

The Evolving Role of Ultrasound in Diagnosis and Treatment of Eye Emergencies: A Narrative Review

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Abstract: In clinical practice, ocular emergencies provide a considerable challenge, typically necessitating prompt and precise diagnosis to avoid irreversible vision impairment. The accessibility, speed, and diagnostic capability of conventional imaging modalities are limited in specific situations, notwithstanding their effectiveness. In the management of ocular emergencies, ultrasound has become a revolutionary technology, providing real-time, non-invasive, and very precise diagnostic and therapeutic possibilities. The present narrative review examines the dynamic nature of ultrasonography in the management of ocular emergencies. It assesses the diagnostic precision, clinical use, therapeutic effectiveness, prospects, and the necessary training for healthcare practitioners. Through the synthesis of existing empirical data, this study emphasizes the capacity of ultrasound to improve patient outcomes and optimize emergency ophthalmic care.

Keywords: ocular emergencies, ultrasound, diagnosis, treatment, clinical applications

Introduction

Ocular emergencies encompass a range of acute disorders that pose a threat to vision and require immediate medical management.¹ Timely and accurate diagnosis is necessary to prevent permanent damage.² Ocular emergencies are categorized into traumatic, infectious, intraocular hemorrhage (specifically vitreous hemorrhage), vascular occlusions, detachments (of the retina, posterior vitreous, and choroidal), central nervous system pathologies, and systemic disorders.³ Ocular emergencies constitute an estimated 1.5–3% of the total number of visits to emergency departments (EDs). Approximately 33% of these visits are specifically associated with traumatic eye injuries.⁴ An estimated 55 million eye injuries occur each year, with 19 million leading to vision impairment or complete loss of eyesight.⁵

Conducting prompt assessments of eye disorders in the emergency department (ED) can be challenging because of a general scarcity of specialized equipment, skilled staff, and the time-critical character of emergency ocular problems.⁶ Ultrasound, specifically ocular ultrasound, has become well-recognized as a flexible and efficient imaging technique in emergency ophthalmology.⁷ The initial use of Point-of-Care Ultrasound (POCUS) in emergency department (ED) patients with acute ocular symptoms was reported by Blaivas et al in 2002.⁸ Several published research have demonstrated that ocular POCUS is an invaluable technique for quickly and precisely diagnosing eye diseases.⁹

This review explores the many aspects of ultrasonography in diagnosing and treating ocular emergencies, including its accuracy, particular applications, effectiveness, potential advancements, and the required training for its best use.

The Diagnostic Accuracy of Ultrasound in Ocular Emergencies

Ultrasound Modalities in Ophthalmology

The three most used forms of ocular ultrasonography are A-scan, B-scan, and ultrasonic biomicroscopy (UBM).¹⁰ An A-scan, also known as an amplitude scan, generates a solitary sound beam that forms a one-dimensional image marked by spikes representing various tissue densities. By way of contrast, a B-scan (or brightness scan) offers a two-dimensional cross-sectional representation of the eye, where reflections of greater amplitude are shown as brighter spots in the recorded image. The UBM system employs a much higher frequency to offer high-resolution cross-sectional imaging exclusively of the anterior segment of the eye.¹¹

Comparative Diagnostic Accuracy of Ultrasound in Ocular Emergencies

Multiple studies have shown that ultrasonography is of comparable or better quality to conventional imaging techniques in the diagnosis of certain eye emergencies.¹² For example, a recent meta-analysis study demonstrated that ocular (POCUS) can be valuable for evaluating different forms of ocular trauma with a high level of specificity and sensitivity.¹³ The sensitivity and specificity found for lens dislocation were 0.97 (95% CI, 0.83–0.99) and 0.99 (95% CI, 0.97–1.00), respectively; for intraocular foreign body 1.00 (95% CI, 0.81–1.00) and 0.99 (95% CI, 0.99–1.00), respectively; and for globe rupture 1.00 (95% CI, 0.63–1.00) and 0.99 (95% CI, 0.99–1.00), respectively. Similarly, ultrasound has proven effective in detecting retinal detachment with a combined sensitivity and specificity of 0.94 and 0.94.¹⁴

Advantages of Ultrasound in Ocular Emergencies Over Traditional Imaging

The application of clinical ultrasonography for ocular pathology has significantly grown in recent years, particularly concerning its diagnostic capabilities in emergency medicine.¹⁵ Ultrasound is a safe non-radiational procedure executed directly at the patient's bedside. The ultrasound eye examination is possible even in cases of substantial eyelid edema and limited patient cooperation, therefore enabling the acquisition of images through closed eyelids.¹⁶ Furthermore, it can offer clinically significant data even in patients for whom fundus examination is difficult or unfeasible (eg, because of anterior chamber opacifications).¹⁷

Identifying Clinical Applications of Ultrasound in Eye Emergencies

Ocular Trauma

Ocular trauma is the most common diagnosis for patients presenting to the ED with ocular complaints; trauma is the leading cause of non-congenital unilateral blindness in children.¹⁸ In the emergency department, ocular trauma often manifests as contusions and lacerations of the ocular adnexa, fractures of the orbital wall, corneal abrasion, vitreous hemorrhage, ruptured globe, and foreign items within the eye or retina.¹⁹ Diagnostic procedures for ocular injuries include computed tomography (CT) and magnetic resonance imaging, all of which are resource-intensive and may necessitate patient cooperation, as well as slit lamp biomicroscopy and ophthalmologic examination. Each of these modalities may be unavailable in settings with limited resources.²⁰ By contrast to conventional imaging methods, POCUS provides a cost-efficient and immediate analysis of cross-sectional pictures of the eye and orbit, even when optically opaque intervening structures are present.²¹

In the identification of intraocular and intraorbital foreign bodies, as well as vitreous and retrobulbar hemorrhages, POCUS can be especially helpful. POCUS can detect ocular foreign objects as echogenic material present in the ocular globe.²² Conducting ocular POCUS with caution is necessary to detect ocular foreign bodies and should be avoided if there is a strong suspicion of intraocular foreign bodies. The detection of a foreign body indicates globe rupture, which requires immediate cessation of ocular POCUS.²³

Typically, hemorrhage is detected on ocular POCUS screening as an irregular collection of blood. The Ocular POCUS technique is highly effective in detecting retrobulbar hematomas, which are distinguished by the presence of an anechoic accumulation of fluid in the retrobulbar space directly behind the eye.²⁴ A “guitar-pick” sign can also be seen when the posterior ocular globe undergoes a conical distortion and bears a resemblance to a guitar pick.¹³ The characteristic manifestation of vitreous hemorrhage is the presence of blurred hyperechoic material in the posterior region, which will

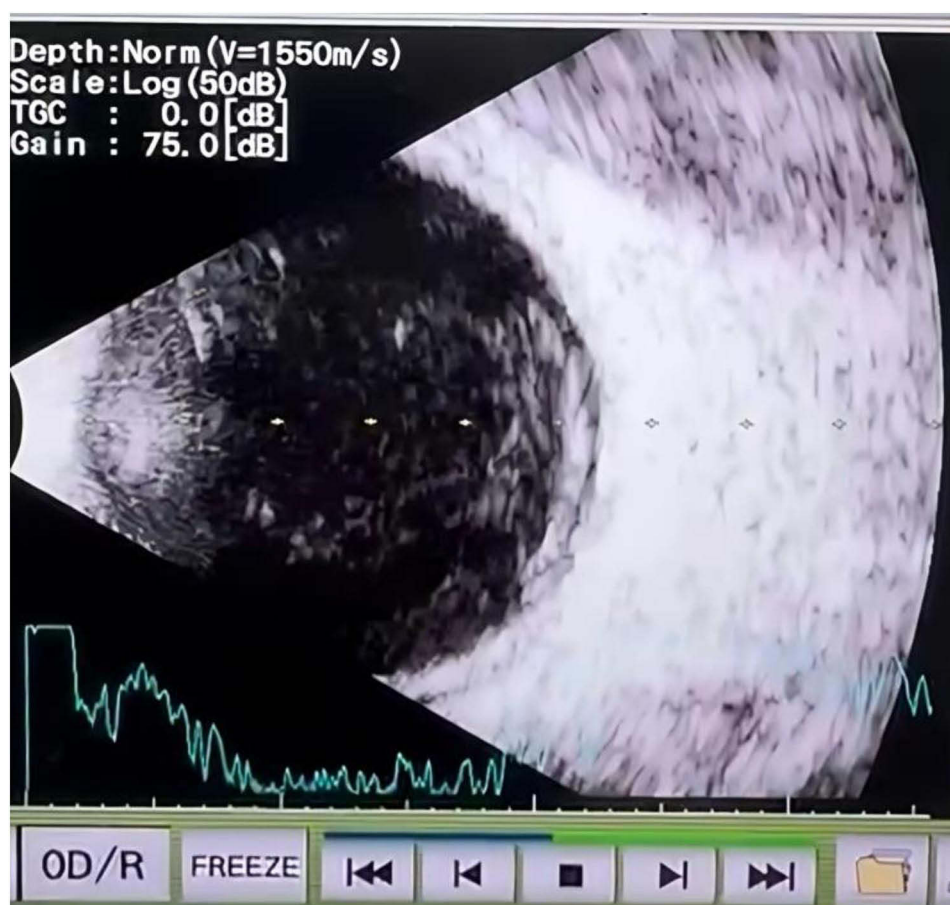


Figure 1 The figure displays an ultrasound image with a normalized depth scale, assuming a sound speed of 1550 m/s, which is typical for soft tissue.

move and change in position alongside eye motion. This occurrence has been denoted as the “snow globe” effect in scientific articles.¹³ [Figure 1](#)

Retinal Detachment (RD)

Retinal detachment (RD) is a critical ocular emergency threatening vision. Patients experiencing retinal detachment frequently arrive at the emergency department with an onset of new floaters, flashes, or more severe unilateral visual impairment, such as a visual loss characterized as a descending curtain.²⁵ Ultrasound plays a crucial role in the diagnosis of retinal detachment, particularly when media opacities restrict fundoscopic examination. The technology can distinguish between different forms of detachments and evaluate their extent and position, therefore directing surgical procedures.⁹ Ultrasound imaging can be used to visualize hemorrhagic changes and exclude the possibility of retinal tears or detachment in cases of vitreous hemorrhage.²⁶ The prompt evaluation, diagnosis, and treatment of a patient presenting with complaints of retinal detachment are necessary to prevent the possibility of irreversible vision impairment.²⁷ The POCUS is a valuable tool in the emergency department for diagnosing retinopathy (RD). It has demonstrated its efficacy as a rapid, precise, and noninvasive approach to promptly exclude or diagnose retinal detachment.²⁸ POCUS assessment of retinal detachment in the emergency department entails the use of a high frequency (7.5–14 MHz) linear-array probe and the closed-eye approach. In individuals in a healthy state, the retina will exhibit hyperechoic characteristics and remain attached to both the choroid and sclera. Under typical gain settings, retinal detachment seen with POCUS will manifest as a hyperechoic ribbon-like structure located anterior to the choroid.²⁹

Acute Glaucoma

Ultrasonography biomicroscopy (UBM) is a crucial method for diagnosing, assessing, and monitoring glaucoma patients. UBM is a crucial technique used to assess the anterior segment of the eye.³⁰ It is particularly important in individuals with opaque corneas when traditional examination techniques are unable to provide many diagnostic insights. Regarding glaucoma patients, UBM can accurately determine the specific kind of glaucoma and its underlying mechanism, formulate a suitable treatment strategy, and monitor the patient's progress. Both primary angle closure glaucoma (PACG) and primary open-angle glaucoma (POAG) patients can have their angle closure mechanism clarified by a UBM.^{31,32}

Central Retinal Artery Occlusions (CRAO)

CRAO is a critical ocular condition marked by the abrupt obstruction of the central retinal artery, the main blood vessel that supplies the retina. Such occlusion results in swift and profound vision impairment in the afflicted eye.³³ The prevalence of CRAO in the United States is estimated to be between 1 to 1.9 per 100,000 individuals, with incidence rising to 10 per 100,000 in persons aged ≥ 80 .³⁴ Doppler ultrasound enhances CRAO diagnosis by demonstrating absent or markedly reduced flow in the central retinal artery, often with compensatory increased flow in the ophthalmic artery. This asymmetry is best observed by comparing the affected eye to the contralateral side.³⁵ In thromboembolic CRAO, Doppler may also reveal atherosclerotic plaques in the carotid or ophthalmic arteries. The POCUS method for CRAO evaluation mirrors RD screening, using a high-frequency linear-array transducer and closed-eye technique. CRAO may be incidentally detected during RD assessment.³⁵ A hyperechoic signal in the optic nerve (the “retrobulbar spot sign” [RBSS]) suggests a fibrin-cholesterol thrombus.³³ Galust et al³⁵ reported that RBSS has a sensitivity of 89% and specificity of 94% for thromboembolic CRAO, though Doppler remains the gold standard for flow assessment. In suspected giant cell arteritis, temporal artery Doppler can complement ocular ultrasound by revealing the “halo sign” (circumferential hypoechoic wall thickening), guiding urgent corticosteroid therapy.^{33,35}

The Efficacy of Ultrasound-Guided Procedures in Treatment

Future Directions and Experimental Techniques

The effective management of eye disease by traditional methods is hindered by the existence of both static and dynamic obstacles, which restrict the efficient penetration of medications delivered topically, orally, and systemically toward the intended therapeutic objectives.³⁶ Emerging research suggests that ultrasound-guided drug delivery could improve the accuracy of drug administration, potentially minimizing complications such as bleeding or retinal damage. Experimental studies indicate that ultrasound may enhance the delivery of macromolecules across various ocular barriers.³⁷ For example, preclinical and early clinical investigations have demonstrated its utility in improving intravenously administered viral delivery to the retina, enhancing steroid transport into the anterior chamber, and facilitating nanoparticle penetration past the inner limiting membrane after intravitreal injection.³⁸ While several studies have explored ultrasound-assisted drug delivery to ocular structures, further research is needed to establish standardized protocols and confirm clinical efficacy, particularly in ED settings.³⁷

Drainage of Hyphema and Vitreous Hemorrhage

Ultrasound-assisted drainage procedures show promise in improving the safety and precision of evacuating hyphema and vitreous hemorrhage. Real-time ultrasonographic imaging may help reduce the risk of iatrogenic damage to ocular tissues during intervention.³⁹ However, current clinical adoption varies, and surgical decision-making remains guided by specific indications. For hyphema, surgical evacuation is typically reserved for cases with complications such as corneal blood staining or uncontrolled intraocular pressure risking optic atrophy.⁴⁰ In vitreous hemorrhage, immediate intervention is warranted if ultrasonography detects concurrent retinal detachment or breaks.²⁵ While ultrasound enhances visualization, its routine integration into drainage procedures requires further validation to establish standardized protocols and confirm long-term outcomes.

Emergency Procedures in Trauma

The use of ultrasound-guided techniques in orbital trauma can effectively aid in the treatment of complicated injuries, such as decompression in orbital compartment syndrome.⁴¹ Orbital compartment syndrome (OCS) is an uncommon and potentially eyesight-threatening condition that necessitates prompt detection and therapy to maintain vision. The primary treatment for suspected OCS with evidence of optic nerve damage is immediate surgical decompression. The inclusion of real-time imaging guarantees precise and prompt execution of treatments, hence improving patient results.⁴²

Future Directions in Ultrasound Technology for Eye Emergency Care

Emergency physicians' use of ultrasound (US) imaging has become increasingly important in clinical settings over the last ten years. Scientific literature has shown that emergency physicians are capable of accurately performing and interpreting bedside US evaluations, which directly affects the quality of care.¹² The US in the emergency department (ED) serves to assist in diagnosis, influence management decisions, expedite dispositions, and evaluate critical patients who are too unstable to be evaluated by other imaging modalities.⁴³ Technological advancements, such as high-resolution probes, portable handheld devices, and improved software algorithms, are expected to further enhance the diagnostic and therapeutic capabilities of ultrasound in ophthalmology.⁴⁴

The integration of artificial intelligence (AI) and machine learning into ultrasonography systems can improve the interpretation of images, decrease diagnostic errors, and optimize workflow. AI-powered tools can help in detecting diseases, measuring quantities, and predicting outcomes, thus enhancing clinician expertise.⁴⁵ AI-related technology for analyzing US imaging has also demonstrated success in oncology for noninvasively identifying cancer patients, assessing malignant degrees, or predicting prognosis. Although significant progress has been made in recent years, the development of AI approaches specifically linked to US imaging in the emergency department has not yet been promptly summarized.⁴⁶

Training and Implementation for Effective Use of Ultrasound in Emergencies

The use of ultrasound has recently been incorporated into the curriculum for undergraduate students. There is a general agreement that ultrasound training should be included in undergraduate education; however, there has been no consensus established regarding the quantity of time that should be spent on training, as well as the substance of the training and the techniques that should be used to provide it.⁴⁷ For the purpose of instructing fundamental sciences such as anatomy, ultrasound training during the early years of undergraduate medical education is especially beneficial. The acquisition and interpretation of ultrasound pictures, on the other hand, becomes increasingly significant as one gets older.⁴⁸ Several studies emphasize the significance of a standardized formal education program and the availability of ultrasound machines in the emergency department. These measures are taken to guarantee that consistent practices are maintained and retained, which ultimately results in safer practices and more satisfied patients.⁴⁹

Despite the extensive literature on the feasibility, usefulness, and applications of ultrasound, there is a lack of evidence on the most effective training and obstacles to using ultrasound in low-resource settings.⁵⁰ Implementing ultrasound in emergency ophthalmology encounters obstacles such as restricted equipment access, inconsistent training, and reluctance to embrace new technologies. Therefore, effective implementation strategies include incorporating ultrasound training into medical education, offering mentorship and support to early adopters, and establishing standardized protocols. Collaboration between institutions and professional organizations can facilitate widespread adoption and standardization.⁵¹

Conclusion

Prompt and accurate diagnosis is essential to prevent irreversible harm in instances of ocular emergencies, which pose significant risks to ocular vision. This review emphasizes the critical importance of Point-of-Care Ultrasound (POCUS) in the rapid diagnosis and management of acute emergencies. Ultrasound has proven to be highly effective as a diagnostic tool in several eye emergency conditions, showing remarkable sensitivity and specificity in detecting ocular

trauma, retinal detachment, vitreous hemorrhage, and other sudden visual emergencies. Its non-invasive nature, ability to be performed at the patient's bedside, and effectiveness even in challenging situations, including limited patient cooperation or the presence of media opacities, make it an essential resource in emergency operations.

Moreover, the use of ultrasound-guided interventional methods has enhanced the precision of therapies, including the delivery of medications and drainage operations, thus validating its effectiveness in the treatment of eye emergencies. Ongoing technological advancements, such as high-resolution probes and the integration of artificial intelligence, are anticipated to augment the capabilities of ultrasonography in ocular emergency care. These technological advancements demonstrate the potential to enhance the precision of diagnosis and streamline procedures. AI-integrated ultrasound is particularly relevant for emergency physicians (for initial triage and rapid diagnosis), ophthalmologists (for specialized assessment and treatment planning), and radiologists (for confirmatory imaging and complex cases), fostering interdisciplinary collaboration.

However, the successful incorporation of ultrasonography in emergency ophthalmology depends on adequate training and the proper availability of resources. This study emphasizes the need to include standardized ultrasound training in medical education and setting clear criteria to ensure consistent and effective use in emergency departments. To optimize patient outcomes and fully harness the benefits of ultrasound in ocular emergencies, it is essential to address these challenges, particularly in resource-constrained environments.

Abbreviations

EDs, Emergency Departments; POCUS, Point-of-Care Ultrasound; UBM, Ultrasonic Biomicroscopy; RD, Retinal Detachment; OCS, Orbital compartment syndrome; AI, Artificial Intelligence; US, Ultrasound.

Data Sharing Statement

All data are available upon request from the Ahmed Saad Al Zomia, ahmedszomia@gmail.com.

Author Contributions

All authors made a significant contribution to the work reported, whether in the conception, study design, execution, acquisition of data, and interpretation, or in all these areas; took part in drafting revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare no conflicts of interest in this work.

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