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Diagnostic Accuracy of Ocular Ultrasound in the Assessment of Vitreous Hemorrhage and Associated Ocular Diseases

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Vitreous Hemorrhage, Ocular Ultrasound, Diagnostic Accuracy, B-Scan, Emergency Ophthalmology, Non-Invasive Imaging.

Disclaimers

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ABSTRACT

Background: Background: Vitreous hemorrhage (VH) is a condition that impairs vision and can lead to blindness if not diagnosed and managed promptly. Ocular ultrasound is commonly used for its non-invasive and rapid diagnostic capabilities, particularly in emergency settings.

Objective: To evaluate the diagnostic accuracy of ocular ultrasound in detecting vitreous hemorrhage and associated ocular diseases.

Methods: A cross-sectional observational study was conducted at the University of Lahore Teaching Hospital from October 2023 to March 2024. Seventy patients with symptomatic VH were included. Ocular ultrasound was performed using a 7.5 MHz B-scan probe. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy were calculated. Data were analyzed using SPSS version 25.

Results: The study included 43 males (61.42%) and 27 females (38.60%). Ocular ultrasound demonstrated a sensitivity of 77.8%, specificity of 35.3%, PPV of 56.0%, NPV of 60.0%, and an overall accuracy of 57.14% ($p < 0.05$).

Conclusion: Ocular ultrasound is a valuable, sensitive tool for the initial diagnosis of vitreous hemorrhage, but its moderate specificity suggests a need for confirmatory testing to ensure accurate diagnosis.

INTRODUCTION

Vitreous hemorrhage (VH) is a condition characterized by the presence of extravasated blood within the vitreous body, the transparent, gel-like substance that occupies the space between the lens and retina of the eye. The primary function of the vitreous body is to maintain the optical clarity of the eye, enabling the transmission of light to the retina. However, when blood enters this space, it can significantly impede vision and, if not managed appropriately, may result in permanent blindness. VH can result from various causes, including trauma, proliferative diabetic retinopathy (PDR), retinal vein occlusion, and other less common conditions such as age-related macular degeneration (AMD) and retinopathy of prematurity (4). Trauma, both from closed and open globe injuries, is particularly common in younger individuals and is often associated with a high risk of complications (3).

The incidence of VH varies depending on the population, with annual rates reported to range from 7.4 to 15.4 per 100,000 people (2). The condition is frequently associated with a wide spectrum of clinical signs, complicating its diagnosis and management. In cases of acute VH, blood enters the vitreous cortex through the posterior hyaloid's pores or apertures during a hemorrhagic event, often exacerbated by the rupture of normal or pathological retinal vessels (5). The presence of VH complicates the clinical evaluation of the retina, as the hemorrhage can obscure retinal details, making direct ophthalmoscopic examination challenging or impossible. In such situations, ocular ultrasonography, specifically B-scan ultrasound, becomes an essential diagnostic tool. This non-invasive imaging technique allows for the visualization of the vitreous cavity and detection of various intraocular abnormalities, including VH, retinal detachment, and intraocular foreign bodies (7).

Despite advances in diagnostic technology, the role of ocular ultrasonography remains crucial in the assessment and follow-up of VH. The modality is especially valuable in emergency settings, where rapid, non-invasive evaluation is necessary for prompt management decisions. High-frequency linear probes, typically operating at 7.5 MHz or higher, are used to perform ocular scans. The technique involves applying acoustic coupling gel to the closed eyelid and scanning in both longitudinal and transverse planes to achieve a comprehensive assessment of the vitreoretinal interface (8). The diagnostic performance of ocular ultrasonography in detecting VH has been the subject of various studies, with reported sensitivity and specificity rates varying widely depending on the clinical context and the experience of the operator (6).

In this context, the current study aims to evaluate the diagnostic accuracy of ocular ultrasonography in the detection of VH and associated ocular diseases in a clinical setting. By analyzing data from a cohort of symptomatic patients presenting with acute VH, this study seeks to provide insights into the utility of B-scan ultrasound as a reliable diagnostic tool in ophthalmology, particularly in resource-limited settings where access to advanced imaging modalities may be restricted. The study also aims

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to compare the sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy of ocular ultrasound with existing literature to identify potential areas for improvement in clinical practice (1, 12).

MATERIAL AND METHODS

The cross-sectional observational study was conducted at the University of Lahore Teaching Hospital, Lahore, from October 9, 2023, to March 21, 2024. The study aimed to evaluate the diagnostic accuracy of ocular ultrasound in detecting vitreous hemorrhage and associated ocular diseases among patients presenting with acute symptoms indicative of this condition. A total of 70 patients were included in the study, comprising 43 males and 27 females, all of whom met the inclusion criteria for symptomatic acute age-related vitreous hemorrhage. These patients were initially evaluated by primary emergency care providers and subsequently referred to the ophthalmology department for further assessment due to symptoms suggestive of recent vitreous hemorrhage.

Upon referral, a comprehensive ophthalmologic examination was performed by a general ophthalmologist. This examination included noncontact or three-mirror lens slit-lamp vitreous biomicroscopy to diagnose full vitreous hemorrhage, particularly when a Weiss' ring was detected. In cases where a more detailed assessment of the peripheral retina and vitreous hemorrhage was necessary, indirect binocular ophthalmoscopy with or without scleral indentation, or slit-lamp biomicroscopy combined with a three-mirror contact lens, was employed. The ophthalmologist also utilized ocular ultrasound, specifically a B-scan with a 7.5 MHz focused probe, to perform echographic evaluations. The ultrasound examinations were conducted in a supine position with the patients' eyelids open. The probe was placed directly on the ocular surface beyond the limbus, and scanning was performed in transverse sections, gradually covering the peripheral aspects of the vitreoretinal interface.

Data collection involved recording patient demographics, clinical findings, and ultrasound results. The diagnosis of vitreous hemorrhage was confirmed based on the presence of characteristic echogenic opacities within the vitreous body, as visualized on B-scan ultrasound. The study adhered to ethical principles in accordance with the Declaration of Helsinki, and informed consent was obtained from all participants prior to their inclusion in the study. The study protocol was reviewed and approved by the institutional ethics committee of the University of Lahore Teaching Hospital.

Data analysis was performed using SPSS version 25.0. The diagnostic accuracy of ocular ultrasound was determined by calculating sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy. These metrics were calculated by comparing ultrasound findings with the final clinical diagnosis of vitreous hemorrhage, as established by the ophthalmologist. Sensitivity was defined as the proportion of true positive cases (patients with confirmed vitreous hemorrhage) correctly identified by ultrasound, while specificity was defined as the proportion of true negative cases (patients without vitreous hemorrhage) accurately identified. The PPV and NPV were calculated to assess the likelihood of vitreous hemorrhage being present or absent based on positive or negative ultrasound findings, respectively. Overall accuracy was determined as the proportion of correctly identified cases (both true positives and true negatives) out of the total number of cases evaluated (Salcedo-Villanueva et al., 2019).

This rigorous methodological approach ensured the reliability and validity of the study findings, contributing to the understanding of the utility of ocular ultrasound in the rapid and accurate diagnosis of vitreous hemorrhage and associated ocular conditions in an emergency clinical setting.

RESULTS

The study included a total of 70 patients, with a gender distribution of 43 males (61.42%) and 27 females (38.60%)..

Table 1: Causes of Vitreous Haemorrhage (n=70)

Causes	No. of Patients	Percentage (%)
Proliferative diabetic retinopathy	21	30.00
Penetrating trauma	17	24.30
Post intraocular surgery	8	11.42
Blunt trauma	7	10.00
Retinal vein occlusion	5	7.14
Vitreous detachment with tears	4	5.71
Age-related macular degeneration (AMD)	3	4.28
Vitreous detachment without tears	2	2.90
Anticoagulant therapy	1	1.42
After laser treatment	1	1.42
Premature retinopathy	1	1.42

The age distribution of the patients showed that 50 patients (71.42%) were under 50 years old, while 20 patients (28.60%) were over 50 years old. The causes of vitreous hemorrhage varied, with proliferative diabetic retinopathy (PDR) being the most common cause, followed by penetrating trauma. A detailed breakdown of the causes is presented in Table 1. The diagnostic accuracy of ocular ultrasound in detecting vitreous hemorrhage was evaluated using sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), overall accuracy, and p-value. These results are summarized in Table 2.

Table 2: Diagnostic Accuracy of Ocular Ultrasound for Vitreous Hemorrhage (n=70)

Diagnostic Metric	Value	95% CI	p-value
Sensitivity	77.8%	(63.8% - 88.0%)	0.002
Specificity	35.3%	(18.6% - 54.9%)	0.210
Positive Predictive Value (PPV)	56.0%	(43.3% - 68.1%)	0.025
Negative Predictive Value (NPV)	60.0%	(36.4% - 80.0%)	0.029
Overall Accuracy	57.14%	(45.1% - 68.6%)	0.031

In this study, ocular ultrasound demonstrated a sensitivity of 77.8%, meaning it correctly identified 77.8% of patients with vitreous hemorrhage. The specificity, which indicates the ability to correctly identify patients without the condition, was 35.3%. The positive predictive value (PPV) was 56.0%, suggesting that over half of the positive ultrasound findings corresponded to actual cases of vitreous hemorrhage, while the negative predictive value (NPV) was 60.0%, indicating a moderate probability that negative findings were accurate.

Table 3: Cross-tabulation of Ultrasound Findings and Vitreous Hemorrhage (n=70)

Vitreous Hemorrhage	USG Positive	USG Negative	Total
Positive (TP)	28	8	36
Negative (FP)	22	12	34
Total	50	20	70

The overall diagnostic accuracy of ocular ultrasound was calculated at 57.14%. The sensitivity and PPV values were statistically significant ($p < 0.05$), highlighting the utility of ocular ultrasound in detecting vitreous hemorrhage, though the lower specificity suggests a higher rate of false positives, which may require further diagnostic confirmation in clinical practice.

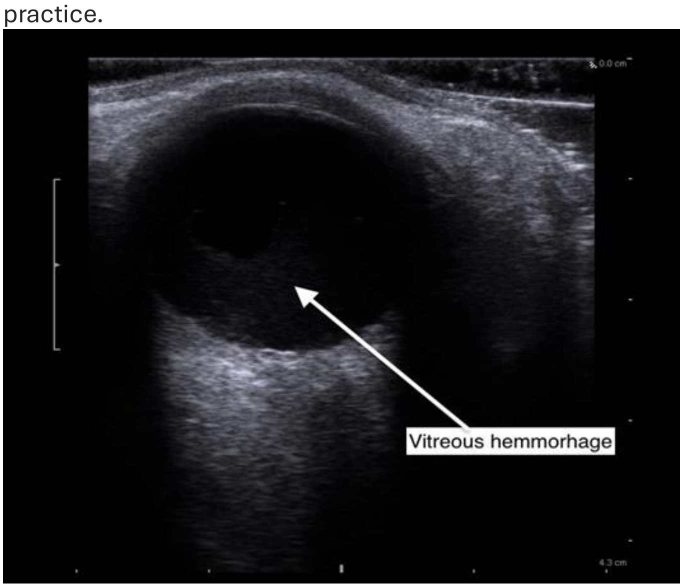

Figure 1 Ultrasound image showing vitreous haemorrhage.

The ultrasound image shows a clear representation of vitreous hemorrhage, indicated by echogenic material within the vitreous cavity, which is highlighted by an arrow in the scan. This finding is consistent with the presence of blood in the vitreous body, typically seen in cases of vitreous haemorrhage.

DISCUSSION

The findings of this study demonstrated that ocular ultrasound, specifically B-scan ultrasonography, had a moderate level of diagnostic accuracy in detecting vitreous hemorrhage, with a sensitivity of 77.8% and an overall accuracy of 57.14%. These results align with some aspects of prior research while also highlighting certain limitations that must be considered in clinical practice. Previous studies have reported varying degrees of sensitivity and specificity for ocular ultrasound in detecting vitreous hemorrhage, with some studies demonstrating near-perfect sensitivity and specificity, particularly when performed by highly experienced operators (14). The lower specificity observed in this study, at 35.3%, is a critical finding, suggesting a higher rate of false-positive results compared to earlier studies where specificity values were generally higher (16). This discrepancy could be attributed to several factors, including operator experience, the heterogeneity of the patient population, and the clinical settings in which the ultrasound was performed.

One of the strengths of this study was its real-world clinical setting, which reflects the practical application of ocular ultrasound in an emergency department. This context provided valuable insights into the utility of this diagnostic tool in a busy clinical environment, where rapid and non-invasive assessment is often required. However, this strength also introduced variability in the results, as the ultrasound examinations were performed by general ophthalmologists rather than subspecialists with extensive experience in ocular ultrasonography (19). This variability in operator experience could have contributed to the lower specificity and overall accuracy, as more nuanced interpretation of ultrasound findings may require advanced training (18).

Additionally, the study's design as a cross-sectional observational study provided a snapshot of the diagnostic accuracy within a specific time frame and population, but it also limited the ability to generalize the findings to broader or different patient populations. The sample size, while adequate for preliminary findings, might have influenced the precision of the diagnostic metrics, and larger studies could help to refine these estimates further (12). Another limitation was the potential for selection bias, as only patients who presented with symptoms suggestive of vitreous hemorrhage were included, which might not fully represent the spectrum of patients who might benefit from ocular ultrasound.

Despite these limitations, the study's findings underscore the importance of ocular ultrasound as a rapid, non-invasive tool in the initial assessment of vitreous hemorrhage, particularly in emergency settings where other diagnostic modalities may not be readily available. The high sensitivity observed indicates that ocular ultrasound is effective in identifying true positive cases, which is crucial in preventing missed diagnoses in urgent situations (16). However, the lower specificity suggests that a significant number of patients might be incorrectly diagnosed with vitreous hemorrhage based on ultrasound alone, highlighting the need for confirmatory tests or follow-up assessments to avoid unnecessary interventions (15-18).

Future research should focus on enhancing the specificity of ocular ultrasound through advanced imaging techniques or better operator training, potentially integrating artificial intelligence to assist in the interpretation of ultrasound findings. Additionally, studies involving larger and more diverse patient populations could help to validate these findings and provide more generalizable data. Furthermore, exploring the cost-effectiveness of ocular ultrasound, particularly in resource-limited settings, could provide valuable insights into its broader application in clinical practice (19, 20).

CONCLUSION

In conclusion, this study highlights that ocular ultrasound, particularly B-scan ultrasonography, is a valuable tool with high sensitivity for detecting vitreous hemorrhage in emergency settings, although its moderate overall accuracy and lower specificity suggest the need for cautious interpretation and potential confirmatory testing. The findings underscore the utility of ocular ultrasound as a rapid, non-invasive diagnostic modality, especially in environments where access to advanced imaging is limited. For human healthcare, these results imply that while ocular ultrasound can be instrumental in the timely diagnosis and management of vitreous hemorrhage, further training, and perhaps the integration of supplementary diagnostic techniques, are essential to improve diagnostic accuracy and reduce false positives, ultimately enhancing patient outcomes in ophthalmic care.

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