Ocular Ultrasound and its Clinical Applications

Savleen Kaur and Ramandeep Singh

Contents

Introduction 27
The Hardware 27
The Technique 28
Normal Ultrasound 30
Case 1: Granulomatous Panuveitis in a 14-Year-Old Girl 32
Case 2: Leukocoria with Hypopyon in a 5-Year-Old Girl 35
Suggested Reading 35

Introduction

Ultrasound has become a standard diagnostic modality in almost all medical specialties. The use of ultrasound in ophthalmology began in 1956 by the work of Mundt and Hughes. The first use of B scan with the immersion technique was reported by Baum and Greenwood that was later replaced by the contact method by Bronson and Turner. The ultrasound has substantially helped in establishing the diagnosis of several ocular pathologies in the posterior segment.

Ultrasound waves have a frequency greater than 20,000 Hz, rendering them inaudible to the human ear. For the practical purposes, commercial probes in ophthalmic practice use frequency of 10 MHz. The 10 MHz probe provides an excellent resolution of 940 µm with a restricted depth of 4 cm, thus imaging the posterior segment of the eye quiet well. The 10 MHz probe can be used to examine low intensity scatterers, such as the vitreous humor. The 20 MHz probes on the other hand have a deeper focus with sharper lateral resolution compared with the 10 MHz probe and can be used to better detect details at the posterior pole and in the orbit.

S. Kaur · R. Singh (✉)
Department of Ophthalmology, Advanced Eye Centre, Postgraduate Institute of Medical Education and Research (PGIMER), Chandigarh, India
e-mail: mailsavleen@gmail.com; mankoo95@yahoo.com

The Hardware

The machine consists of a probe with a piezoelectric crystal near its surface, which transmits these high frequency ultrasound waves into the eye. These waves strike the ocular structures and are reflected back. The probe converts these reflected waves into electric signals, which are reconstructed on a monitor.

Being relatively superficial, to image the eye, lesser penetration and more resolution is required, provided extremely well by the 10 MHz probe. The eye is relatively a small organ as compared to the rest of the body, as well as superficial, filled with low absorption fluids. Sound travels faster through solids as compared to liquids, an important principle to be kept in mind as the eye has both. Hence velocity of the sound waves in every medium that the wave passes should be known.

The A or the Amplitude scan gives a one-dimensional view of the reflected echoes in the form of spikes. The height of the spike is proportional to the reflectance of the structure. It gives information regarding the lesions' character as well as size (Fig. 1a).

V. Gupta et al. (eds.), *The Uveitis Atlas*,
https://doi.org/10.1007/978-81-322-2410-5_8

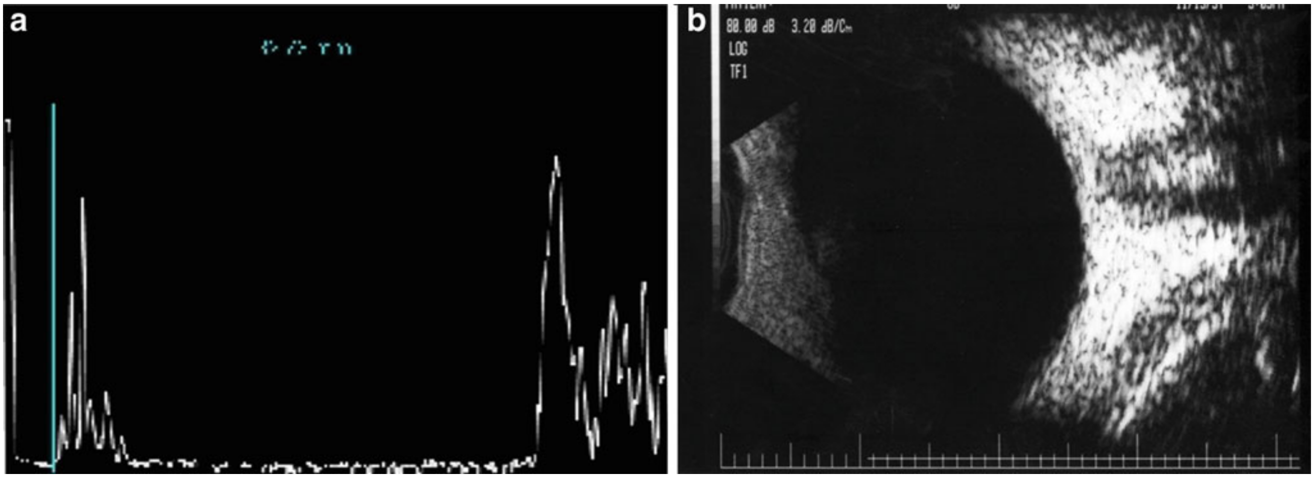

Fig. 1 (**a**) The A (Amplitude) scan gives a one-dimensional view of the reflected echoes in the form of spikes. From anterior to posterior (*left* to *right*), the highest spikes correspond to cornea, lens, and retina. (**b**) The B (Brightness) scan gives a two-dimensional image, composed of dots with brightness proportional to the reflectivity of the tissue

The B or the Brightness scan gives a two-dimensional image, composed of dots with brightness proportional to the reflectivity of the tissue. It gives information about the topography of the lesion (Fig. 1b).

The Technique

The procedure should always be explained to the patient. The patient can be seated on a reclining chair or made to lie on a bed. If the examiner is right handed, he/she should be preferably sitting on the right of the examiner. A white line or dot (marker) on the probe indicates the orientation of the probe and represents the upper portion of the display. The B scan requires a coupling medium in the form of gel, which provides an optimal contact between ultrasonic head and tissue to ensure the perfect sound transmission without interference of air. The probe can be placed on the conjunctiva or the cornea.

Type of Scans

The basic examination gives information of the topographic data (extent and location), quantitative data (reflectivity and attenuation), as well as the kinetic data (motility and after movement) of any pathology.

1. **Axial:** The probe is placed on the cornea and the patient fixes in the primary gaze. It displays the optic nerve head in the center in a vertical axial scan with marker facing towards 12 o'clock. For a horizontal axial scan, the marker is oriented nasally and it will show the macula below the optic nerve head. These are the easiest to obtain but sound attenuation from the lens hinders the resolution of the scan (Fig. 2a and b).
2. **Transverse:** It avoids scanning through the lens and provides lateral extent of the lesions. The probe is placed at limbus and as the probe moves from limbus to fornix, it scans the opposite wall posterior to anterior. By convention, the marker is oriented nasally in case of superior and inferior scans and marker is oriented towards 12 o'clock in case of nasal and temporal scans (Fig. 3).
3. **Longitudinal:** The probe is placed longitudinally from limbus to fornix. By convention the marker is oriented towards the limbus, i.e., each clock hour. It provides an anteroposterior extent of the ocular wall along one meridian only from the peripheral retina above and the optic nerve head below (Fig. 4).

Analysis

Quantitative analysis includes topographical analysis including reflectivity, internal structure, and sound attenuation. Reflectivity is measured by the height on 'A' scan and brightness on 'B' scan. Reflectance signals are compared to the highly reflective sclera and very low reflective vitreous cavity (Fig. 5). Sound attenuation implies decline of spikes' height due to sound absorption. Highly reflective and regularly structured lesions will provide the strongest sound absorption and the maximum decline in spike height. The probe emits oscillating sound waves, which are represented as multitude of dots on a screen. There are various adjustments one can make for a better quality scan.

Gain

The amplitude of the display and sensitivity can be altered by adjusting the gain in decibels (db). Higher gain implies

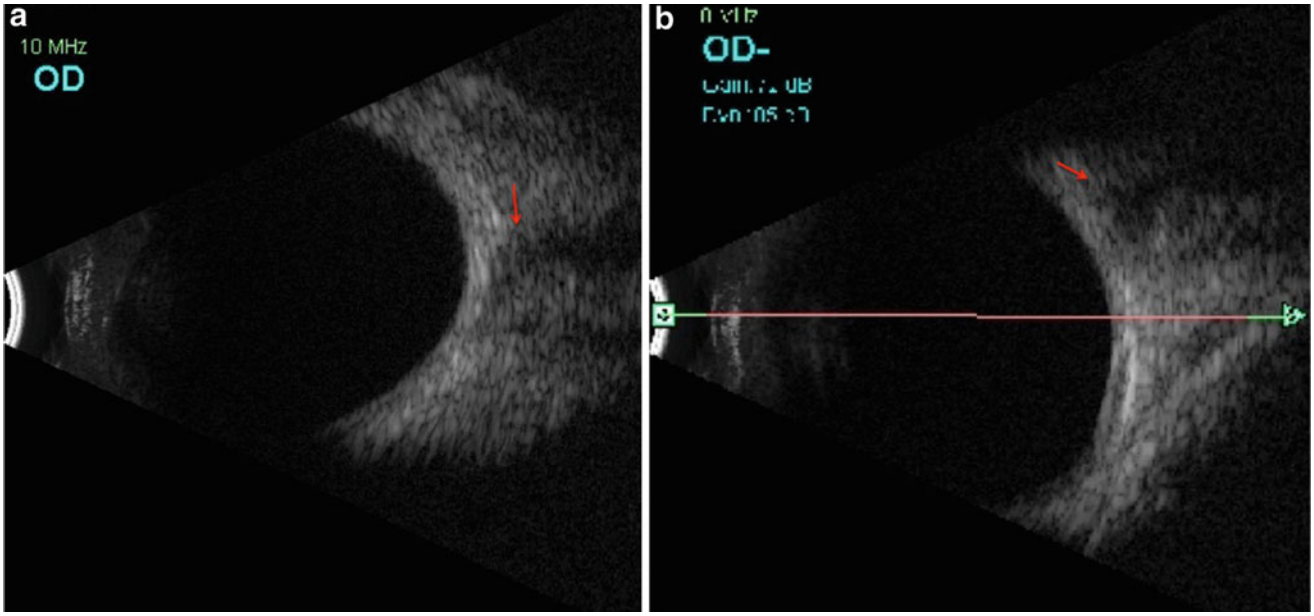

Fig. 2 In the axial scan, the probe is placed on the cornea and the patient fixes in the primary gaze. It displays the optic nerve head in the center in the vertical axial scan (*arrow*) (**a**) and above the midline in the horizontal axial scan. (*arrow*) (**b**)

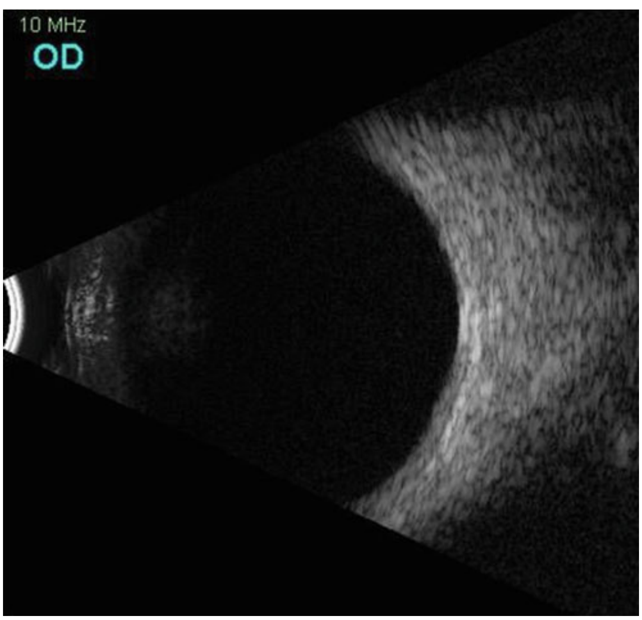

Fig. 3 Transverse scan avoids scanning through the lens and it scans the opposite side of the eye

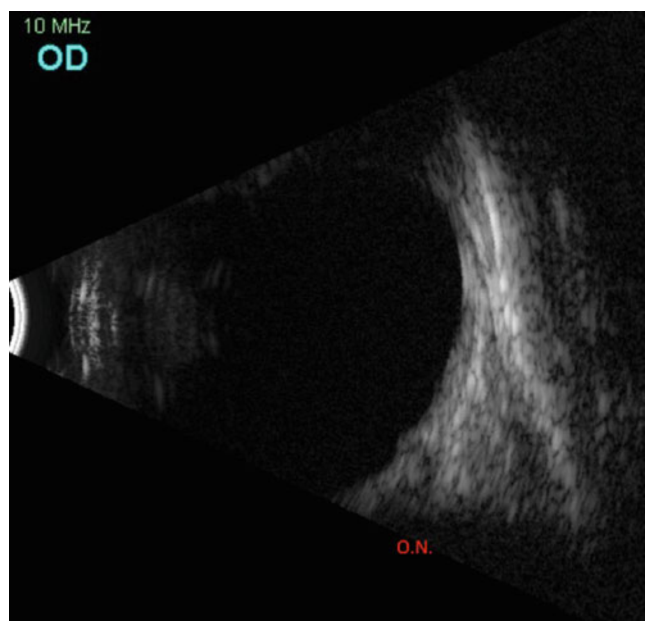

Fig. 4 Longitudinal scan provides an anteroposterior extent of the ocular wall along one meridian only from the peripheral retina above and the optic nerve (*ON*) head below

weaker signals that are also displayed. Lower gain means weaker signals disappear and stronger signals remain.

Scale

A variable gray-scale format is used to display the returning echoes as a two-dimensional image. Reducing gray scale increases the contrast.

Pearls

1. The more perpendicular the probe is held to the surface, more echo is reflected back from the surface into the probe, hence brighter the image.
2. It can be performed on open eye for better images if patient is cooperative.

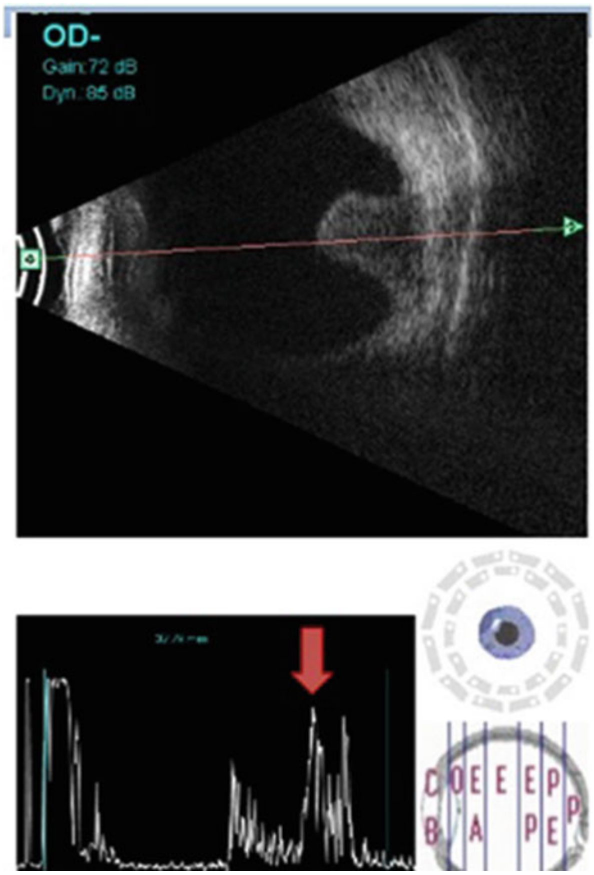

Fig. 5 Reflectivity is measured by the height on ‘A’ scan and brightness on ‘B’ scan. Reflectance signals are compared to the highly reflective retina and very low reflective vitreous cavity

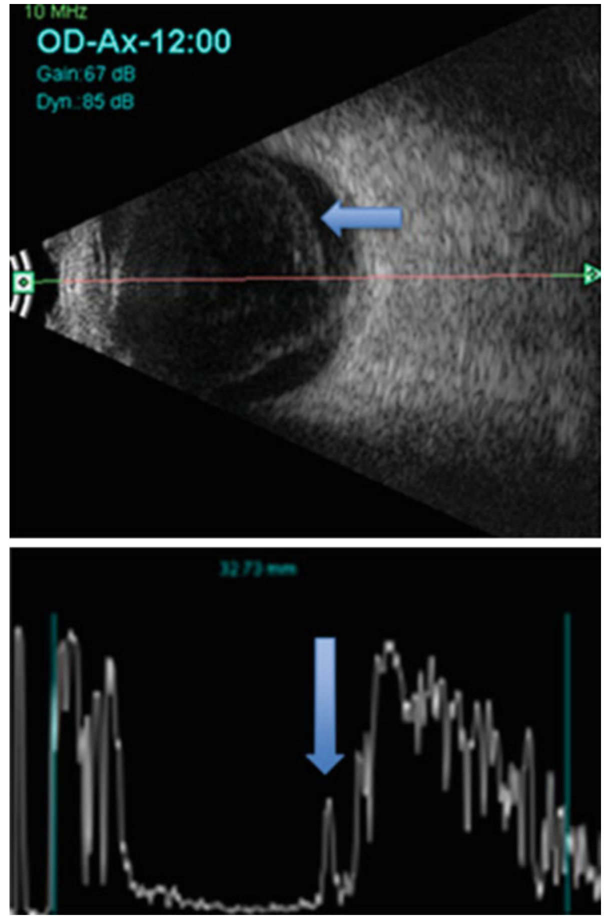

Fig. 6 Posterior vitreous separation seen as a mobile and thin low reflective line (*arrow*). It is less reflective as compared to the retina (*arrow* in A scan below)

3. Begin examination at stronger gain and highest gray scale and decrease it later to delineate pathologies.

Normal Ultrasound

A normal 10 MHz scan shows spikes from both anterior and posterior surfaces of cornea, while anterior lens spike and posterior iris usually merge together. The posterior curvature of the lens is clearly demonstrated. The display has posterior pole on the right with the vitreous cavity in the center. Areas that are closest to the probe are imaged to the left of the screen and those farthest away are imaged to the right.

The normal vitreous is relatively echolucent and ultrasonographically clear (Fig. 1b). On A scan, there are no echoes between the posterior lens capsule and the retina. Occasional small dots or linear echoes can be seen at the highest gain settings, but they fade rapidly as the gain is reduced. In an aging eye, due to vitreous syneresis, low to medium reflective opacities can be seen. Posterior vitreous separation is seen as a mobile and thin low reflective line on the B scan (Fig. 6). It is less reflective as compared to the retina (Fig. 7) and disappears when the gain is reduced. In cases of vitreous cells, the cavity is seen filled with small dots of low to medium reflectivity (Fig. 8).

The choroid is thick echographically. Opposed retina and choroid produce a highly reflective double spike on A scan – one from vitreoretinal interface and the other from retinochoroidal interface (Fig. 9). Retina is seen on B scan as an opaque, smooth, and acoustically opaque surface with high reflectivity echoes inseparable from the choroid-sclera complex. The retinal spike corresponds to 100% on the echo intensity scale if the beam is perpendicular to the retina in A scan (Fig. 7).

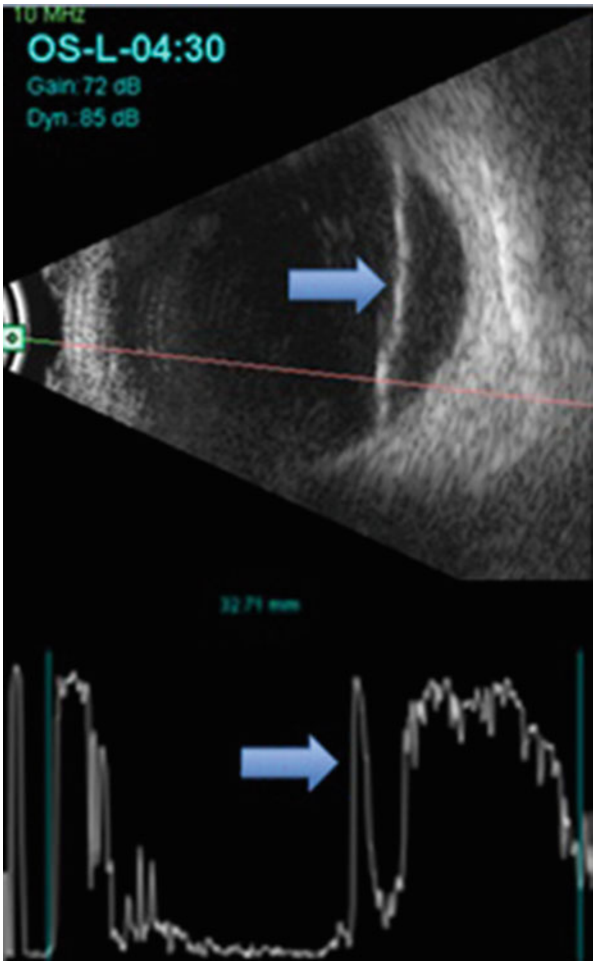

Fig. 7 Retina seen on B scan as an opaque, smooth, acoustically opaque surface (*arrow above*) with high reflectivity corresponding to 100% on the echo intensity scale if the beam is perpendicular to the retina in A scan (*arrow* in figure below)

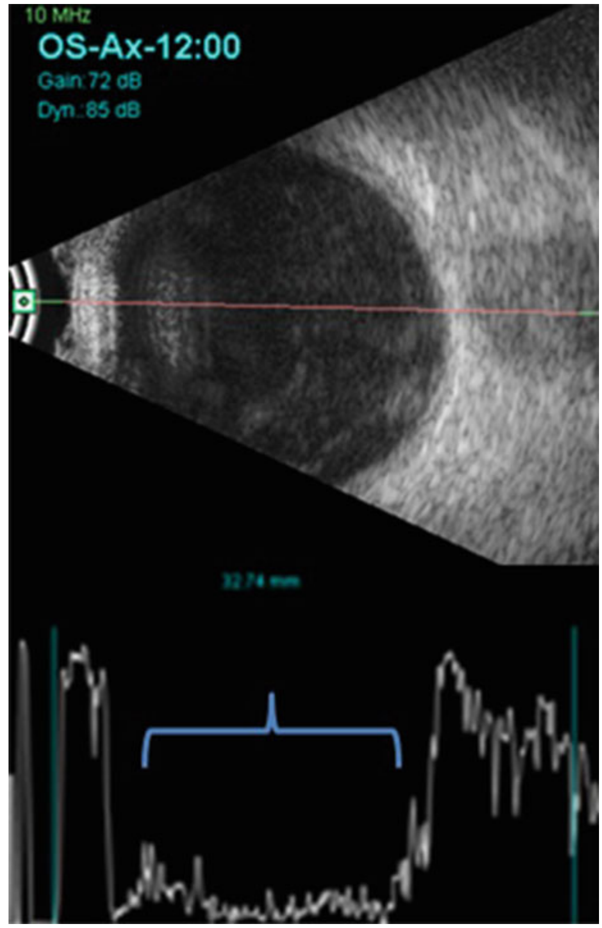

Fig. 8 In a horizontal axial scan, vitreous cavity is seen filled with small dots and lines that give homogenous echoes. On A scan, these have low to medium reflectivity

Strong echoes, such as those seen from sclera or detached retina, are displayed brightly at high instrument gain and remain visible even when the gain is reduced. Weaker echoes, such as those from a vitreous hemorrhage, are seen as a lighter shade of gray that disappear when the gain is reduced.

Vertical axial USG B scan is used to measure the retinochoroid thickness (RCT). It is measured with a caliper tool as the distance between outer border of the hyper-eflective retina and the sclera (Fig. 10). The best area to measure RCT is the peripapillary area. The availability of 20-MHz probe has made the imaging of RCT macula much better with higher resolution (Fig. 11).

Highly reflective structures at the back of the eye such as chorioretina, sclera, optic nerve sheaths, and extraocular muscles sheaths are seen at higher resolution with the 20 MHz probe. Optic nerve is seen as a wedge-shaped acoustic void in the retro-orbital region and extraocular muscles seen as echolucent to hyporeflective structures. The episcleral space separates the globe wall from the orbit and is seen as a thin dark line.

Limitations

There are certain limitations to ultrasound also. These include operator dependency, contact with the globe which may cause eye pain, interference from overlying bone or air, and inferior spatial resolution when compared with CT or MRI.

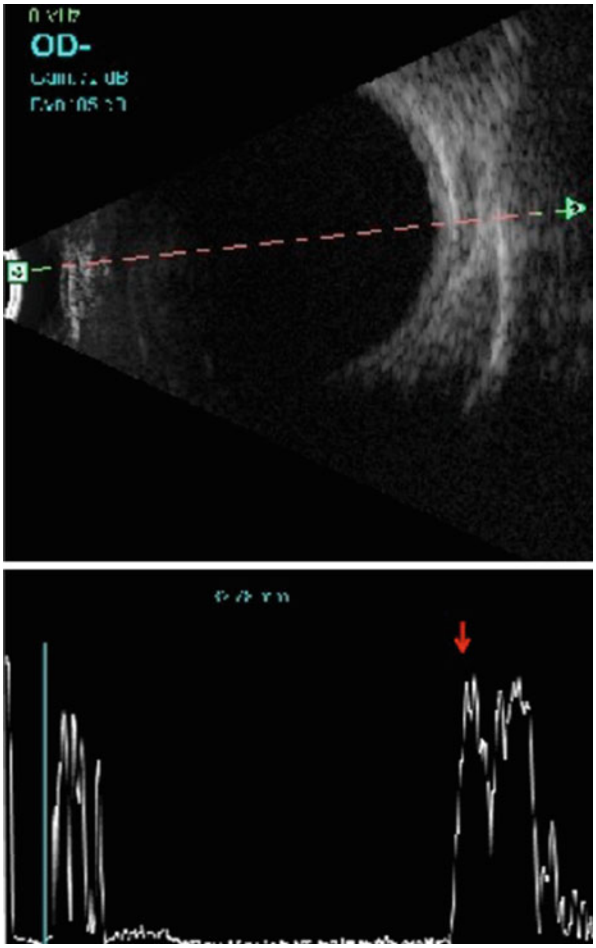

Fig. 9 Highly reflective double spike (*red arrow*) (one from vitreoretinal interface and the other from retinochoroidal interface) on A scan produced by the opposed retina and choroid

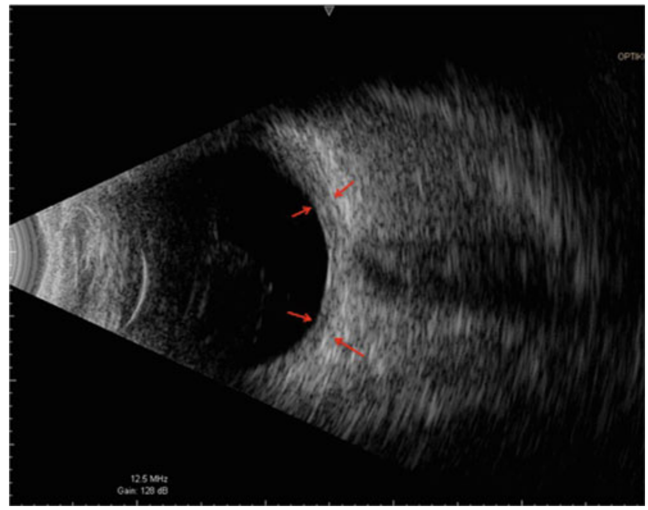

Fig. 10 Retinochoroidal thickness measured with calipers perpendicular to the retinal surface (*red arrows*). Optic nerve is visible in USG image

Case 1: Granulomatous Panuveitis in a 14-Year-Old Girl

A 14-year-old girl presented with decreased vision in both eyes for 1 month with no systemic complaints. At presentation, her best-corrected visual acuity (BCVA) was counting fingers close to face in both eyes. Her intraocular pressure with Goldmann Applanation tonometery was 26 mmHg in both eyes. Anterior segment examination on slit lamp biomicroscopy revealed bilateral panuveitis with iris bombe, iris neovascularization, iris nodules, and granulomatous keratic precipitates (arrow) (Fig. 12). There was no view of the fundus in both eyes. USG of both eyes showed bilateral no to minimal vitreous echoes with retinochoroidal thickening (Fig. 13). Diagnosis of "Probable Vogt Kayanagi Harada disease" was made in both eyes. She received intensive topical betamethasone and mydriatics drops with intravenous methyl prednisolone 1 g for 5 days followed by oral steroids. After 3 months of tapering doses of steroids and immunosuppression, symptoms resolved (Fig. 14) with bilateral sunset glow fundus (Fig. 15) and her BCVA improved to 20/80 in both the eyes.

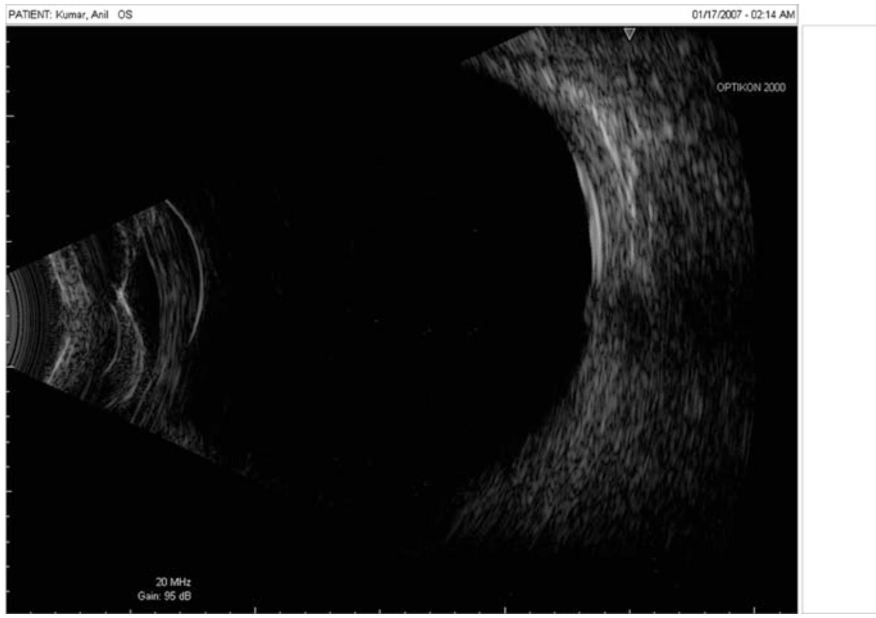

Fig. 11 High-resolution USG with the 20-MHz probe delineates the posterior segment of the eye including the macula (*arrow*) better than 10-MHz probe

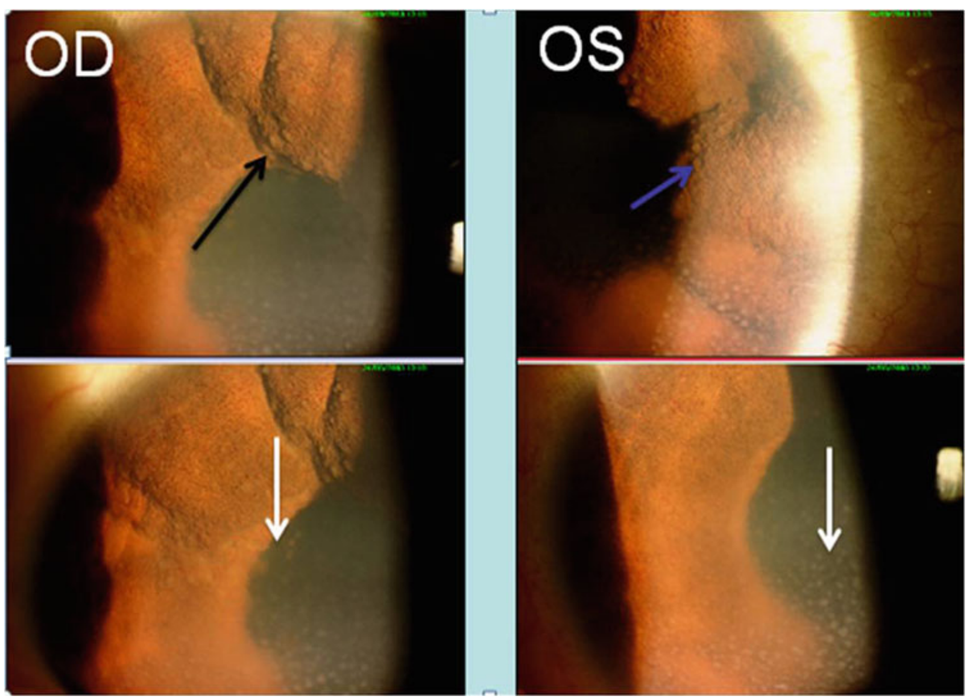

Fig. 12 Anterior segment photograph of both eyes showing mutton fat keratic precipitates on the posterior corneal surface (*white arrows*) with iris nodules (*blue arrow*). Note the presence of iris bombe in all quadrants (*black arrow*)

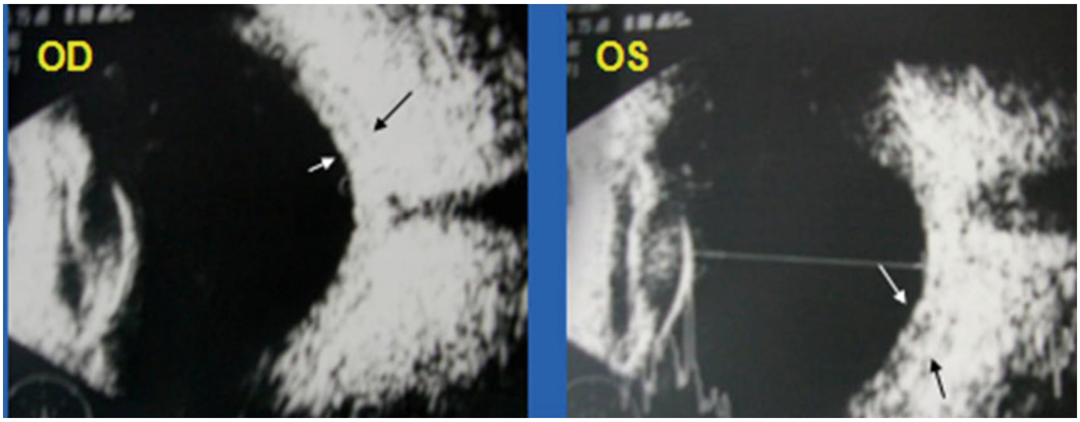

Fig. 13 Ultrasonography revealed bilateral retinochoroidal thickening seen as increased thickness between the hyper reflective retina (*white arrow*) and the posterior layers of choroid (*black arrow*)

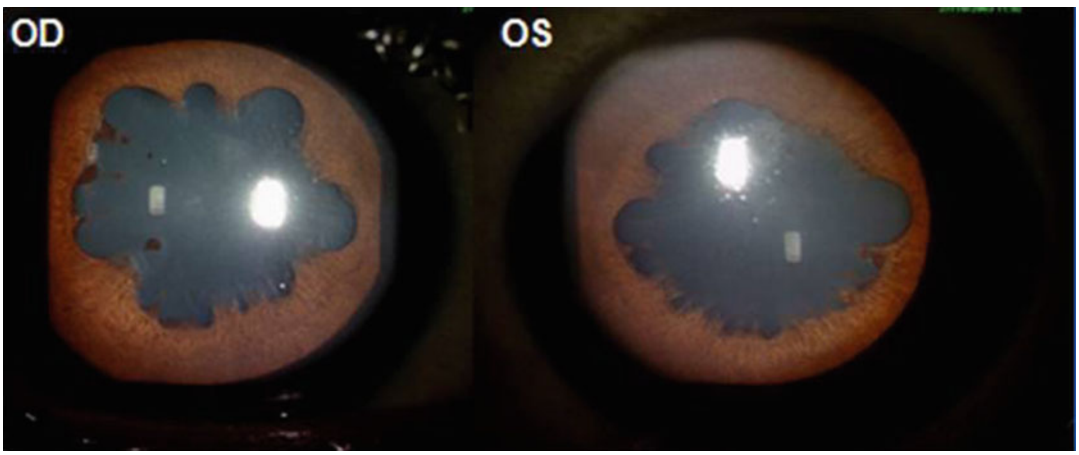

Fig. 14 Anterior segment photograph of the above case showing resolution of inflammation and development of festooned pupil after treatment

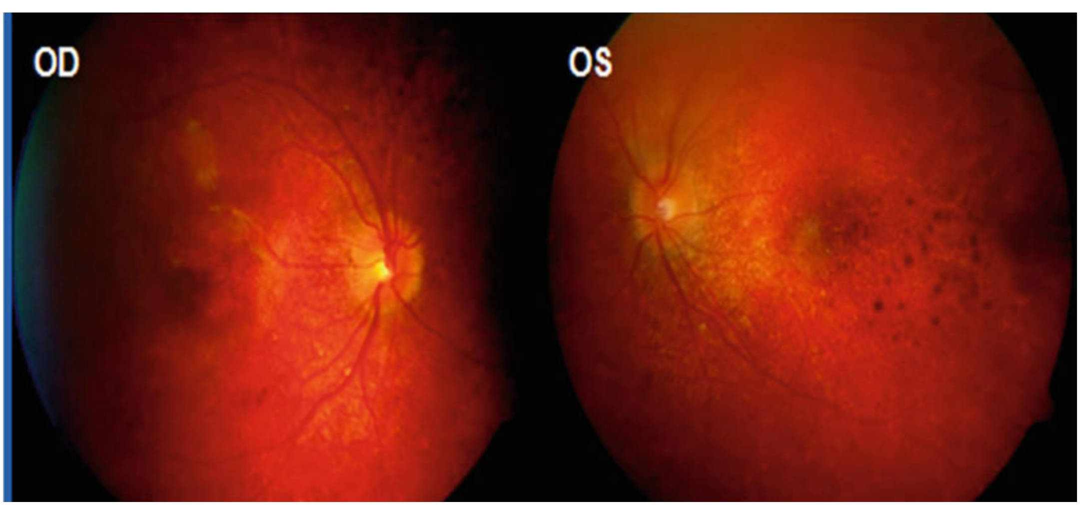

Fig. 15 Posterior segment photograph of the above case showing bilateral sunset glow fundus

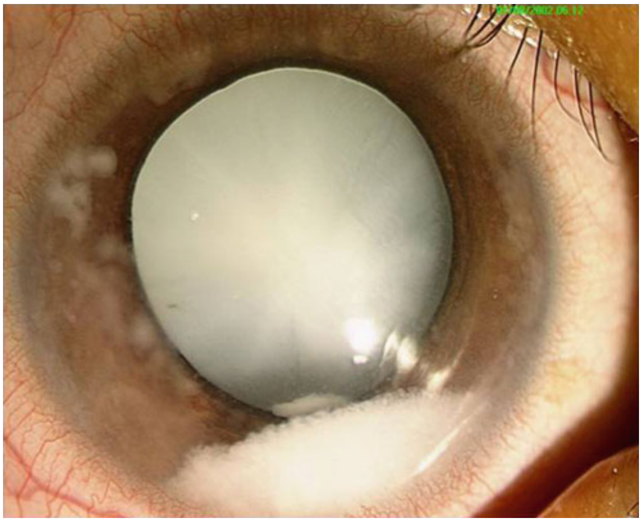

Fig. 16 Anterior segment photograph of the right eye of the patient with total white cataract with ectropion uvea along with large fluffy white cells with hypopyon in the anterior chamber

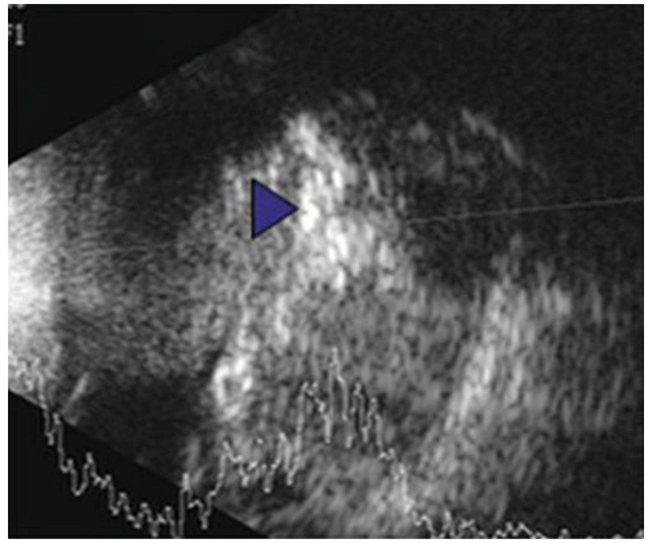

Fig. 17 Ultrasonography revealed mass lesion in the posterior segment along with calcification (*arrow*)

Case 2: Leukocoria with Hypopyon in a 5-Year-Old Girl

A 5-year-old girl presented with a whitish opacity in the right eye. Her parents noticed this opacity 1 month back. At presentation, her best-corrected visual acuity (BCVA) was 20/40 in the right eye and light perception in the left eye. Anterior segment examination on slit lamp biomicroscopy of the left eye revealed a total white cataract with large cells in the anterior chamber with hypopyon (Fig. 16). USG of the left eye was done, as there was no view of the posterior segment. USG revealed mass lesion in the eye along with calcification (Fig. 17). USG helped in clinching the diagnosis of retinoblastoma.

Key Points

- Ultrasound has become a standard tool in the hands of retina and uvea specialists.
- The 10 MHz probe provides an excellent resolution of the posterior segment of the eye quiet well, especially in eyes with poor media.
- Ultrasonography is a reliable tool for the diagnosis and evaluation of intraocular inflammatory conditions, especially in cases where media clarity is poor.
- Ultrasound studies should be used in conjunction with detailed clinical examination in cases of uveitis.

Suggested Reading

Baum G, Greenwood I. The application of ultrasonic locating techniques to ophthalmology. II. Ultrasonic slit lamp in the ultrasonic visualization of soft tissues. Arch Ophthalmol. 1958;60:263–79.

Bronson NR. Development of a simple B scan ultrasonoscope. Trans Am Ophthalmol Soc. 1972;70:365–408.

Hewick SA, Fairhead AC, Culy JC, Atta HR. A comparison of 10 MHz and 20 MHz ultrasound probes in imaging the eye and orbit. Br J Ophthalmol. 2004;88(4):551–5.

Mundt Jr GH, Hughes Jr WF. Ultrasonics in ocular diagnosis. Am J Ophthalmol. 1956;41:488–98.