Ultrasound Triage of Ocular Blast Injury in the Military Emergency Department

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ABSTRACT Introduction: Ultrasound (US) provides rapid effective assessment of the globe. In Afghanistan, ocular blast injuries are common. We present a case series demonstrating the value of US in this context. Methods: 29 patients with suspected blast eye injury had both computed tomography (CT) of the head and ocular US as part of their standard care in a military hospital in Afghanistan. The US images were assessed by blinded consultants (emergency department and radiology) and compared with the CT reports. Results: 18 patients had an intraocular injury on either CT or US. CT identified 11 injuries. US detected 18, including all 11 detected by CT. Inter-rater agreement was high (28/29). Discussion: This series suggests that US may be as good as CT at detecting ocular blast injuries. However, inability to follow up local national patients meant that the clinical relevance of these findings cannot be quantified. US is likely to have a role on deployed operations in triaging possible ocular injuries. Conclusions: US is an easy, cheap alternative to CT for the assessment of blast injury to the eye. It appears to have identified all injuries detected by CT in this series and can be accurately interpreted by emergency physicians.

INTRODUCTION

In military operations, eye injuries are common, accounting for 13% of all U.S. casualties in Afghanistan and Iraq.[1] Improvised explosive devices (IEDs) are common, and blast injuries to the eyes are frequent—especially in civilians wearing no eye protection. Blast injuries to eyes mainly fall into two categories. Primary injuries result from shear forces and manifest as hemorrhages, detachments, or even globe rupture. Secondary injuries are caused by debris (from the device, or material around it) thrown by the explosion.

Computed tomography (CT) is considered to be the imaging modality of choice for the assessment of a blast-injured globe (particularly for penetrating trauma) but it has limitations—in cohort studies, the sensitivity of CT for clinically occult open-globe injuries ranged from 71 to 75%.[2,3] Explosive debris is often nonmetallic, which might reduce sensitivity still further—this has been clearly shown for plain x-rays.[4] Ultrasound (US) is commonly requested by emergency physicians (EPs) for the detection and localization of foreign bodies under the skin, where sensitivities of 94% have been reported.[5] In vitro studies show that it is as good as[6] or better than CT[7] at detecting soft tissue foreign bodies, especially if hypodense. US scanners are now routinely available in medical facilities supporting UK and U.S. deployed military operations, and increasing numbers of EP are competent in their use for trauma scanning. US is a recognized specialist tool for the investigation of a variety of ocular injuries, with one series of civilian patients with a range of intraocular injuries (globe rupture, lens dislocation, and detachments) showing 99% sensitivity (CI 94–100%) in the hands of an EP compared with CT and/or ophthalmologist review.[8]

It has found limited acceptance in the emergency department (ED), despite studies showing its value for the diagnosis of globe rupture, vitreous hemorrhages, retinal detachments, retrobulbar hemorrhages[9] and raised intracranial pressure.[10] In penetrating injury, in particular, this may be due to concerns about pressure on an open globe causing further damage. It is very easy to learn if one has a basic grounding in ultrasonography,[11] and if the technique is carried out with care, one should demonstrate at all times that no pressure is being applied.

Expertise to deal with eye injuries on deployment is limited—ophthalmologists are not deployed by UK forces and are available only at some U.S. hospitals. Many smaller health care units undertaking the initial management of casualties have no CT facility. Injured civilians are transferred to local health care providers whenever the infrastructure can manage them, but these have similarly limited access to ophthalmology. It is therefore essential that potential eye injuries are identified early so that appropriate transfers can be arranged. Currently, at the UK hospital at Camp Bastion, this mandates transfer of approximately 100 miles by air. Transfer must be reserved for those most likely to benefit from ophthalmology review. Although the prognosis for visual recovery in military penetrating eye trauma is poor, there is some evidence that vision can sometimes be improved if the fragment is extracted.[12–14] A subgroup of patients cannot comply with visual assessment (e.g., intubated in intensive care) and have injuries associated with ocular blast injury (e.g., penetrating eyelid injury) but no overt globe injury on careful inspection. These patients need

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to be triaged for transfer to facilities able to manage them. US may provide a tool for this triage.[15]

OBJECTIVES

To assess the suitability of US as a first-line investigation for ocular trauma resulting from blast in a deployed military setting.

METHODS

Design and Setting

A case series was collected in the field hospital at Camp Bastion, Helmand Province, Afghanistan, during 6 months from November 2009 to April 2010. The Chair of the Local Research and Ethics Committee (S.H.'s home area) confirmed that no ethical approval was required as patients only received USs and CTs if indicated as part of their standard care.

Patient Selection

The cases series contains consecutive patients with facial trauma as a result of blast injury, suspected of having intraocular hemorrhage or foreign body (because of trauma visible to the eyelids or immediate surrounds, pupil irregularity, or lack of pupillary response to direct illumination). Patients were not assessed if they proceeded direct to theatre except when the surgeon dealing with the facial injuries felt that it would assist them. Patients were excluded if they had clear evidence of an open eye injury. A SonoSite M-Turbo US scanner (SonoSite, Bothell, WA) with a standard 10 to 5 MHz linear array vascular probe was used to assess the affected globe(s).

Method of Measurement

The ultrasonographer gently removed any surface grit or foreign objects, preferably by lifting away with forceps. A thick layer of US gel was applied. The gel was gently applied close to the lid to avoid trapping air between layers of gel and to avoid pressure from falling gel. The high-frequency linear array was then applied, ensuring that a thick layer of gel was seen between the probe and the lid at all times. Absolutely no pressure on the lids was acceptable. When feasible, an assistant observed and advised the ultrasonographer when the probe appeared to be close to the lids. If the patient was conscious, he was advised to tell the ultrasonographer if he felt the probe touch his lid. The depth setting generally used was less than 4 cm, in some reduced to less than 2 cm to concentrate on the anterior chamber. Examples of the image quality are shown in Figure 1. Still images and 6-second video clips were saved, anonymized, and saved for review. CTs were reported by the duty radiologist at the time the scan was performed.

Analysis

Each US scan was retrospectively assessed by both an US-experienced EP (J.R.) and a radiologist (J.P.), both masked to the CT result and the clinical outcome. When both agreed that there was evidence of blast injury (blood in the globe, foreign body, retinal detachment, or globe collapse), this was designated an abnormal US scan. If there was disagreement, then they discussed the images and came to a consensus. If they could not, then this disagreement was noted and a second (masked) radiologist (D.G.) made the final decision. The US diagnosis was then compared with the CT report. When the patients were International Security Assistance Force (ISAF) troops (United States, United Kingdom, or

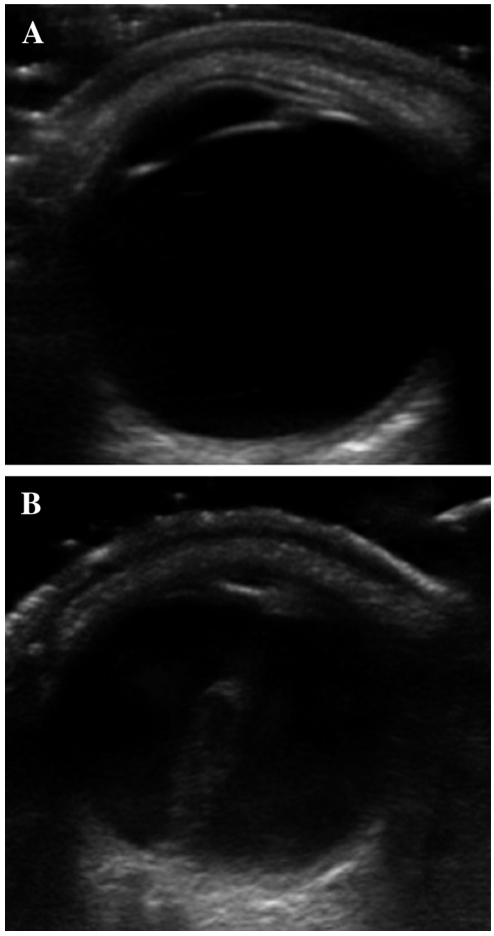

FIGURE 1. (A) US of a normal globe. The cornea, anterior chamber, iris, vitreous, and posterior wall can be clearly seen. (B) Collapsed anterior chamber, track with hemorrhage and foreign body in the posterior wall.

TABLE I Comparisons of CT and US Scan Reports for 29 Patients Who Underwent Both

CT Finding	US Finding	Patient Numbers	Total
Positive	Positive	1–3, 8, 9, 12–15, 19, 23, 26, 28	13
Negative	Positive	5, 7, 9–11, 13, 25	7
Positive	Negative	—	0
Negative	Negative	4a, 6, 16–18, 20–22, 24, 27, 29	11

[a] Called US positive by EP, negative by radiologist. Adjudicated negative.

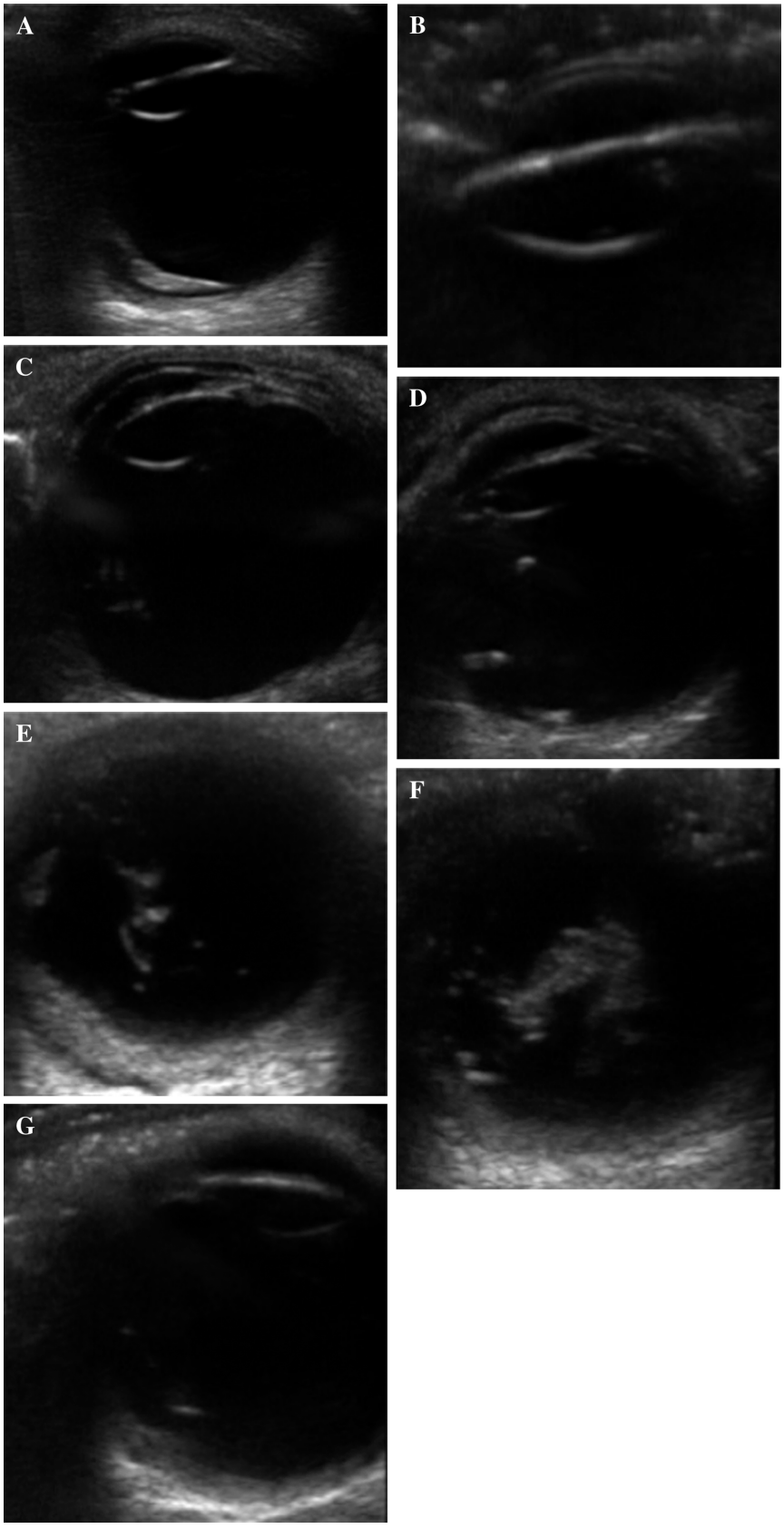

FIGURE 2. US scans suggesting blast injuries, which were not identified on CT: (A) Posterior hemorrhage, (B) foreign body behind iris, (C) collapsed anterior chamber and vitreous foreign body, (D) multiple vitreous foreign bodies, and (E–G) hemorrhage and foreign bodies.

Danish) with a positive US but negative CT, further information was sought from their receiving hospitals. When studies were undertaken on local Afghans, no means of follow-up past discharge from the hospital was possible.

RESULTS

40 patients had at least one eye US scanned. 11 had a low level of clinical suspicion and had no other clinical indication for a head CT—for these the decision was taken not to perform a CT solely to rule out ocular injury. All 11 in this group had USs reported as normal by both assessors.

29 had a 6 slice CT of the head (including the globes) for an ocular or other head/face indication and also had an US scan—these 29 made up our dataset. There was immediate agreement between assessors in 26/29 US scans. Where there was initial disagreement, consensus was reached twice (with both assessors changing their decision once) yielding eventual agreement in 28/29. In one case, there was no agreement—J.P. viewing a finding as an artifact while J.R. felt it was a foreign body. The adjudication by D.G. was of a normal US scan. The comparison between US finding and CT report is shown in Table I. EP interpretation of the scans was accurate (compared with radiologist assessment) with a sensitivity of 100% (95% CI 82–100) and a specificity of 90.9% (95% CI 65–99.4). Significant injury was diagnosed on 18/29 US scans and 11/29 CTs. All patients with normal US scans (11/29) had normal CT scans as well. The 11 injuries diagnosed on CT were also seen on US, giving a sensitivity of 100% (95% CI 78–100). Figure 2 shows the US findings thought to represent significant injuries that were NOT seen on CT (7 patients). As can be seen, the appearances are quite striking and would not appear to be artifact or easily confused with a normal scan, even by an inexperienced practitioner. The pictures demonstrate the features typical of foreign bodies, hemorrhage, or both.

DISCUSSION

US is generally thought to be sensitive for intraocular penetrating foreign bodies but is often considered a specialist investigation. CT or plain orbital views are often employed instead, especially if craniofacial or brain injuries are also suspected. These are sensitive for metallic foreign bodies, but in the context of an IED injury, they may be less so. Nonmetallic penetrating foreign body is relatively uncommon outside this arena but does still occur; therefore, the findings are relevant wherever access to an ophthalmologist is difficult.

Ocular ultrasonography is still a novel technique in emergency medicine in the United Kingdom and is not in widespread use. There may be several reasons for this. There is concern about the ability of nonradiologists to perform and interpret US. This study suggests that an experienced EP may detect ocular injuries nearly as accurately as a radiologist. Also there is concern that probe pressure on an open globe could extrude the ocular contents. We required an ultrasonically visible layer of gel between the probe and the eyelid proving that no pressure is applied.

Despite the performance of US in this series, this is not a comparison study of US versus CT. There are several key issues that need to be remembered. First, all Afghan patients (36/40) were lost to follow-up. The 4 ISAF soldiers injured were all known to have globe injuries from the CT or had normal scans both on US and CT and no further documented ophthalmological follow-up. It is certain that the population was at high risk of penetrating ocular trauma. All were injured by flying debris and had either eyelid trauma or eye signs suggesting injury, making it likely that an abnormal finding on US was a true positive. Our use of two masked assessors yielded high first-time inter-rater agreement, which also supports genuine findings. However, without ophthalmological assessment, there is no gold standard assessment to confirm the validity of these findings. It is impossible to determine with certainty whether the surplus of diagnoses by US represents true positives missed by CT, or false positives. Indeed, the 11 who had no CT could have included US false negatives, exaggerating the apparent sensitivity. Second, the visual acuity was not recorded in the majority of these patients. Many remained unconscious for their stay at the facility before returning to the local health system, and there was no means of follow-up. As a result, the one key piece of information in terms of the prognosis of the injury is also missing from this study. Finally, the CT scanner had a lower resolution than most currently used in the United Kingdom. However, it may be representative of the capability on future military operations. Despite these limitations, there can be no doubt that US shows promise in the assessment of the blast-injured globe. In the military context, where transfer for gold standard assessment may be difficult and dangerous, it may provide a useful triage tool.

CONCLUSIONS

US offers a sensitive screening tool for penetrating foreign body or blast injury to the globe. It may even be more sensitive than 6 slice CT. US is portable, cheap, and easy to interpret. Careful assessment by an appropriately trained practitioner in selected cases allows a high-yield, low-risk examination. We recommend that patients with suspected eye injuries from IEDs should undergo careful US examination by appropriately trained personnel as part of a process of triage for ophthalmological assessment.

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