Vilnius University Press

Contents lists available at Vilnius University Press

Acta Medica Lituanica
2023. Online ahead of print

ISSN 1392-0138 eISSN 2029-4174
DOI: https://doi.org/10.15388/Amed.2023.30.2.9

Utility of High-Resolution Ultrasonography in the Evaluation of Posterior Segment Ocular Lesions Using Sensitivity and Specificity

Deb K. Boruah*
All India Institute of Medical Sciences, Guwahati, Assam, India

Daisy Vishwakarma
Department of Ophthalmology, Assam Medical College & Hospital, Dibrugarh Assam, India

Pallavi Gogoi
Department of Library and Information Science, DHSK College, Dibrugarh, Assam, India

Navneet R. Lal
Department of Radio-diagnosis, Assam Medical College & Hospital, Assam, India

Arup Deuri
Department of Ophthalmology, Lakhimpur Medical College & Hospital, Lakhimpur Assam, India

Abstract. ***Background:*** High-resolution Ultrasound (USG) provides good anatomical details of the ocular posterior segment and depicts the various pathological conditions affecting the ocular posterior segment, which helps ophthalmologists for choosing the best treatment options. This study aims to evaluate the utility of High-resolution Ultrasonography in the Evaluation of Posterior Segment Ocular lesions by using Sensitivity and Specificity.

Materials and Methods: A hospital-based retrospective study enrolled 81 patients in a tertiary care hospital. Clinical and ophthalmological examinations were performed followed by USG of the orbits. B-mode USG was done with a 7.5–13 MHz linear probe. The final diagnosis was made by correlating the USG findings with clinical and ophthalmological examinations.

Statistical analysis: Sensitivity, specificity, the positive predictive value, the negative predictive value, and the accuracy of B-scan USG were compared with the ophthalmological findings by using the Chi-square test.

Results: Of 81 patients (n=48 males and n=33 females) with a mean age of 38.98 ± 16.48 [SD] years, posterior segment ocular lesions in association with cataracts were found in 27 (33.3%) patients, whereas 14 (51.9%) patients had posterior vitreous detachment (PVD), 10 (37%) patients had retinal detachment (RD), and 1 (3.7%) patient had choroidal detachment (CD). Posterior segment ocular pathologies were found in 17 (21%) patients with blunt ocular injuries, whereas 8 (47.1%) patients had PVD, 4 (23.5%) patients had RD and 4 (23.5%) patients had CD. The ocular USG had a sensitivity of 87.32%, specificity of 80%, and accuracy of 86.42% with a statistically significant difference between the USG findings and the Ophthalmology diagnosis of the posterior segment ocular abnormalities of a *p*-value of 0.0005.

Conclusion: High-resolution ultrasound is one of the best and an easily available imaging modality for the evaluation of posterior segment ocular pathologies, especially in the presence of opaque ocular media.

Keywords: ultrasonography (USG), posterior segment, posterior vitreous detachment (PVD), retinal detachment (RD), choroidal detachment (CD)

* Corresponding author: Deb K. Boruah, All India Institute of Medical Sciences, Guwahati, Assam, India. E-mail: debpal8028@gmail.com

Received: 16/04/2023. **Revised:** 08/06/2023. **Accepted:** 08/06/2023

Aukštos raiškos ultragarso naudingumas vertinant užpakalinio akies segmento pažeidimus: jautrumas ir specifiškumas

Santrauka. ***Kontekstas.*** Aukštos raiškos ultragarsas (trumpinama USG) suteikia kokybišką ir detalią anatominę informaciją apie užpakalinį akies segmentą bei parodo įvairias patologines būkles, paveikiančias užpakalinį akies segmentą. Tai teikia galimybę oftalmologams pasirinkti geriausią gydymo variantą. Šiuo tyrimu siekiama įvertinti, kiek naudingas aukštos raiškos ultragarsas, vertinant užpakalinio akies segmento pažeidimus, ir kaip tai atspindi jautrumas ir specifiškumas.

Medžiagos ir metodai. Ligoninėje (tretinio lygmens medicinos įstaigoje) atliktas perspektyvusis tyrimas, kuriame dalyvavo 81 pacientas. Atlikti klinikiniai ir oftalmologiniai akių tyrimai, po kurių buvo atliekamas akiduobės USG. B režimo USG buvo atliktas su 7,5–13 MHz linijiniu zondu. Galutinė diagnozė pateikta susiejant ultragarso duomenis su klinikiniais ir oftalmologiniais tyrimais.

Statistinė analizė. Jautrumas, specifiškumas, teigiama nuspėjamoji vertė, neigiama nuspėjamoji vertė ir B režimo USG buvo lyginami su oftalmologinių tyrimų išvadomis pasitelkiant chi kvadrato testą.

Rezultatai. Iš 81 paciento (n = 48 vyrai ir n = 33 moterys), kurių vidutinis amžius 38,98 ± 16,48 [SD] metai, užpakalinio akies segmento pažeidimai, susiję su katarakta, buvo nustatyti 27 (33,3 %) pacientams, o 14 (51,9 %) pacientų nustatyta užpakalinė stiklakūnio atšoka (trumpinama PVD), 10 (37 %) pacientų buvo tinklainės atšoka (trumpinama RD), o 1 (3,7 %) pacientui nustatyta choroidinė atšoka (trumpinama CD). Užpakalinio akių segmento patologija nustatyta 17 (21 %) pacientų, kurie buvo patyrę akių pažeidimus neaštriu daiktu, o 8 pacientams (47,1 %) nustatytas PVD, 4 (23,5 %) pacientams RD bei 4 pacientams (23,5 %) buvo CD. Akių USG jautrumas 87,32 %, specifiškumas siekė 80 %, o tikslumas buvo 86,42 %. Nustatytas statistiškai svarbus skirtumas tarp USG rezultatų ir užpakalinio akies segmento anomalijų oftalmologinės diagnozės; nustatyta *p* vertė 0,0005.

Išvada. Aukštos raiškos ultragarsas yra vienas iš geriausių bei lengvai prieinamas raiškaus vaizdavimo modalumas vertinant užpakalinio akies segmento patologijas, ypač kai akyse yra kokių nors neskaidrių elementų.

Raktažodžiai: ultragarsas (USG), užpakalinis akies segmentas, užpakalinė stiklakūnio atšoka (PVD), tinklainės atšoka (RD), choroidinė atšoka (CD)

Introduction

The posterior segment of the eye is composed of the vitreous cavity, retina, choroid, sclera and episcleral tissue. High-resolution Ultrasonography (USG) provides important information to the ophthalmologist in a variety of ocular diseases in all age groups [1,2]. Ocular USG gives real-time and high-resolution images of the eye and provides better information than CT and MRI for the evaluation of most of the pathologies of the posterior segment of the eye [2].

In presence of opaque media, the high-resolution ocular USG provides important information regarding the status of the posterior segment and various pathologies like retinal, choroidal, vitreous detachments and tumors where clinical and routine ophthalmological examinations are less informative [3]. Ocular USG is the most important imaging modality for providing detailed information of the status of the posterior segment of the eyeball in patients having opaque media in corneal opacities, anterior chambers pathology, dense cataract, vitreous hemorrhage and some inflammatory conditions [1,4]. In such situations ocular USG provides details of the posterior segment disease conditions and helps in choosing different treatment options for the ophthalmologist.

Dynamic ocular USG is vital in distinguishing various ocular conditions like vitreous, retinal and choroidal detachments [5]. The anterior segment ocular globe pathologies of the cornea, anterior chamber, iris, posterior chamber and lens can be detected by ophthalmologist either clinically or with help of ophthalmoscopy, slit lamp examination and US biomicroscopy [6,7]. However, high-resolution ocular USG provides very clear and distinct information on disease processes affecting the posterior segment of the eye. Even in the presence of clear media, high-resolution ocular USG

provides important information in the evaluation of intraocular tumors, choroiditis and retinitis [1]. Using color Doppler helps in the evaluation of a suspected case of central retinal vessels occlusion, inflammatory condition, diabetes, characterizing and differentiating various intraocular tumors also [4,8,9]. Color Doppler imaging (CDI) and pulse wave (PW) Doppler are helpful in differentiating membrane/band or detachment in the posterior segment of eyeball. Though cataract detection is primarily not an indication for ocular USG, but the assessment of the posterior segment of the eyeball is important in cataractous patients to rule out associated posterior segment pathologies which fail to be detected by ophthalmoscope [5,10].

This study aims to evaluate the added value of high-resolution Ultrasonography in the evaluation of Posterior Segment Ocular lesions.

Materials and Methods

After approval from the institutional ethics review committee, a hospital-based retrospective study was conducted in a tertiary care hospital in Northeast India from June 2018 to July 2021. Clinical and ophthalmological examinations were performed in the department of Ophthalmology in all patients before undergoing B-mode USG. USG was done in Aplio-500 (Toshiba Medical Systems Corporation, made in Tokyo, Japan) machine using a 7.5–13 MHz linear probe. Informed consent was obtained from all patients before undergoing ocular USG (Figure 1).

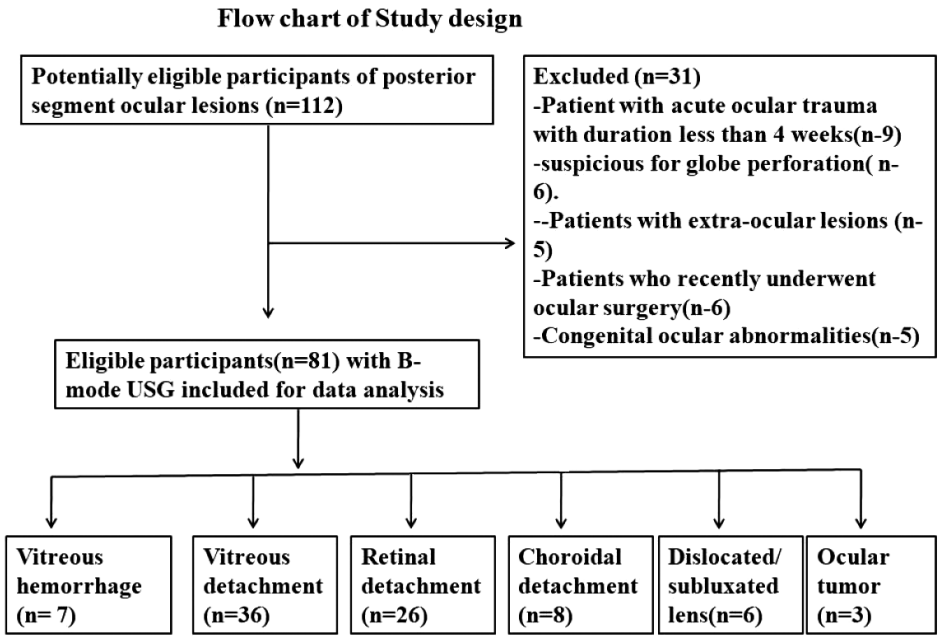

Figure 1. Flowchart of the study design.

Patient selection

Inclusion Criteria:

1. Patients clinically suspected to have posterior segment ocular lesions in the presence of clear or opaque conducting media on ophthalmological examinations.
2. Patient presents with proptosis.
3. Patient with suspected intraocular tumor.

Exclusion Criteria:

1. Patients with acute ocular trauma with a duration of less than 4 weeks.
2. Patient is suspicious for globe perforation.

3. Patients with extra-ocular lesions.
4. Patients who recently underwent ocular surgery.
5. Congenital ocular abnormalities.

The ocular ultrasound was performed on a patient in a supine position with closed eyelids after the application of adequate coupling gel. The ocular globes were scanned initially in a neutral position. The neutral USG imaging was started with axial sections from the upper to lower pole of the entire globes, sagittal sections from the temporal to the nasal side and sometimes oblique images of ocular globes. During dynamic examinations of ocular globes, patients are asked to move their eyes from right to left, up and down without opening their eyelids. Dynamic ocular USG examinations were performed in suspected patients of vitreous, choroidal or retinal detachments.

Sonographic evaluation of the posterior segment of the eyeball

The USG diagnosis was made based on features of location, morphology, echopattern, acoustic nature of the lesion and kinetics of the lesion during eye movements. Color Doppler imaging (CDI) and Pulse wave (PW) Doppler imaging were done for posterior segment neomembrane/band or retinal/choroidal detachment and look for color and pulse wave Doppler parameters and compared with the central retinal artery and ciliary arterial flow. The USG findings were compared with the ophthalmological examination findings. The final diagnosis was made by correlating ocular USG findings with clinical, ophthalmoscopic examination findings, follow-up or cross-sectional imaging findings.

Statistical analysis

Data were presented in terms of mean and percentage. Calculations were done using SPSS programs (Statistical Package for the Social Science version 16, SPSS Inc., Chicago, USA). We calculate the sensitivity, specificity, positive predictive value, negative predictive value and accuracy of B-scan USG compared with the ophthalmologist's final diagnosis by using the Chi-square test.

Results

Demography and clinical profile

The study sample comprised of 81 patients (n=48 males and n=33 females) with a mean age of 38.98 ± 16.48 [SD] years and a male:female ratio of 1.45:1. The maximum posterior segment ocular abnormalities were observed in 21 (25.6%) patients in the 41–50 years age group followed by 17 (21%) patients in the 31–40 years age group. A history of ocular injury more than 4 weeks was found only in 17 (21%) patients. Clinically 61 (75.3%) patients presented with decreased vision, 13 (16%) patients with loss of vision, redness and preorbital swelling in 6 (7.4%) patients and leukocoria in 1 (1.2%) patient. Ocular USG was indicated for the assessment of the vitreous cavity in 55 (67.9%) patients, opaque media in 23 (28.4%) patients and suspected ocular mass lesion in 3 (3.7%) patients.

Ocular USG findings

Table 1 shows the various posterior segment ocular abnormalities in our study sample. The maximum number of ocular abnormalities observed in this study sample is made of multiple combined ocular pathologies in 18 (22.2%) patients, followed by isolated retinal detachment in 17 (21%) patients, vitreous detachment (Figure 2 A-F) with cataracts in 11 (13.6%) patients, isolated vitreous detachment in 10 (12.3%) patients and retinal detachment (Figure 3 A-C) with cataract in 8 (9.9%) patients as shown in Table 1.

T**able 1.** Distribution of various posterior segment ocular pathologies in 81 patients.

Ocular abnormality	Total abnormalities	Right Ocular abnormalities (n=47)	Left Ocular abnormalities (n=44)
Dislocated/subluxated Lens + Vitreous Hemorrhage + Vitreous detachment	6(7.4%)	5(6.2%)	1(1.2%)
Vitreous Hemorrhage + Vitreous detachment	1(1.2%)	1(1.2%)	0
Vitreous detachment + cataract	11(13.6%)	6(7.4%)	5(6.2%)
Vitreous detachment	10(12.3%)	6(7.4%)	4(4.9%)
Asteroid Hyalosis	4(4.9%)	3(3.7%)	1(1.2%)
Retinal detachment	17(21%)	8(9.9%)	9(11.1%)
Retinal detachment with cataract	8(9.9%)	4(4.9%)	4(4.9%)
Retinoblastoma	1(1.2%)	1(1.2%)	0
Choroidal detachment	2(2.5%)	1(1.2%)	1(1.2%)
Choroidal detachment + Osteoma	1(1.2%)	1(1.2%)	0
Choroidal Osteoma	1(1.2%)	1(1.2%)	0
Choroidal mass	2(2.5%)	0	2(2.5%)
Optic nerve Drusen	3(3.7%)	1(1.2%)	2(2.5%)
Ophthalmitis (Pan/endopthalmitis)	6(7.4%)	2(2.5%)	4(4.9%)
Multiple combined pathologies	18(22.2%)	7(8.6%)	11(13.6%)

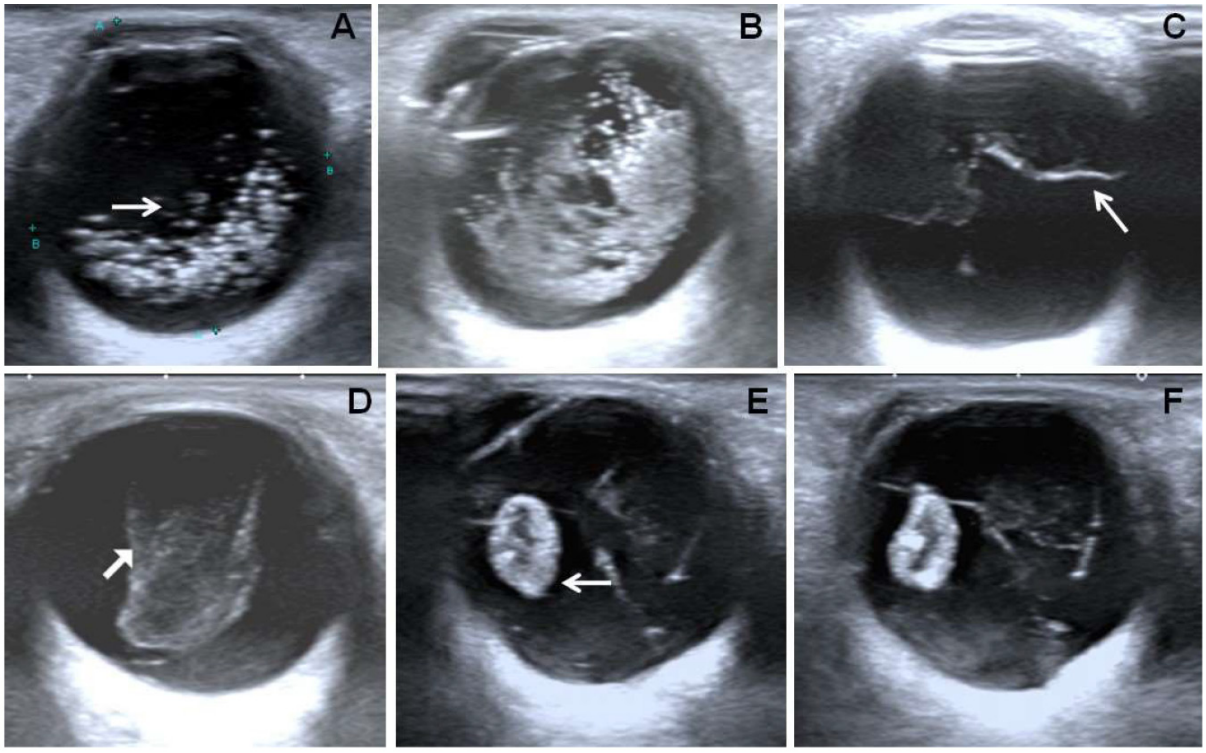

Figure 2. 62 years female with gradual progressive visual loss in both eyes, the (A & B) USG images of right as well as left orbital globes showed extensive echogenicities of **asteroid hyalosis** within the vitreous cavities, more on the left side with a mild form of bilateral posterior vitreous detachment. 46 years male patient with gradual visual loss in both eyes, (C&D) USG images showed right-sided partial and left-sided complete posterior vitreous detachment (arrows). Another 55 year female patient with 2 months old history of left ocular injury with visual loss, the (E &F) USG images of the left orbital globe showed **dislocated lens** (arrow) with irregular echogenic chronic **vitreous hemorrhage** and neomembrane formation.

Laterality and primary location of ocular pathologies

Involvement of the right eyeball was observed in 37 (45.7%) patients, the left eyeball in 34 (42%) and both eyeballs in 10 (12.3%) patients. Isolated vitreous cavity involvement was observed in 32 (39.5%) patients, retina in 21 (25.9%) patients (Figure 3 D-E), choroid in 5 (6.2%) patients and optic nerve head in 3 (3.7%) patients. Involvement of multiple ocular coats or structures was observed in 20(24.7%) patients (Figure 3 F). Single ocular coat or structure involvement was observed in 34 (42%) patients, two ocular coats or structures in 29 (35.8%) patients, three in 15 (18.5%) patients and four in 3 (3.7%) patients.

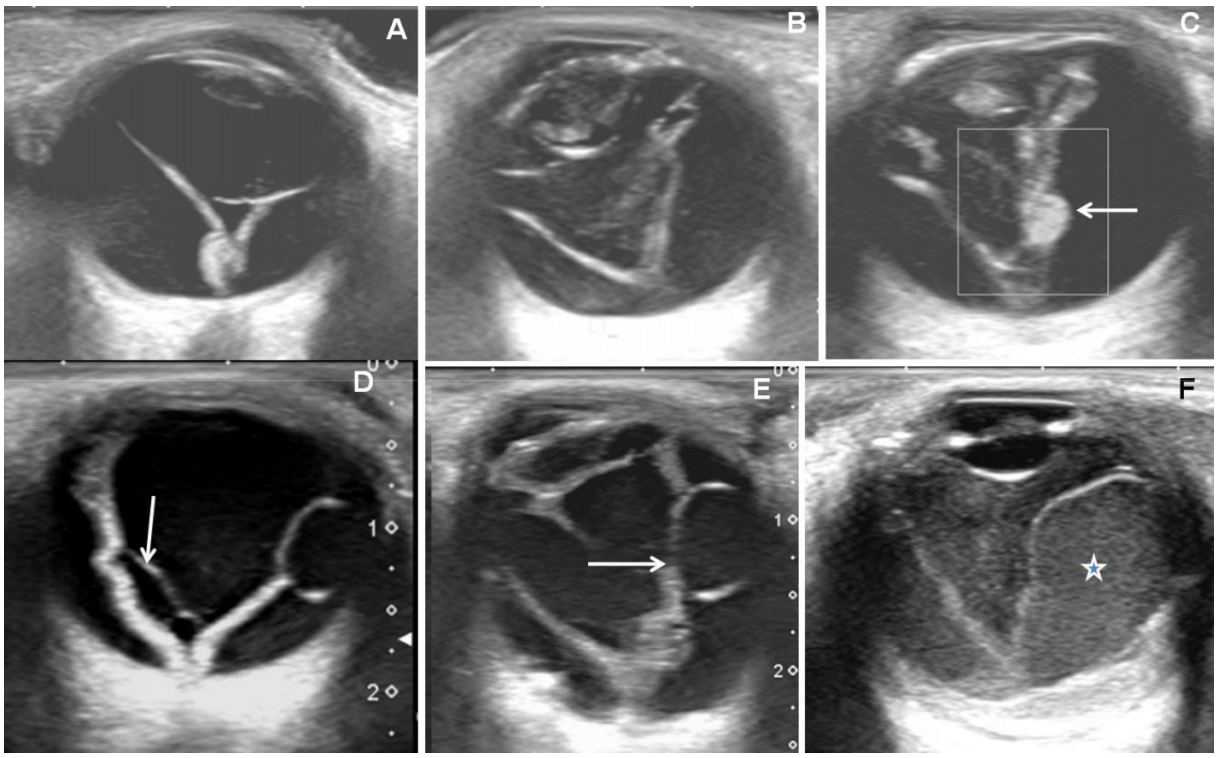

Figure 3.10 years male with visual loss in the left eye**,** the (A, B &C) USG images of left orbital globe showed "V-shaped" **retinal detachment with smaller echogenic nodular lesions** within the detached retina (arrow). 67 years male patient with complete right-sided visual loss, the (D & E) images showed rhegmatogenous retinal detachment with multiple echogenic neomembranes (arrow in image D) and cystic changes within the detached retina (arrow in image E). Another 22 years female patient with redness, pain, and visual loss on the left side**,** the (F) USG image of left orbital globe showed iso-echoic to slight echogenic debris within the vitreous cavity (*) with the presence of retinal detachment and thickening sclera of **Panophthalmitis.**

Ocular USG findings in association with cataracts

27 (33.3%) patients with posterior segment ocular lesions associated with cataracts. 14 (51.9%) patients of cataracts associated with posterior vitreous detachment (PVD), 10 (37%) patients with retinal detachment (RD) and 1 (3.7%) patient with choroidal detachment (CD). No statistically significant difference was found between the RD, PVD and CD in presence of cataracts as shown in Table 2.

Table 2. High resolution ocular USG findings of posterior segment ocular detachments in association with cataract and ocular trauma.

Posterior segment lesion	Total cases (n/%)	Presence of Cataract	No cataract	p-value (Chi-square)	History of Injury	No Injury	p-value (Chi-square)
Retinal detachment (RD)	26(32.1%)	10(37%)	16(29.6%)	0.615	4(23.5%)	22(34.4%)	0.561
Posterior vitreous detachment (PVD)	36(44.4%)	14(51.9%)	22(40.7%)	0.356	8(47.1%)	28(43.8%)	1
Choroidal detachment(CD)	8(9.9%)	1(3.7%)	7(13%)	0.258	4(23.5%)	4(6.3%)	0.05

Ocular USG findings in association with ocular injury

17 (21%) patients with posterior segment ocular lesions associated with blunt ocular injuries. 8 (47.1%) patients were associated with posterior vitreous detachment (Figure 2 E-F), 4 (23.5%) patients with retinal detachment and another 4 (23.5%) patients with choroidal detachment (Figure 4 A-D). No statistically significant difference was found between the RD and PVD with blunt ocular trauma, however statistical significance difference (p-value 0.05) was found between the CD and ocular trauma, shown in Table 2.

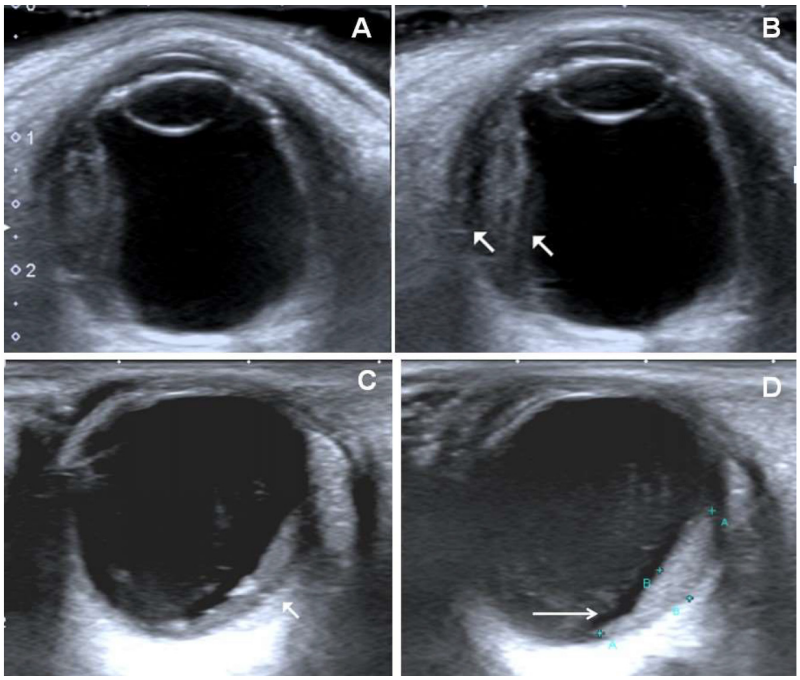

Figure 4. 34 years female with post-traumatic gradual visual loss in right eye the (A&B) USG images of right orbital globe showed choroidal detachment in temporal side with iso-echoic to echogenic **subchoroidal hematoma** (arrows). Another 45 years male patient with post-traumatic left-sided visual loss**,** the (C & D) USG images of left orbital globe showed an irregular outlined lesion of choroidal hematoma in the temporal side of the choroid with echogenic foci within (thin arrow in image C) and associated choroidal detachment (arrow in image D).

Color Doppler Imaging (CDI) and Pulse wave (PW) Doppler imaging of posterior segment neomembrane/band or retinal/choroidal detachment

Color and pulse wave Doppler were performed in the posterior segment neomembrane/band or retinal/choroidal detachment. Out of 26 (32.1%) patients with retinal detachment, 21 (25.9%) patients showed color uptake with a similar spectral flow pattern of the central retinal artery. In 8 (9.9%) patients of choroidal detachments, 5 (6.2%) patients showed color uptake with a similar spectral flow pattern of the ciliary artery.

Sensitivity and specificity of B-scan ocular USG

The various B-mode ocular USG findings were compared with ophthalmological findings. The B-mode ocular USG had a sensitivity of 87.32% with a 95% confidence interval of 77.30–94.04%, specificity of 80% with a 95% confidence interval of 44.39–97.48%, positive predictive value of 96.88% with 95% confidence interval of 89.95%-99.08%, negative predictive value of 47.06% with 95% confidence interval of 30.95–63.08% and accuracy of 86.42% with 95% confidence interval of 77–93.02%. There was a statistical significance between the difference between the B-mode USG findings and ophthalmology diagnosis of posterior segment ocular abnormalities of a (*P*-value 0.0005), shown in Table 3.

Table 3. Comparison between the B-mode USG findings and ophthalmology diagnosis of posterior segment ocular abnormalities in 81 patients.

Test Results	Value	Confidence Interval(CI)	p-value (Chi-square)
Sensitivity	87.32%	77.30–94.04%	0.0005
Specificity	80%	44.39–97.48%	
Positive Predictive value	96.88%	89.95–99.08%	
Negative Predictive value	47.06%	30.95–63.08%	
Accuracy	86.42%	77–93.02%	

Discussion

The pathologies of the cornea, anterior chamber, iris, posterior chamber and lens are usually evaluated with clinical inspection, ophthalmoscopy, slit-lamp examination and less frequently require B-mode ultrasonography [6,7]. High-resolution ocular Ultrasonography is proved to be an important tool in the diagnosis of various posterior segment ocular pathologies. Ocular USG is the investigation of choice for the evaluation of posterior segment ocular pathologies in patients with dense opaque media. Its noninvasiveness, cost-effectiveness and no radiation exposure had various added advantages. Various nontraumatic pathologies affect the posterior segment of the orbital globe including congenital, infective, inflammatory, vascular, neoplastic and degenerative conditions, where ocular USG plays an important role, not in diagnosis but also in post-treatment follow-up. The most common nontraumatic posterior segment ocular lesions detected on B-mode USG included retinal detachment, vitreous hemorrhage, posterior vitreous detachment and neoplasm [11].

Lens pathology: Cataract changes occur commonly in the older age group due to degenerative changes. Cataract in young patients occurs due to congenital cataracts, secondary to trauma or infection. In our study sample, 27 (33.3%) patients with posterior segment ocular lesions associated with cataracts. In partial lens dislocation, the lens remains attached to the ciliary body while in a complete dislocation, the lens sinks into the vitreous cavity. Post-traumatic lens dislocation is commonly associated with vitreous hemorrhage [12]. In our study sample, 6 (7.4%) patients had subluxated / dislocated lenses with vitreous hemorrhage and vitreous detachment.

Vitreous pathology: Asteroid hyalosis**,** which is characterized by fine echogenic opacities within the vitreous cavity, is seen on B-mode ultrasound because of fatty calcium soap deposits and which produce a sparkling appearance [7,13]. Vitreous hemorrhage is one of the most common pathologies of posterior segment ocular lesion, which may occur due to vasoproliferative disease (diabetic retinopathy), posterior vitreous detachment, age-related macular degeneration and trauma. B-mode USG shows initial echogenic contents within the vitreous cavity and with the subsequent organization of hemorrhage leading to neomembrane formation. Long-standing vitreous cavity membrane

adherent to the retina might cause tractional retinal detachment and in such a situation vitrectomy is required [3,13,14]. In posterior vitreous detachment (PVD), the posterior vitreous capsule detaches from the retina and appears as an undulating membrane that moves freely during dynamic B-mode ocular USG and should swirl away from the optic disc region [3,13]. In our study sample, vitreous hemorrhages were found in 7 (8.6%) patients. Incidence of nontraumatic vitreous hemorrhage was found by Haile M et al. [15] in 2.5% of patients and by Qureshi MA et al. [16] in 3% of patients. But in our study sample out of 7 (8.6%) patients with vitreous hemorrhage, 6 (7.4%) patients had a post-traumatic vitreous hemorrhage and only 1 (1.2%) patient had a nontraumatic vitreous hemorrhage. Qureshi MA et al. [16] found an incidence of PVD in 2% of patients. In our study sample, 36 (44.4%) patients had vitreous detachment without history of trauma in 28 patients.

Retinal pathology: Previous studies showed an incidence of retinal detachment (RD) in 3% of patients by Qureshi MA et al. [16], 1.5% by Haile M et al. [15] and 0.94% by Chanchlani M et al. [17]. In our study sample, retinal detachment was found in 26 (32.1%) patients, where 10 (12.3%) patients were associated with cataracts.

Choroidal pathology: In our study sample, the choroidal detachment was found in 8 (9.9%) patients, where 1 (1.2%) patient was associated with choroidal osteoma.

Color Doppler imaging (CDI) and Pulse wave (PW) Doppler were performed in posterior segment ocular neomembrane/band or retinal/choroidal detachment and compared with the central retinal arterial and ciliary arterial flow pattern. The retinal detachment showed a similar spectral flow pattern to the central retinal artery while the choroidal detachment shows a similar to the ciliary artery [18,19]. No color uptake was observed in neomembrane/band of vitreous detachment. In our study sample, 21 (25.9%) patients out of 26 patients of RD showed color uptake with a similar spectral flow pattern of central retinal artery and 5 (6.2%) patients of choroidal detachment out of 8 patients of choroidal detachment showed color uptake with similar spectral flow pattern of a ciliary artery. Uji Y et al. [20] showed a sensitivity of 92.3% and a specificity of 100% to differentiate retinal detachment from vitreous detachment, where color Doppler imaging (CDI) showed color uptake in the retinal detachment and no color uptake in vitreous detachment. A previous study conducted by Akhlaghi M et al. [21] showed a sensitivity of 91.3% and specificity of 88.1% in the detection of retinal detachment with color Doppler imaging (CDI).

Conclusion

Ocular USG should be considered as a first imaging modality for the evaluation of posterior segment ocular lesions. USG is a readily available, cost-effective, nonionizing and reliable imaging modality for the evaluation of ocular lesions. It provides real-time imaging of various ocular pathologies, especially in patients with opaque ocular media. B-scan ocular USG had a higher resolution as compared to both CT and MRI scans for the diagnosis of posterior segment ocular pathologies.

References

1. Byrne SF, Green RL. Physics and instrumentation. In: Byrne SF, Green RL, eds. *Ultrasound of the eye and orbit*. 2nd ed. Mosby; 2002:1-14.
2. Sharma OP. Orbital sonography with it's clinico-surgical correlation. *Indian J Radiol Imaging*. 2005;15(4):537-554. doi:10.4103/0971-3026.28792
3. Aironi VD, Gandage SG. Pictorial essay: B-scan ultrasonography in ocular abnormalities. *Indian J Radiol Imaging*. 2009;19(2):109-115. doi:10.4103/0971-3026.50827
4. Hayden BC, Kelly L, Singh AD. Ophthalmic ultrasonography: Theoretic and practical considerations. *Ultrasound clinics*. 2008;3(2):179-183. doi:10.16966/2639-152X.103

5. Dessi G, Lahuerta EF, Puce FG, Mendoza LHR, et al. Role of B-scan ocular ultrasound as an adjuvant for the clinical assessment of eyeball diseases: A pictorial essay. *J Ultrasound*. 2014;18(3):265-277. doi:10.1007/s40477-014-0153-y
6. Silverman RH. High-resolution ultrasound imaging of the eye - a review. *Clin Experiment Ophthalmol*. 2009;37(1):54-67. doi:10.1111/j.1442-9071.2008.01892.x
7. Bedi DG, Gombos DS, Ng CS, Singh S. Sonography of the eye. *AJR Am J Roentgenol*. 2006;187(4):1061-1072. doi:10.2214/AJR.04.1842
8. Madhpuriya G, Gokhale S, Agrawal A, Nigam P, et al. Evaluation of Hemodynamic Changes in Retrobulbar Blood Vessels Using Color Doppler Imaging in Diabetic Patients. *Life (Basel)*. 2022;12(5):629. doi:10.3390/life12050629
9. Harris A, Guidoboni G, Siesky B, Mathew S, et al. Ocular blood flow as a clinical observation: Value, limitations and data analysis. *Prog Retin Eye Res*. 2020;100841. doi:10.1016/j.preteyeres.2020.10084
10. Silva CT, Brockley CR, Crum A, Mandelstam SA. Pediatric ocular sonography. *Semin Ultrasound CT MR*. 2011;32(1):14-27. doi:10.1053/j.sult.2010.09.005
11. Adebayo SB, Onabolu OO, Bodunde TO, Ajibode HA. Ocular B-scan Ultrasound using non-dedicated Ultrasound system: Preliminary Report from Sagamu. *Nigerian Med Pract*. 2007;52(4):82-84. doi:10.4314/nmp.v52i4.28909
12. Roque PJ, Hatch N, Barr L, Wu TS. Bedside ocular ultrasound. *Crit Care Clin*. 2014;30(2):227-241. doi:10.1016/j.ccc.2013.10.007
13. Arthurs B, Schuler RC, Kreifels W, Suszanski J, et al. Asteroid Hyalosis Seen on Ocular Point-of-Care Ultrasound. *Clin Pract Cases Emerg Med*. 2019;3(3):318-320. doi:10.5811/cpcem.2019.6.42935
14. Fielding JA. The assessment of ocular injury by ultrasound. *Clin Radiol*. 2004;59(4):301-312. doi:10.1016/j.crad.2003.10.010
15. Haile M, Mengistu Z. B-Scan ultrasonography in ophthalmic disease. *East Afr Med J*. 1996;73(11):703-707. https://pubmed.ncbi.nlm.nih.gov/8997857/
16. Qureshi MA, Laghari K. Role of B-Scan Ultrasonography in Pre- Operative Cataract Patients. *Int J Health Sci (Qassim)*. 2010;4(1):31-37. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3068804/
17. Chanchlani M, Chanchlani R. A Study of Posterior Segment Evaluation by B-Scan in Hyper Mature Cataract. *Clin Exp Ophthalmol*. 2016;7(1):516. doi:10.4172/2155-9570.1000516
18. Wu J, Zou L, Wu Z, Cheng L. High frequency color Doppler image of choroidal detachment. *Yan Ke Xue Bao*. 2000;16(1):61-64. https://pubmed.ncbi.nlm.nih.gov/12579732/
19. Ido M, Osawa S, Fukukita M, Sugimoto M, Wakitani Y, Ito Y, et al. The use of colour Doppler imaging in the diagnosis of retinal detachment. *Eye (Lond)*. 2007;21(11):1375-1378. doi:10.1038/sj.eye.6702442
20. Uji Y, Ido M, Osawa S, Fukukita M, Wakitani Y, Itoh Y, et al. The use of color Doppler imaging in the differentiation of retinal detachment from vitreous membrane. *Invest Ophthalmol Vis Sci*. 2004;45(13):2399. https://iovs.arvojournals.org/article.aspx?articleid=2407939
21. Akhlaghi M, Zarei M, Ziaei M, Pourazizi M. Sensitivity, Specificity, and Accuracy of Color Doppler Ultrasonography for Diagnosis of Retinal Detachment. *J Ophthalmic Vis Res*. 2020;15(2):166-171. doi:10.18502/jovr.v15i2.6733