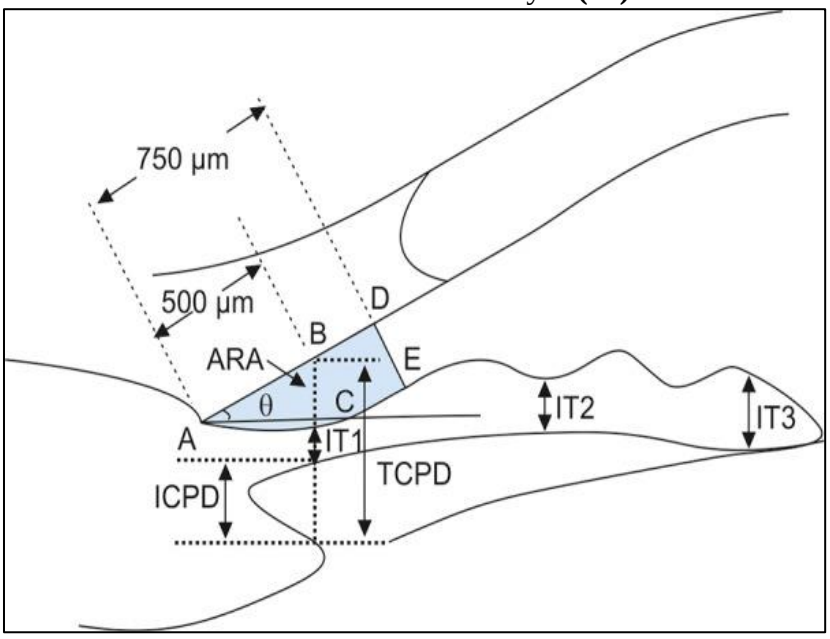

Fig. (3): Parameters commonly used for image analysis of UBM. ARA: Angle recess area at 750 microns anterior to the scleral spur; IT1-3: Iris thickness at various locations to the scleral spur; TCPD: Trabecular ciliary process distance; ICPD: Iris ciliary process distance **(21)**.

2. Angle Width by Degree of Angle:

Measurement of the angle in degrees (trabecular-iris angle, TIA) was also proposed by Pavlin, defining the angle as the apex of lines passing through the point on the meshwork 500 microns anterior to the scleral spur and the point on the iris perpendicularly opposite **(23)**.

3. Angle Width by Angle Recess Area

The ARA was defined as the area bordered by the anterior iris surface, corneal endothelium and a line perpendicular to the plane of the corneal endothelium drawn to the iris surface from a point 750 microns anterior to the scleral spur **(21)**.

4. Measurement of Iris Contour, Thickness and Relationship with Ciliary Body.

The relationship between the iris and the trabecular meshwork is central to the understanding of angle-closure**)**. A line was first extended from the most peripheral point to the most central point of the iris pigment epithelium. A perpendicular line is created from this line to the iris pigment epithelium at the point of the greatest concavity or convexity. **Pavlin et al. (23)** proposed that iris thickness measured at three locations, perpendicular to the horizontal plane of the iris, the measurements of thickness were made at 500 microns from the scleral spur (IT1), at 2 mm from the iris root (IT2), and at the maximum iris thickness near the pupil margin (IT3).

In order to describe the location of the ciliary processes, **Pavlin and Foster (23)** used the trabecular meshwork ciliary process distance (TCPD), measuring this perpendicularly through the iris to opposing body of the ciliary process from a point 500 microns anterior to the scleral spur along the plane of the corneal endothelium.

Iris-lens contact distance (ILCD) is another measurement believed to give a measure of pupil block. It is measured along the iris pigment epithelium from the pupil border to the point where the iris physically leaves contact with the anterior surface of the lens **(21)**.

Table (1): Parameters proposed by **Pavlin and Foster (23)**.

Parameter	**Description**
AOD	Distance between the trabecular meshwork and the iris at 500 microns anterior to the scleral spur.
TCPD	Distance between the trabecular meshwork and the ciliary process at 500 microns anterior to the scleral spur.
IT1	Iris thickness at 500 microns anterior to the scleral spur.
IT2	Iris thickness at 2 mm from the iris root.
IT3	Maximum iris thickness near the pupil margin.
ICPD	Distance between iris & ciliary process along the line of TCPD.
ILCD	Contact between the iris and the lens.
TIA91	Angle of the angle recess.

Clinical Application of UBM

A. Cornea

1. Normal Cornea

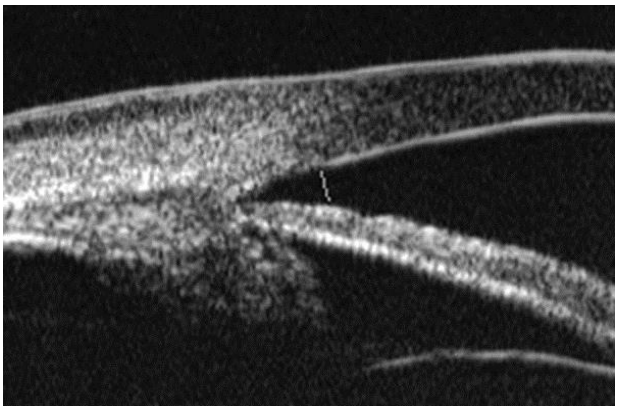

Fig. (4): Normal cornea UBM **(21)**.

Epithelium forms a smooth reflection line on the surface. The highly reflective line right below the epithelium is Bowman's membrane. The distance between the smooth surface line and highly deflective line suggests the thickness of corneal epithelium. Corneal stroma is the layer with lower and regular reflection. The 3rd high reflective line is the Descemet's membrane and endothelial layer **(21)**.

2. Corneal Edema:

The typical features are irregular surface (epithelium) and increasing reflectivity of corneal stroma. Bulla may be presented on anterior surface line in some severe cases **(21)**.

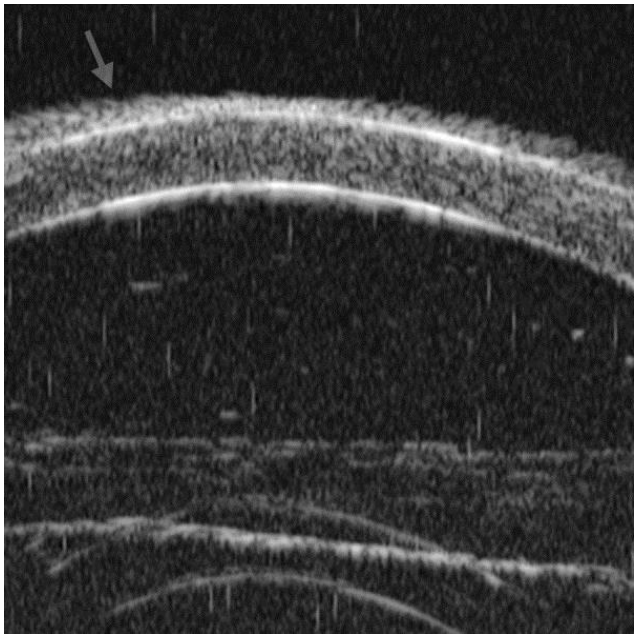

Fig. (5): Corneal edema. The epithelium layer is thickened loosing smooth and regular surface (white arrow). The stroma also turns thickened appearing highly reflective **(21)**.

3. Blood Staining of the Cornea

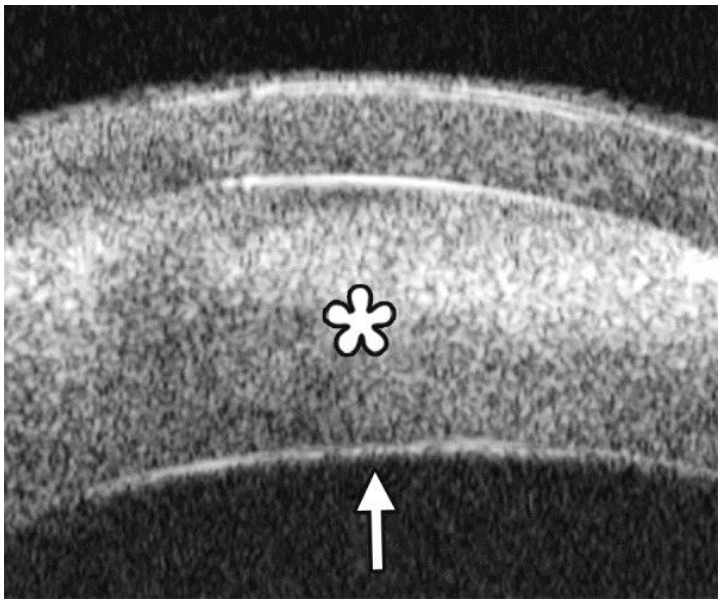

Fig. (6): UBM image of blood staining of cornea, showing epithelial surface edema, high reflection in stroma, anterior chamber shallowing with suspected lens dislocation (the highly reflective line marked by white arrow represents anterior surface of lens); anterior chamber was filled with blood clot (asterisk) of various densities **(21)**.

4. Descemet's Membrane Detachment:

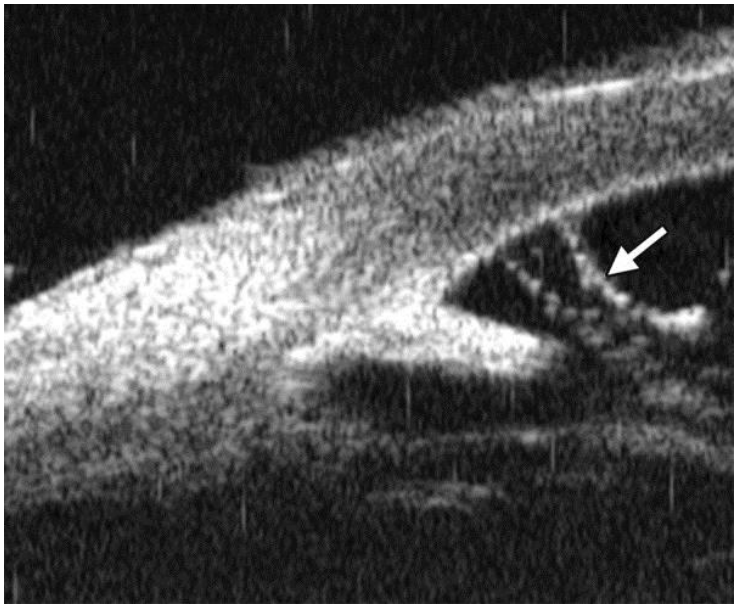

Fig. (7): Descemet's membrane detachment after phacosurgery. The detached Descemet's membrane is marked by white arrow as highly reflective line from posterior corneal surface near the incision site **(21)**.

5. Descemet's Membrane Folds:

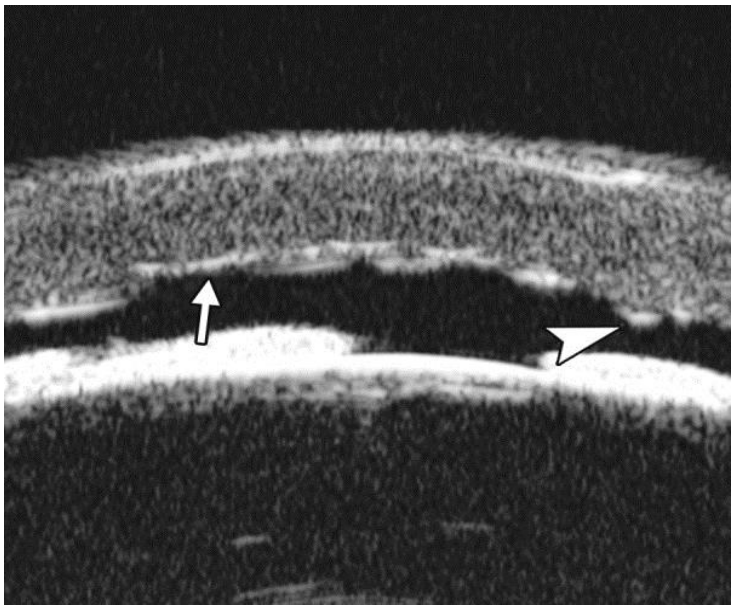

Fig. (8): Endothelial changes in endothelial keratitis. Corneal stroma is thickened with irregular endothelium surface (white arrow). KP is illustrated as hyperechoic spots attached on the corneal back (white arrowhead). Furthermore, the examination demonstrated shallow ACD and iris atrophy in this case **(21)**.

6. Corneal Dystrophy

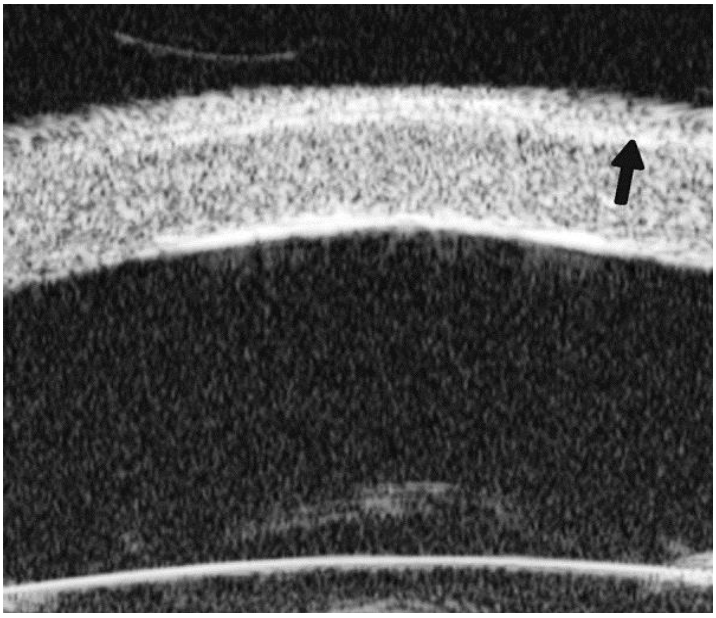

Fig. (9): UBM demonstrated Bowman's membrane loses its continuity and turned irregular with localized hyperechoic dots and flacks (black arrow). Corneal stroma appears edematous because of epithelium dysfunction **(21)**.

B. Sclera

The space for examination is limited by the lid fissure width and eyecup. UBM is only able to examine the area anterior to equator. Normal sclera is a dense connective tissue. Typical UBM feature is a regular high reflectivity signals (sclera) with relatively lower reflective tissue surrounding or inside, e.g., episcleral tissue, ciliary body or choroids **(22).**

1. Episcleritis

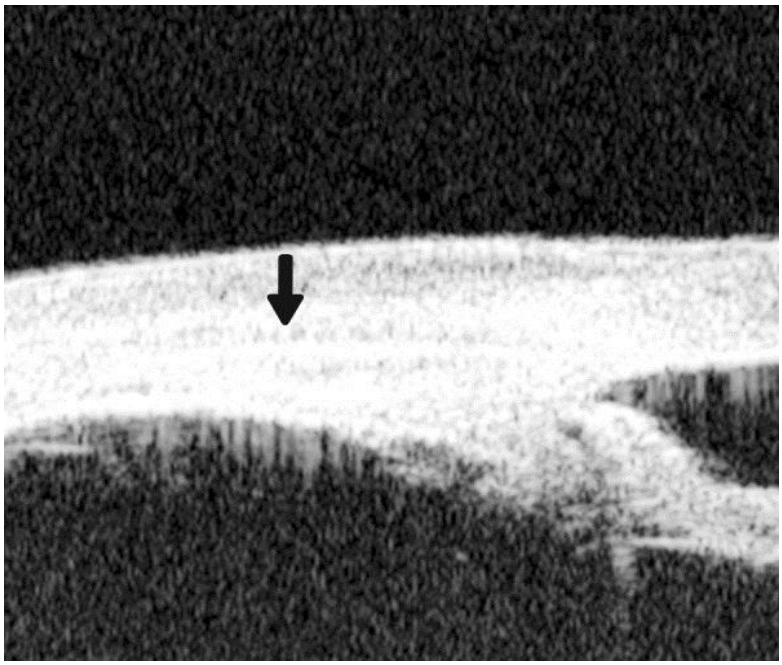

Fig. (10): Episcleritis. UBM reveals thickening of the episclera tissues, but the stroma of sclera is not affected. A distinct border (black arrow) was observed between scleral stroma and episcleral tissues (including bulbar conjunctiva and Tenon's capsule) **(21)**.

2. Scleritis:

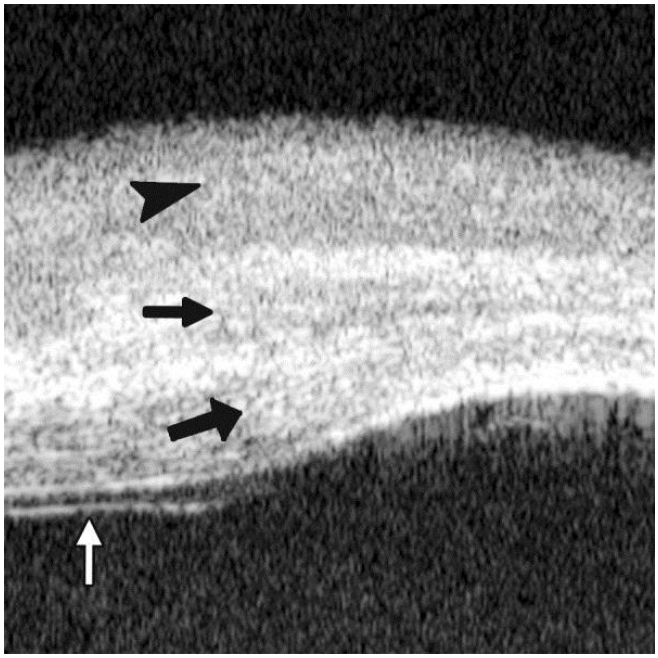

Fig. (11): UBM imaging demonstrates the inflammation affects both episclera and sclera stroma—thickening of episclera (top black arrowhead) and diffuse decreasing reflectivity regions within the stroma (middle black arrow). Internal layer of sclera is also affected (bottom black arrow). **(21)**.

C. Anterior Chamber
1.AC depth (Central and peripheral)
2. Anterior Chamber Angle:
a. Primary Angle-Closure Glaucoma
Pupil Block Predominated
Before laser PI and after laser PI.

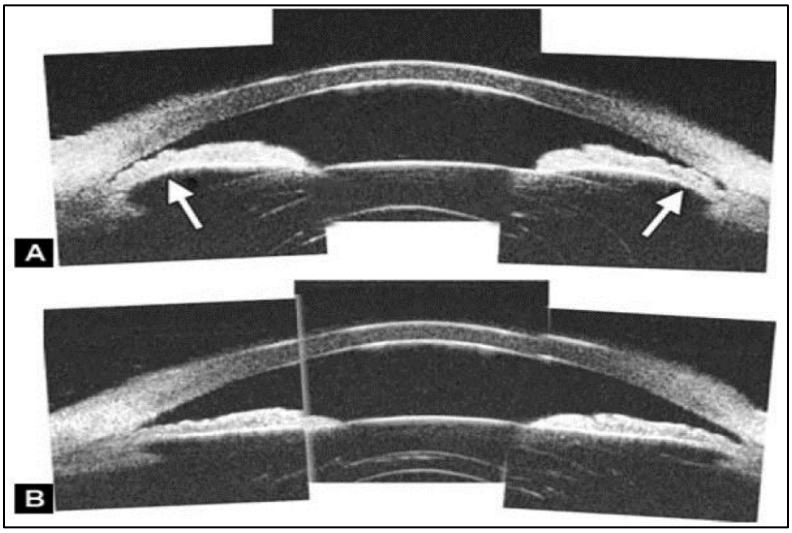

Fig. (12): This UBM image-montage shows the effect of laser iridotomy. Angles have opened after laser PI, and the bombe iris (marked by white arrow in Fig. A) becomes flat (shown as Fig. B). The iris insertion is located in the middle of the anterior face of the ciliary body, suggesting the location of iris insertion is important **(21)**.

Non-pupil Block:

Before laser PI and after laser PI.

Anterior rotation of ciliary body, anterior iris insertion, iris thickness and configuration at insertion, all contribute to the angle-closure in those predominantly caused by non-pupil block mechanism. Laser peripheral iridotomy only has limited efficacy in these cases. Argon laser peripheral iridoplasty may have better outcome but need further evidence to prove **(21)**.

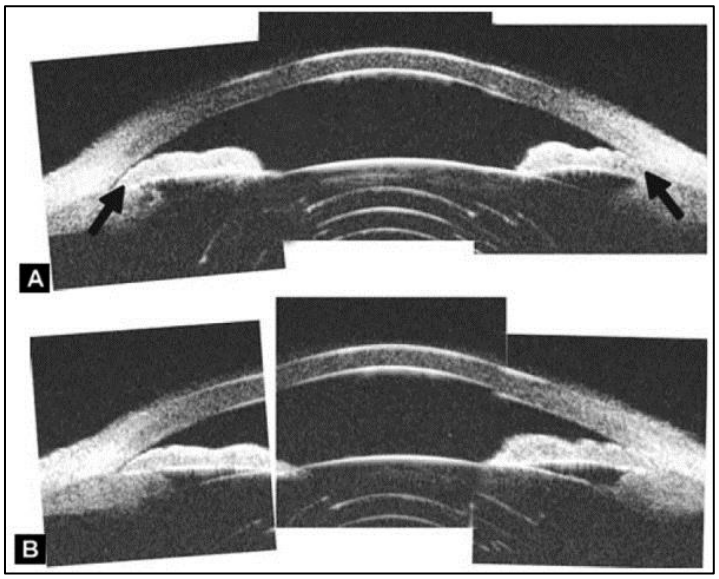

Fig. (13): Typical anteriorly rotated, large ciliary body supports the peripheral iris (black arrow in Fig. A), preventing the peripheral iris moving backward after laser iridotomy (shown in Fig. B). Anterior location of the iris insertion also plays a role in this mechanism **(21)**.

b. Peripheral Anterior Synechiae (PAS)

Gorin described the gonioscopic features of the drainage angles and postulated two kinds of closure: B-type (closure from the bottom of the drainage angle, as marked by black arrow in Fig. 13 (A) and S-type (closure that starts from Schwalbe's line, as marked by white arrow in Fig. 13 (B) **(21)**.

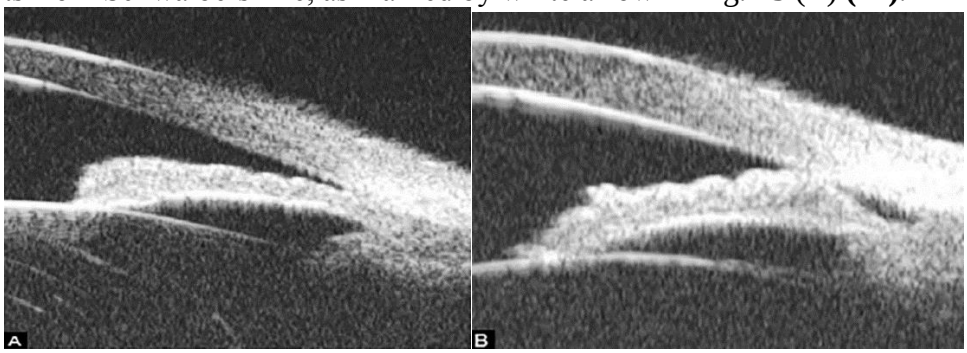

Fig. (14): A and B: PAS of B-type and S-type (these images demonstrate appositional closure instead of PAS) **(21)**.

c. Secondary Angle Closure

1. Angle closure secondary to iris abnormalities.
2. Secondary to lens subluxation.
3. Neovascular glaucoma **(20)**.
4. Iridocorneal endothelial syndrome (ICE)
5. Pigmentary dispersion syndrome
6. Malignant glaucoma **(20)**.

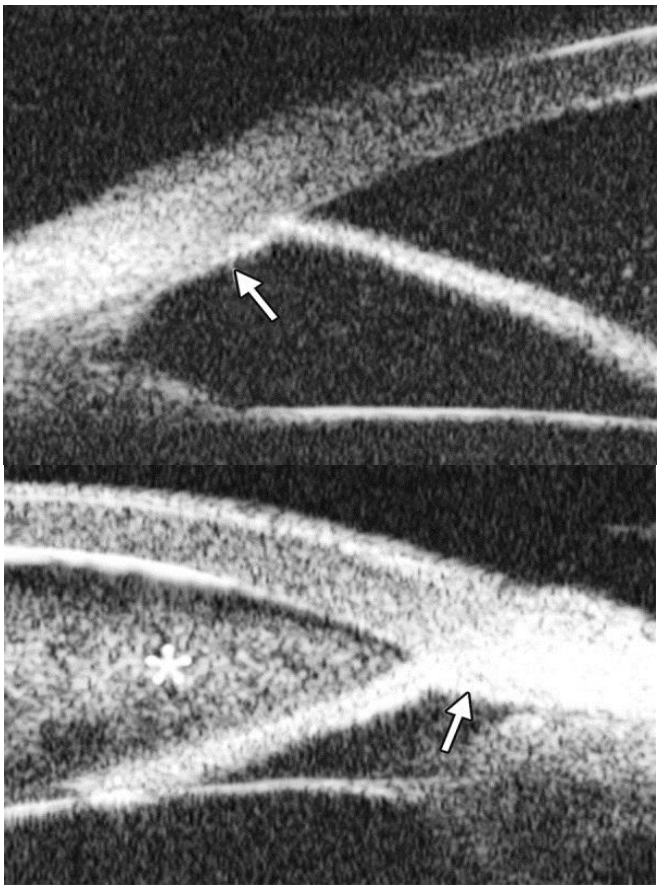

Fig. (15): Neovascular glaucoma **(21)**.

d. Congenital glaucoma

Fig. (16): Congenital glaucoma **(20)**.

C. Lens

1. Morphological abnormalities of the lens
2. Lens thickness
3. Lens subluxation

Normal Intraocular Lens

Complication of Intraocular Lens Implantation.

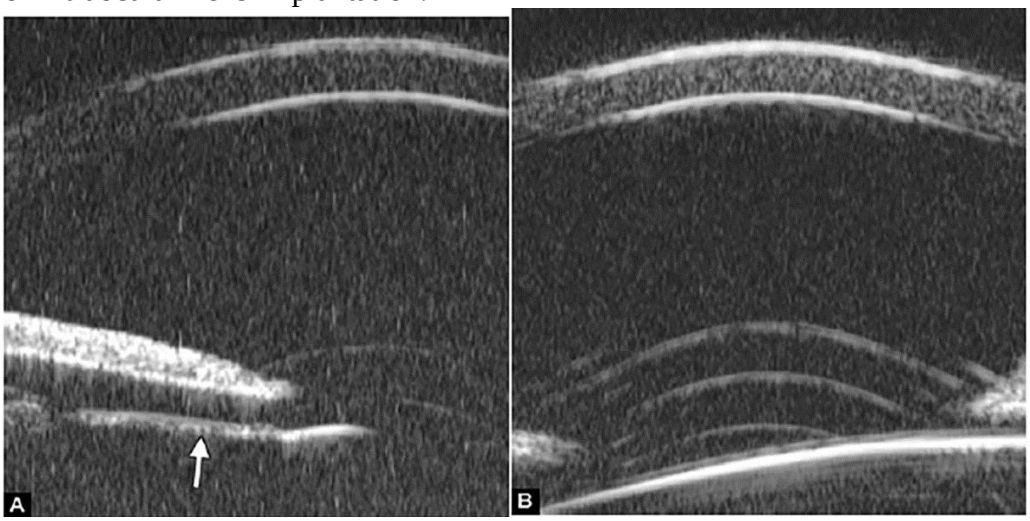

Fig. (17): Intraocular lens dislocation: (A) the IOL dislocated to underneath the iris (white arrow) with the loop exposed in pupil area, (B) the IOL dislocation in sagittal axial, presenting as IOL lying at different distance to iris on two polars **(21)**.

D. Uvea

Anterior Uveitis

UBM demonstrated high reflectivity floaters in the anterior chamber (Fig. 17A), slight edema of ciliary body covered by exudative material (white arrow in Fig. 17B) as well as the inflammatory exudation attached on the zonules **(21)**.

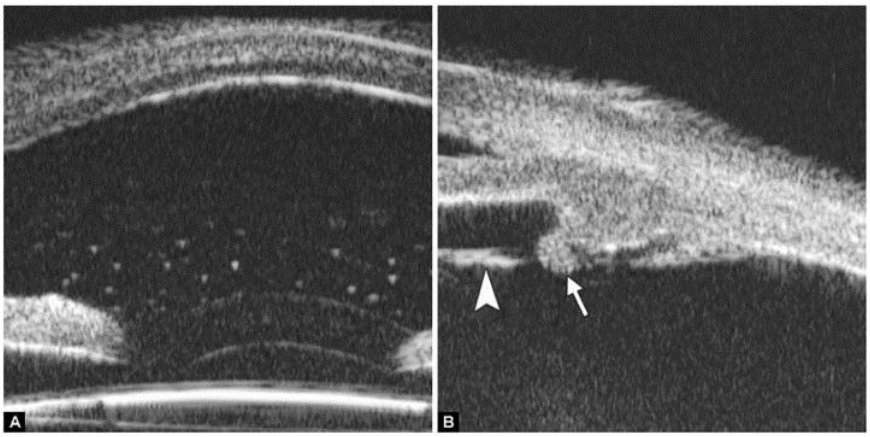

Fig. (18): Anterior uveitis **(21)**.

E. Vitreous and Peripheral Retina

Normal Vitreous and Peripheral Retina

Normal pars plana, ora serrata and peripheral retina appear consecutive and smooth in UBM image. The highly reflective line is the anterior border of vitreous **(21)**.

Retinal Detachment (Pars Plana Dialysis)

UBM can detect retinal detachment located in the anterior part of vitreous cavity. In Fig. 18 (A), the line represents the free end of detached retina in pars plana dialysis (white arrow). The fine line (white arrow in Fig. 18B) reveals retinal detachment at very peripheral part of the fundus, which may not easily observed when the pupil is not dilated big enough **(21)**.

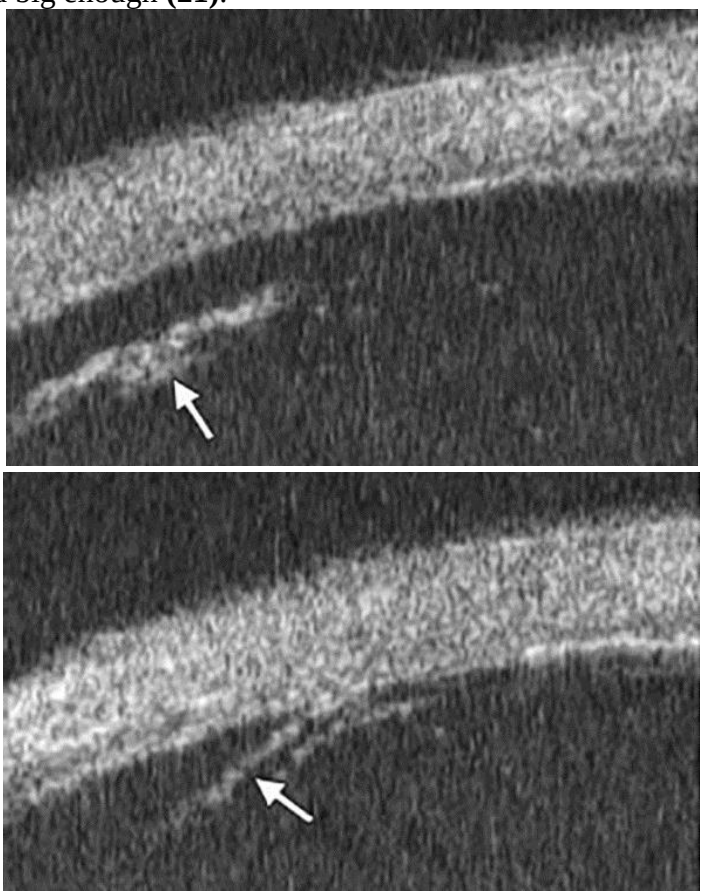

Fig. (19): Pars plana dialysis **(21)**.

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