A Vision Center of Excellence newsletter focused on ocular casualty care and readiness

FRONTLINES OF EYE CARE

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IN THIS ISSUE

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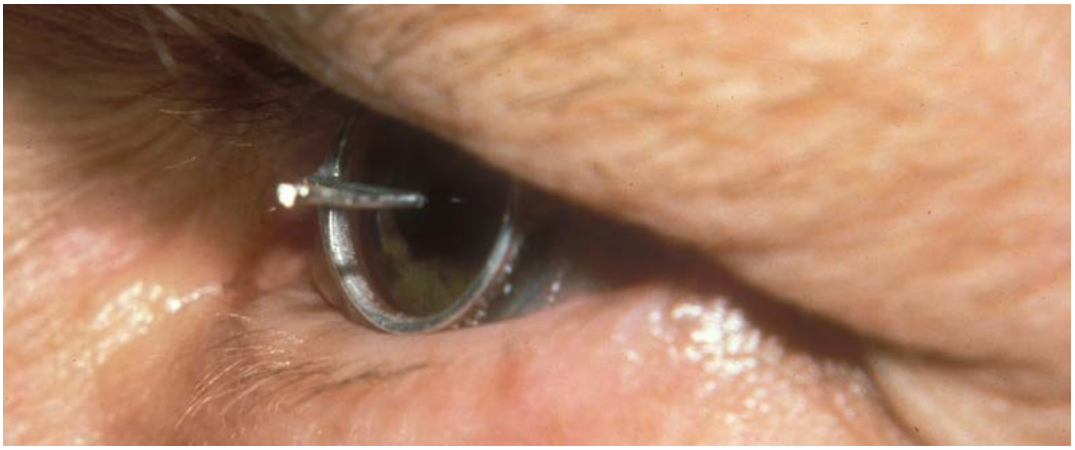

A radiopaque ring used to measure the location of an intraocular foreign body. *(Source: International Centre for Eye Health, London School of Hygiene & Tropical Medicine)*

FEATURE

THE WAR-INDUCED INTRAOCULAR FOREIGN BODY: ITS DIAGNOSIS AND MANAGEMENT FROM 1917-2017

Foreword by: COL (Ret) Robert A. Mazzoli, MD, FACS

Regarding intraocular foreign bodies (IOFBs), it risks stating the obvious to declare that you can't remove what you can't see or don't know is there. Yet this is exactly the situation for IOFBs until very recently. Because hemorrhage is an almost constant companion to ocular trauma, direct observation of retained IOFBs was (is) essentially impossible. X-ray revolutionized the ability to detect many foreign bodies (FBs), but then localizing the object as intraocular or extraocular remained a challenge. Additionally, many FBs are invisible on x-ray and remained enigmatic. It was not until the dawn of ultrasound and computed tomography (CT) that accurate detection and localization became predictable. Even then, removal of the FB posed different technical challenges; what use is it to know of an IOFB if attempted removal causes more trauma and loss of the eye? Clearly, detection and management had to progress hand-in-hand.

These are challenges that faced deployed military ophthalmologists until surprisingly recently. Although sophisticated surgical techniques for removal became available soon after Vietnam, detection remained rooted in World War I – II techniques. It was not until after Desert Shield/ Desert Storm (1990–91) that CT scanners were first deployed to the field, providing significant advancement. Ocular CT is now standard practice in head trauma in the combat zone. This article brings light to that evolution.

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Approximately 18–41% of open globe injuries involve IOFBs, the majority of which are work-related (54–72%), followed by injuries at home (30%).[1] Ocular injuries from FBs vary by size, weight, composition, and the anatomic zone of injury. Associated vision loss is dependent on the amount of damage to intraocular structures, the presence of retinal detachment, and macular injury. The majority of eye injuries with IOFBs occur in young men between 21–40 years of age (66%). The most common causes for IOFBs are hammering (60–80%), power tool use (18–25%), and weapon-related injuries (19%).[1] Unlike the non-combat-related eye injuries with foreign bodies seen in the civilian population, combat-related injuries often involve polytrauma; eye injuries themselves tend to represent ocular polytrauma requiring management by multiple ophthalmic subspecialists. In fact, Colyer et al.[2] reported that 79 eyes of 70 U.S. Service members (25%) evaluated at the former Walter Reed Army Medical Center (WRAMC) for combat-related ocular injury between 2003 and 2007 had an IOFB. Ocular trauma associated with IOFBs often carries a poor prognosis; extensive intraocular injury due to IOFBs has been reported to significantly impact post-operative visual acuity.[2] The presence of IOFBs in open globe injuries also increases the risk of post-traumatic endophthalmitis. In a retrospective case series, Banker et al.[3] observed that the rate of culture-positive endophthalmitis after open globe repair was 8.1% in eyes with IOFBs versus 1.6% in eyes without IOFBs ($P < 0.01$).

The diagnosis and management of IOFBs in both civilian and military personnel have been challenges to ophthalmologists for at least two centuries. Over the years, management of open globe injuries with and without FBs has dramatically improved. This has been driven by the challenging combat-related ocular injuries managed by military ophthalmologists who have the responsibility of providing the highest quality care to injured Service members. This article provides an overview of the evolution of diagnostic and therapeutic techniques for the detection of IOFBs over the past century and the contributions military ophthalmologists have made to this evolution. The diverse nature of IOFBs as well as their variability in size, impact site, and resultant intraocular damage makes meaningful comparisons of statistics difficult; however, some observations are possible (Table 1).

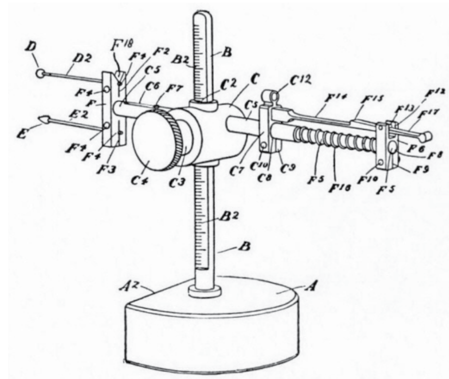
TABLE 1. Characteristics of IOFBs observed in 20th century conflicts[4]

	As % of OGI	% Non magnetic	% of IOFBs removed	% Enucle ated	% Eyes at VA CF or worse
WWI	64	--	52	28	50
WWII	32–64	55	40–60	14–31	40
Korea	--	24	60	--	--
Vietnam	62	25–60	--	--	--
Desert Storm	33	--	--	--	--

OGI – open globe injury; VA CF – visual acuity of counting fingers

Evolution of IOFB Detection Methods

Military physicians were quick to employ radiographic methods after Wilhelm Röntgen developed the x-ray in 1895 and demonstrated its value in medicine.[5] Only six months after this discovery, Lieutenant Colonel Giuseppe Alvaro of the Italian Army made radiographs to find bullets in the forearms of two soldiers in the Abyssinian War of 1896. X-ray technology provided a precise method of detecting retained FBs and, in many cases, eliminated the need for inappropriate exploration of the wound. General radiography was employed to good effect in the subsequent Graeco-Turkish War of 1897, the Tirah Campaign of 1897, the River War of 1898, and the Boer and Spanish-American Wars of 1899.[5]



Sweet Eye Localizer. (Source: U.S. Army Medical Department)

The value of x-ray technology in civilian ophthalmology was also quickly recognized and adopted. In 1896, two American ophthalmologists (Charles H. Williams and, his brother, Francis H. Williams) detected a metallic IOFB in a boy who had sustained it by hammering on a cartridge. After ten minutes of exposing the patient to x-ray, they had localized and successfully removed a strip of copper from the vitreous.[6]

A large number of x-ray techniques for IOFB detection had been developed by the outbreak of World War I. William Sweet, who had developed the Sweet localizer for metallic IOFBs in 1897 and an improved version in 1909, treated injured U.S. Army soldiers during World War I by utilizing these methods.[6] Sir James Mackenzie Davidson, a British ophthalmologist, devised the cross-thread method of localization and applied stereoscopy to the viewing of radiographs. He published his work in 1916 while providing care for World War I casualties. Sweet's method of IOFB localization, along with other methods of localization by simple radiographs focused at cross measurements, stereoscopic radiographs, and fluoroscopy, were employed during World War I.[7] At the beginning of World War I, European armies

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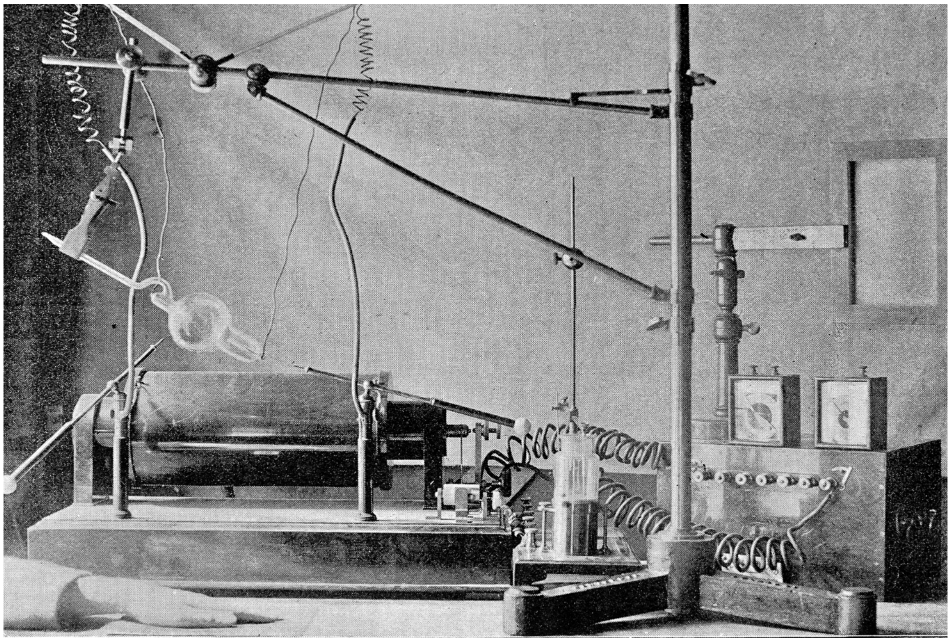


Complete apparatus for the Röntgen Ray. *(Source: David Walsh)*

were provided standard gas x-ray tubes; however, more powerful radiographic equipment was introduced as the war progressed. This advanced equipment was supplied to the American Expeditionary Force during the war, which made full use of these technologies in the detection of FBs.[5]

Despite the advances in x-ray techniques, it appeared that the British Army preferred to use giant magnets to detect magnetic FBs during World War I. The British Army stated that x-ray examination and localization in austere conditions was nearly impossible and that all suspected cases of IOFBs should be evaluated via the magnet test.[8] Giant magnets were made available at Boulogne, Étaples, and Rouen, which were three of the large "eye centers" that were set up at bases by the British. The magnet test was described as "the simplest and most efficient one for detection of a magnetic foreign body in the eye."[8] Cases of IOFBs were common during the war, therefore these magnets were used frequently. On a typical day, 4–5 cases, and sometimes as many as 15 cases, were put up to the magnet in the suspicion of an IOFB. All eye centers needed access to such magnets because of the high number of casualties with IOFBs; however, the magnets were too bulky and expensive to meet this need. To resolve this issue, a "mobile magnet" was developed, which involved a giant magnet mounted to an ambulance that could be transported as needed. This method, however, was also impractical due to the heavy weight of the magnet and the subsequent challenge of transporting it over long distances on poorly built roads. Shortly thereafter, one of the U.S. base hospitals was equipped with a smaller, but very powerful magnet, which was 15 inches long, weighed 30 pounds, and cost approximately $70 in 1918. This magnet made it possible to equip all base hospitals with magnets that are powerful, yet practical for IOFB detection.[8]

During the remaining years of the 20th century, a standard FB x-ray series for suspected IOFBs was developed incorporating Waters', Caldwell, and lateral views. Metal locators (Berman, Roper-Hall and Bronson-Turner) were developed and ultrasonography also became widely available; however, significant advances in our ability to detect IOFBs had to await the advent of CT in the 1970s, and later, magnetic resonance imaging (MRI) for non-metallic FBs.[6]

Management of IOFBs: World War I to Present

World War I and interwar period

Julius Hirschberg revolutionized the treatment of IOFBs by being the first to apply an electromagnet for their extraction.[6] Extraction employing giant and/or hand-held magnets was common by either the anterior route (whereby a magnetic FB in the posterior segment was brought by the magnet into the anterior chamber and removed through a corneal incision) or by the posterior route, usually via direct incision through the sclera, choroid or, if attached, retina, based on proximity to the FB.

While use of a magnet for IOFB removal was a significant advancement, IOFB removal still posed many challenges. On occasion, a magnet would be used to identify the magnetic nature of an IOFB, with the casualty experiencing pain from the FB's movement. Shoemaker[6] recommended that, if practical, IOFB removal should take place as soon after injury as possible while attempting to minimize additional damage to the eye, but added that "…removal by forceps from the vitreous can scarcely be considered as practical, because when successful it is more a question of luck than skill. If large enough to get we might as well take the eyeball." Additional challenges in the removal of IOFBs were illustrated by de Schweinitz and Greenwood,[9] who added that while moderate-sized IOFBs (i.e., 4 x 2 mm) may be removed by a magnet or other method, the result was typically a blinded eye. However, smaller FBs (i.e., 2 x 1/2 mm) were often easier to remove and had significantly better visual outcomes.[9]

Extraction of an FB by the posterior route often led to poor visual outcomes. In a series of 48 patients who underwent IOFB extraction by the posterior route, 31% were blinded, 40% had light perception or counting fingers (CF) vision, 15% had "useful vision" (3/60–6/12), and 15% had "good vision" (6/9 or 6/6) after the procedure.[6] In some cases of extraction

continued from page 3

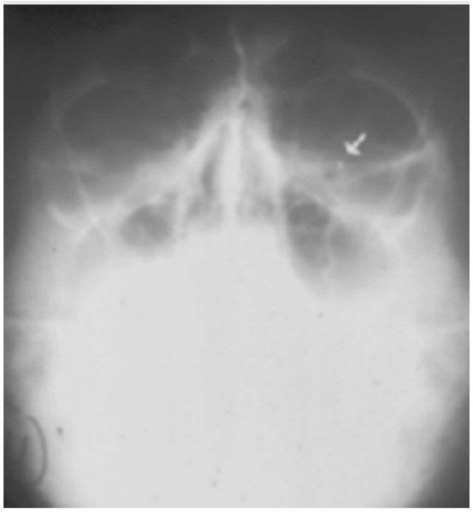
through the posterior route, it was possible to watch forceps move in the vitreous with an ophthalmoscope. After one successful extraction, it was noted that "the lens remained clear but the retina was largely detached by proliferative chorioretinitis [proliferative vitreoretinopathy (PVR)], traumatic."[7] At that time retinal detachment was considered untreatable. It would take almost another 100 years for modern retina surgery and instrumentation to develop. Although retinal holes were first noted after the development of the ophthalmoscope, their significance in the development of retinal detachment was only recognized in 1918 by Jules Gonin. He successfully treated several cases by cauterizing the sclera in the area of the retinal tear.[6]

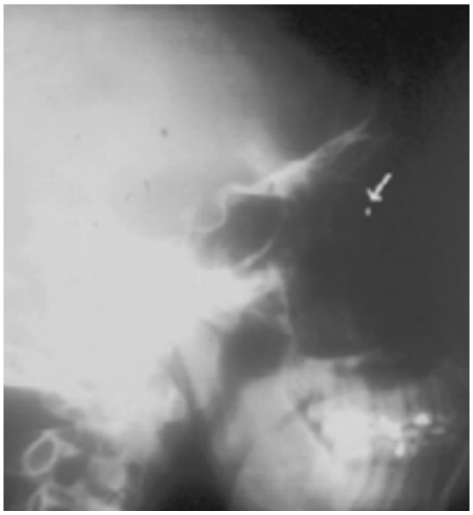
World War II

Combat circumstances in World War II contributed to poor detection and management of IOFBs, which were frequent due to the increased use of explosive devices. At the early points in their care, Service members with IOFBs were rarely evaluated by an ophthalmologist, resulting in delayed treatment of ocular injuries. In addition, most FBs were the result of fragments generated by explosives (particularly landmines) and were typically not magnetic. Removal of these FBs was difficult, if not impossible, and often caused additional damage to the structures of the eye.[10] The controversy over the advisability of anterior versus posterior route extraction of magnetic FBs continued; meanwhile Verhoeff's pars plana vitrectomy approach, the Thorpe endoscope, and the Berman locator were employed. PVR was again recognized as a serious problem. Wilder, at the then Army Institute of Pathology, studied the FBs removed from 150 enucleated eyes, 89 of which were non-magnetic.[10] The authors of *Surgery in World War II, Ophthalmology and Otolaryngology* concluded: "Since, at best, the results of treatment of IOFBs are not outstanding, no precaution should be overlooked that can improve them."[10]

Additional innovation during the World War II era was Ridley's epochal development of the intraocular lens following his observations in war casualties:

> "Ridley drew on prior observations as a military surgeon that both glass and acrylic, under certain conditions, appeared to be inert within body tissues. During World War II some airplane cockpit and gunnery canopies were fabricated from glass and PMMA [polymethyl methacrylate (i.e., Plexiglas™)]. When a canopy was shattered by gunfire, fragments of this material sometimes penetrated the eyes of the flight crew. Ridley observed that unless a sharp edge of the plastic material rests in contact with a sensitive and mobile portion of the eye, the tissue reaction is insignificant. This observation has become one of the most important principles now universally applied to modern lens design and implantation."[11]





Waters' view of a plain radiograph of a patient with an ocular foreign body (left). Lateral plain film view of the same patient (right). (Source: Textbooks of Military Medicine – Ophthalmic Care of the Combat Casualty)

Early in the 20th century, a number of contact lens devices were developed to assist with IOFB detection, such as the Comberg technique, which employed a modified Zeiss lens bearing four radiopaque markers.[6]

Korean War

The prevalence of significant eye injuries in U.S. personnel was reported as being between 3 and 8% during the Korean War. Twenty-four percent of FBs found in 129 eyes were non-magnetic; FBs were removed in 60% of the 129 eyes. As had been true in the World Wars, artillery and tank shell fragments produced most of the eye injuries.[4] Noting the protection provided by even an ordinary pair of glasses, Fair[12] proposed the use of what he termed "Eye Armor" consisting of case-hardened lenses and metal side shields, to protect Service members. Unfortunately, they were rejected, in part because of visual field restriction.

Vietnam War

IOFBs continued to be a major problem over the years of the war, in part because no acceptable form of eye protection was provided to ground combatants. In an analysis of ocular and ocular adnexal injuries sustained by U.S. forces, 272 were noted to contain IOFBs, comprising 15% of the ocular injuries.[13] A separate analysis of 100 eye injuries in 57 casualties cared for at WRAMC identified 22 IOFBs. An analysis conducted at Fitzsimons Army Hospital found retained IOFBs in 51 of 281 casualties. Evaluation

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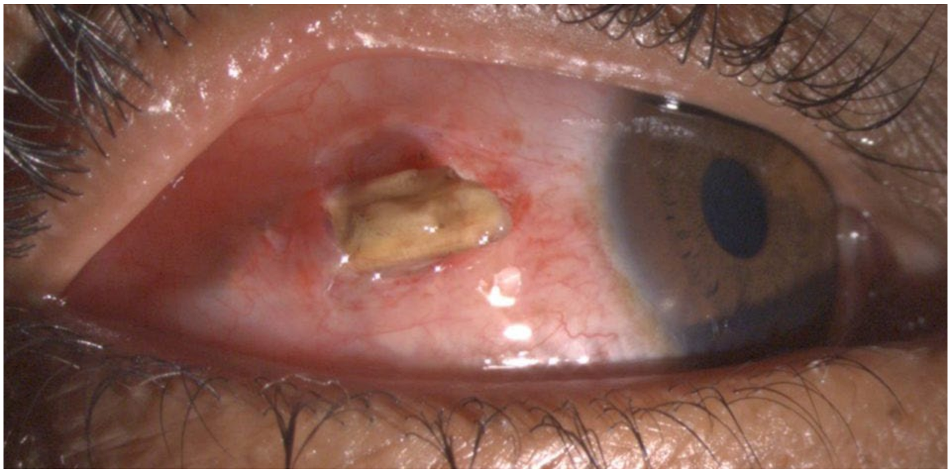
of wound data and munitions effectiveness analysis demonstrated that 68% of non-fatal war wounds of all types in the war were the result of fragments from munitions.[13,14] Sponaugle and McKinley studied 61 FBs removed from the eyes, orbital, or adnexal soft tissues of soldiers and Marines between 1968 and 1969; relevant results are in Table 2.[13]

Extraction of magnetic posterior segment IOFBs by the anterior route gave way to extraction through a scleral incision using a Bronson magnet after diathermy was applied to the choroid. On occasion, the FB would cut through the retina (if attached) and the choroid. If not, the FB would be removed through a choroidal incision when it bulged in response to the magnetic force. Sweet's and Comberg's localization methods were employed when available, and a modified spectacle frame was used when they were not. Penner and Passmore[15] described a magnet-ultrasound test. Cowden and Runyan[16] compared ultrasonography and radiography in FB detection.

Major advances were made in our understanding of FB injuries and their appropriate management in the 1970s. CT and, later, MRI; closed eye vitrectomy with modern instrumentation; therapeutic modalities such as endolaser, silicone oil, and other fluids; combined with a better understanding of PVR and its management; and the management of IOFBs by trained retinal surgeons have resulted in improvements in visual acuity and globe retention. In light of these advances, the best visual results for combat-injured Service members with open globe injuries and IOFBs can only be achieved when these injuries are managed by subspecialty-trained vitreoretinal specialists at a Level IV or V facility or similar facility where modern instrumentation and equipment for retinal surgery is available.[17]



Conjunctival laceration with a foreign body. (Source: Community Eye Health)

Operations Iraqi and Enduring Freedom

Significant advances in the ability to manage IOFBs have been made in the past two decades. MRI (in the absence of magnetic FBs) has allowed improved visualization of non-magnetic and non-metallic IOFBs. This imaging technique has also improved our understanding of the role the vitreous plays in the development of PVR and has improved our understanding of the optimal time for IOFB extraction. IOFBs are being managed by vitreoretinal subspecialists in Level V Military Treatment Facilities (MTFs). Surgical instrumentation for retinal surgery has been miniaturized, thus decreasing the possibility of intraoperative injury. Ancillary therapeutic modalities and the widespread use of topical and systemic fluoroquinolone antibiotics has reduced the incidence of endophthalmitis. As previously mentioned, Colyer et al.[2] reported on 79 eyes containing IOFBs in 70 U.S. soldiers treated at WRAMC with a follow-up at 6 months. Their treatment encompassed a 20 gauge, 3 port vitrectomy with IOFB removal through a limbal or a pars plana incision. The IOFBs varied from 0.1–20 mm (mean = 3.7 mm). The median time to removal was 21 days. The average pre-operative vision was 20/400; the average post-operative vision was 20/120. A visual acuity of 20/40 or better was achieved in 53.4% of casualties and 20/200 or better in 77.5%. There were no cases of endophthalmitis, siderosis, or sympathetic uveitis. However, 10.3% of the casualties either became blind or required enucleation in 6 months. Not surprisingly, poor visual outcome correlated with extensive intraocular injury, as did the prevalence of PVR (21%).

TABLE 2. Classification of foreign bodies observed in casualties during the Vietnam Conflict[13]

Weight (mg)	Total IOFBs	# Metallic	# Magnetic	# Non magnetic
1-100	43	40	24	16
101-300	10	10	7	3
>300	8	8	4	4
Totals	61	58	35	23
(Three FBs were non-metallic: 1 glass, 1 wood, 1 rock)				

Conclusions

The past century has seen dramatic improvement in the diagnosis and management of war-induced IOFBs. Nonetheless, the paramount importance of preventing such injuries from occurring remains. Efforts must continue to develop and distribute improved forms of eye protection, which will especially provide increased protection from blast effects. Despite the favorable results obtained from delayed removal of IOFBs, at least one posterior segment subspecialist should be a member of the Eye Team component of the Head and Neck Team at a Level III deployed MTF. This is particularly beneficial in cases where IOFBs

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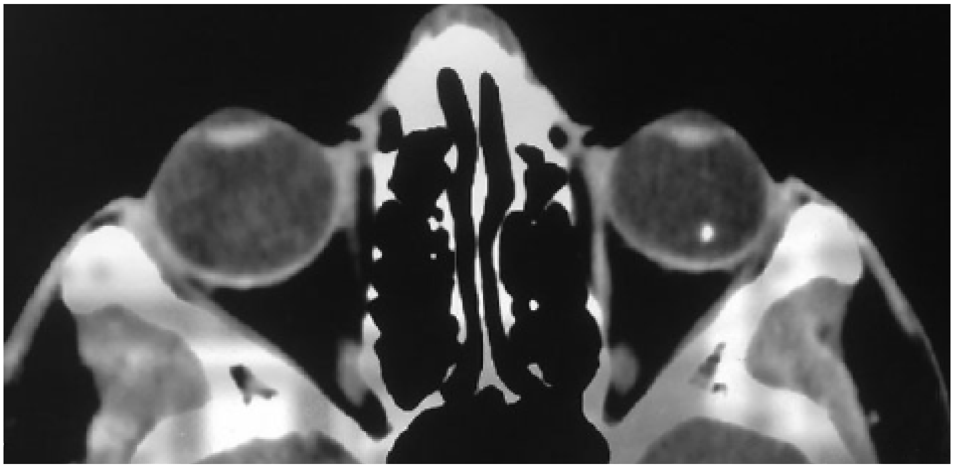
necessitate immediate removal (e.g., pure copper FBs), and the United States may not continue to enjoy the level of air superiority necessary to permit evacuation from the war zone, thus requiring prolonged field care. Additionally, U.S. military medical personnel are required to provide humanitarian care for host country nationals who present with IOFBs and cannot be evacuated to higher levels of care. IOFBs are a common occurrence in war and may be multiple, with one FB potentially masking another; this necessitates repeating the CT scan after initial treatment in military casualties. For radiolucent FBs, not visible by either CT or MRI, ocular ultrasound by a trained ocular ultrasonographer can be utilized after any open globe has been surgically repaired.

The Vision Center of Excellence (VCE) factsheet entitled "Handling of Ocular and Adnexal Foreign Bodies Removed at DoD and VA Medical Facilities" provides valuable information regarding the submission and analysis of FBs by the Joint Pathology Center (JPC) after removal. Another VCE factsheet, "Detection and Initial Management of Ocular Foreign Bodies and Injuries," is in development and will provide general principles for deployed ophthalmologists on the initial diagnosis and treatment of IOFBs **(See "Now See This" for principles for the detection and management of ocular foreign bodies)**.



CT scan of an intraocular foreign body. (Source: National Library of Medicine)

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VISION CENTER OF EXCELLENCE FOCUS ON EMERGENCY OCULAR CARE:

DETECTION AND INITIAL MANAGEMENT OF OCULAR FOREIGN BODIES

Emergency management of ocular trauma is necessary for both the ophthalmic and non-ophthalmic communities. To this end, VCE is sharing quarterly emergency management tips for the non-ophthalmic community as well as Damage Control Ophthalmology (DCO) principles specifically for the ophthalmologist.

In this issue of Frontlines, we share principles for the detection and initial management of ocular foreign bodies. Foreign body (FB) injuries can present a serious threat to vision, as they can damage intraocular contents, induce inflammatory responses, and cause infections. While FBs associated with

Bent paper clips can be used to retract the eyelids to examine the eye for foreign bodies. (Source: James W. Karesh, MD)

blast fragmentation from munitions and explosive devices are the most common FBs found in Service members, fragments associated with hammering and grinding are the most common FBs found in the civilian population. The types of FBs reported in the medical literature include everything from insect and animal parts to plant material and dirt to metal, glass, plastic, paint, human eyelashes, and a large list of other types of material. All patients with suspected FB injuries must receive a face and orbit computed tomography (CT) scan in order to determine the presence and location of FBs. Approximately 8–25% of penetrating ocular injuries involve multiple intraocular and extraocular FBs, therefore the detection and removal of one FB does not rule out the presence of others. Larger FBs can often mask smaller ones, therefore multiple CT scans may be required to ensure that all FBs have been identified. Magnetic resonance imaging (MRI) should only be performed if a ferromagnetic FB has been ruled out. **An ultrasound should never be performed on an injured eye unless an ophthalmologist has ruled out or repaired an open globe injury.** While in general, intraocular foreign bodies (IOFBs) should be removed promptly, in deployed settings it may be best to defer their removal to higher echelons of care by a vitreoretinal subspecialist in more controlled environments.

Both ophthalmologists and non-ophthalmic providers should attempt to remove superficial, non-embedded FBs at more forward echelons of care, if possible. It is important to remember that many types of materials can be retained within the eye for extended periods of time without resulting in any inflammatory reaction or endophthalmitis. Some of the more common of these materials, such as those composed of glass and plastic are, for the most part, inert. Inert, however, does not necessarily mean innocuous; that is, a chemically non-reactive FB can still cause structural damage to the eye. Inertness should not be assumed, and patients who have such FBs should receive close clinical follow-up.

Further principles regarding combat-related ocular trauma need to be developed and formalized. VCE is currently developing DCO principles, which will encompass the following: *Necessity, Urgency, Adequacy, and Avoidance.*

Necessity - Addresses aspects of care that must be applied at a particular point of care prior to transfer to the next level of care. The need for immediate intervention largely depends on severity of injury.

Urgency - Addresses the time frame in which any necessary treatment or intervention must be performed. Severity of injury will dictate urgency with which the eye must be treated.

Adequacy - Addresses how meticulous or definitive repairs must be. Repairs for severe injuries must be meticulous, where the first repair is typically the final one. However general practitioners and ophthalmologists must also identify injuries for which repairs can be ignored, or be temporized and revised later.

Avoidance - Addresses interventions that should not be performed in order to effectively manage the eye injury.

Emergency Management of Ocular Foreign Bodies:
For Non-Ophthalmic Providers

PRINCIPLE 1: Suspect possible open globe injury and retained ocular foreign bodies in any casualty who has:

- Been in the vicinity of an explosion
- Fragment wounds of the head, neck, or face and/or FBs embedded in the eyelids and periocular area
- Any laceration or injury to any part of the eye/lid that would otherwise have been protected by eye protection. Assume all open globe injuries have retained IOFBs until proven otherwise
- Been in the vicinity of a mass casualty event (e.g., terrorist attack, severe weather event, industrial explosions)

PRINCIPLE 2: Perform the ABCs of Eye Trauma for the detection and appropriate management of any retained foreign bodies.

- When possible, obtain a careful history with particular attention to the mechanism of injury, previous eye injuries, chronic ocular conditions, ocular and systemic medications, and previous surgeries
- Obtain visual **Acuity** as soon as possible — it is the most important point-of-injury information. Reduced visual acuity may indicate a serious eye injury and presence of possible ocular FBs
- Perform **Best** possible examination of **Both** eyes. Do not place pressure on an injured eye while conducting the examination. Injuries involving the lids or periorbital areas that should have been adequately protected or covered by eyewear should raise suspicion of open globe injury and/or an IOFB. Absent red reflex may indicate vitreous hemorrhage and possible IOFBs. Evert eyelids to remove FBs from the conjunctival fornix or the back of the eyelid after ruling out open globe injury
- Examine **Contiguous** structures adjacent to the eye. A careful examination of the eyes, orbits, and adjacent structures are necessary when there is head and neck polytrauma resulting from a blast; an injury involving FBs in one area may be accompanied by FB injuries to adjacent structures
- **Drugs**: Antibiotic prophylaxis is important for all open globe injuries, particularly those with IOFBs. Start fluoroquinolone antibiotic PO or IV (e.g. ciprofloxacin 500 mg BID, moxifloxacin 400 mg PO, or levofloxacin 500 mg IV QD) and begin an anti-emetic (ondansetron [Zofran®] 4 mg IV). If necessary, administer ketamine 50 mg IM (q30min PRN) or 20 mg slow IV (q20min PRN) for pain management. **Don't:** DO NOT perform an ultrasound on the eye. It may worsen the eye injury. DO NOT perform an MRI. MRI is contraindicated until the presence of a ferromagnetic IOFB has been ruled out. DO NOT put pressure of any type on an injured eye. Applying pressure may extrude intraocular contents and convert a repairable eye to a non-repairable one. DO NOT attempt to measure intraocular pressure. DO NOT patch the eye
Diagnostic imaging tests, particularly CT scanning, are necessary to determine the presence and location of possible FBs **(See Principle 3)**
- Superficial FBs can be removed with irrigation and/or a cotton-tipped applicator. Intraocular or embedded FBs should not be manipulated and can only be removed by an ophthalmologist. Place an **Eye Shield** over an injured eye and **Evacuate** patient to the nearest ophthalmologist **(See Principle 4)**

PRINCIPLE 3: Obtain appropriate imaging studies to determine the presence of retained foreign bodies.

- CT scan is the single most important diagnostic test. Face and orbital CT imaging with thin axial cuts (1.5–2 mm) should be obtained for evaluating ocular injuries with possible retained FBs. A "head" CT protocol is not sufficient for the detection of ocular FBs; face and orbit CT protocols must be employed
- If CT imaging is unavailable, plain film (posterior-anterior, lateral, and Waters views) can be used to estimate the size, shape, number, and general location of retained FBs. CT scout images, if available, can also provide this information
- Remember — not all FBs are radiopaque, i.e., they are radiolucent and therefore not visible by either CT or MRI. While all magnetic FBs are radiopaque, not all radiopaque FBs are magnetic. Because of this, a high index of suspicion for the presence of FBs must be maintained even in the face of negative imaging. Radiolucent FBs can be identified through ultrasound only after an ophthalmologist has repaired or ruled out an open globe injury

PRINCIPLE 4: SHIELD AND SHIP. Place a rigid eye shield over the injured eye and evacuate patient to the nearest ophthalmologist.

- **SHIELD:** Place a rigid metal or plastic shield over the injured eye in a way that it does not touch the eye. Hold the shield in place with tape. Eye protection (APEL/MCEP), goggles, glasses, or a Styrofoam or paper cup can be used as temporary shields. Ensure that the eye shield vaults over any protruding ocular FBs
- **SHIP:** Evacuate casualty expeditiously to nearest ophthalmologist

Wearing protective eyewear can shield the eye from shrapnel, thus reducing the likelihood of an ocular foreign body. (Source: U.S. Army)

Damage Control Ophthalmology: For Ophthalmologists

DCO PRINCIPLE 1: Examine the eye directly and as thoroughly as possible. Do not rely exclusively on imaging.

- Many injuries can be evaluated and repaired using loupe magnification and bright shadowless lighting. Open globe evaluation and repair requires an operating microscope and appropriate microsurgical instrumentation
- For evaluating extraocular and open-globe injuries associated with FBs, carefully separate all tissues to determine the extent of injuries. Soft tissue swelling, tissue folds, coagulum, and other factors can often hide wound tracts, significant injuries, and FBs. Soft tissue palpation can be helpful for identifying bone fragments and FBs
- When necessary, use a wire speculum, Desmarres retractor, or bent paper clips to retract the eyelids to examine the eye and ocular fornices. Minimize any pressure on the globe
- Meticulous irrigation is required to dislodge any superficial FBs, and all wounds must be explored to their full extent, including deep spaces. This may have to be conducted as part of an examination under anesthesia (EUA). It may be necessary to return to the operating room for additional cleansing

+ **Necessity** – Critical
+ **Urgency** – As soon as possible
+ **Adequacy** – Examination must be comprehensive and accurate. Meticulous exploration and cleansing is necessary. Remember that finding one laceration does not mean you have found all lacerations
+ **Avoidance** – A povidone-iodine (Betadine®) detergent should not be used around the eye

DCO PRINCIPLE 2: Imaging studies are the most important and sensitive method in making an assessment of an open globe injury with intraocular foreign bodies.

- Multiple intraocular and extraocular FBs are often present in penetrating ocular injuries. The detection of one FB does not rule out the presence of others. Careful physical assessment and imaging is needed to identify all FBs. Notably, remember that some FBs are radiolucent and can therefore be missed by a routine CT scan. Maintain a high index of suspicion for the presence of additional FBs even in the face of negative imaging
- Face and orbital CT imaging with thin axial cuts (1.5–2 mm) should be obtained for evaluating ocular injuries with possible retained FBs. After open globe injuries have been repaired, optical coherence tomography (OCT), ocular ultrasound, and MRI (in the absence of retained ferromagnetic FBs) can be used for further ocular evaluation
- An MRI is contraindicated until the presence of an extraocular or intraocular ferromagnetic FB has been ruled out
- Ultrasound should not be performed on an injured eye until an open globe injury has been ruled out or repaired
- FBs can be radioactive (e.g., depleted uranium) and therefore constitute a potential hazard to care providers
- Plain film radiographic imaging has limited usefulness for imaging IOFBs and requires a variety of views that are not familiar to many physicians in the modern age, where CT imaging is readily available. However, plain films are a helpful screening tool when it is not possible to obtain CT images. Plain film (posterior-anterior, lateral, and Waters' views) can be used to estimate the size, shape, and general location of retained FBs. CT scout images, if available, can also provide this information
- Radiolucent FBs can be identified through ultrasound only after an open globe injury has been repaired

+ **Necessity** – Critical. If CT is unavailable, be familiar with historic and plain film localization techniques, or where to look for this information (See Feature Article)
+ **Urgency** – As soon as possible
+ **Adequacy** – A face and orbit CT imaging protocol must be obtained (1.5–2 mm axial slices, with coronal and sagittal reconstructions). A head protocol is inadequate
+ **Avoidance** – Do not perform an MRI unless a ferromagnetic FB has been ruled out. Do not perform an ultrasound unless an open globe injury has been repaired or ruled out

DCO PRINCIPLE 3: FBs that are superficial or composed of toxic material must be removed as soon as possible.

- Intraocular FBs composed of iron, copper, or other reactive metals or material should be removed as soon as possible to prevent permanent toxic injury to the eye. If possible, accessible FBs composed of organic materials (e.g., plant materials or animal parts) should be removed as soon as possible to prevent a severe inflammatory reaction and possible infection
- Remove non-impaled FBs from the skin, conjunctival fornices, posterior surface of the eyelids, and bulbar conjunctiva using irrigation, cotton-tipped applicators, or forceps. Cutaneous FBs can often be removed with low flow irrigation using gentle debridement with a 4 X 4 gauze, a sponge, or a nylon brush. It is important to avoid removal of viable tissue during debridement. More than one effort may be required to remove embedded foreign material (e.g., asphalt, street dirt, powder burns, etc.)
- Take advantage of scheduled general anesthesia events to cleanse, wash out, and gently debride adnexal soft tissue
- Copious irrigation is often necessary after removal of concrete and plaster or other solid FBs containing alkali to mitigate the effects of any chemical injury
- Extraocular FBs composed of glass, plastic, and non-reactive metals can often be left in place if they (1) will not result in additional ocular injury, (2) are not easily accessible, or (3) if their removal will result in additional ocular damage

+ **Necessity** – Mandatory
+ **Urgency** – As soon as possible. Delayed removal of FBs can cause additional ocular damage, particularly with regard to metallosis or reactive FBs
+ **Adequacy** – Meticulous
+ **Avoidance** – N/A

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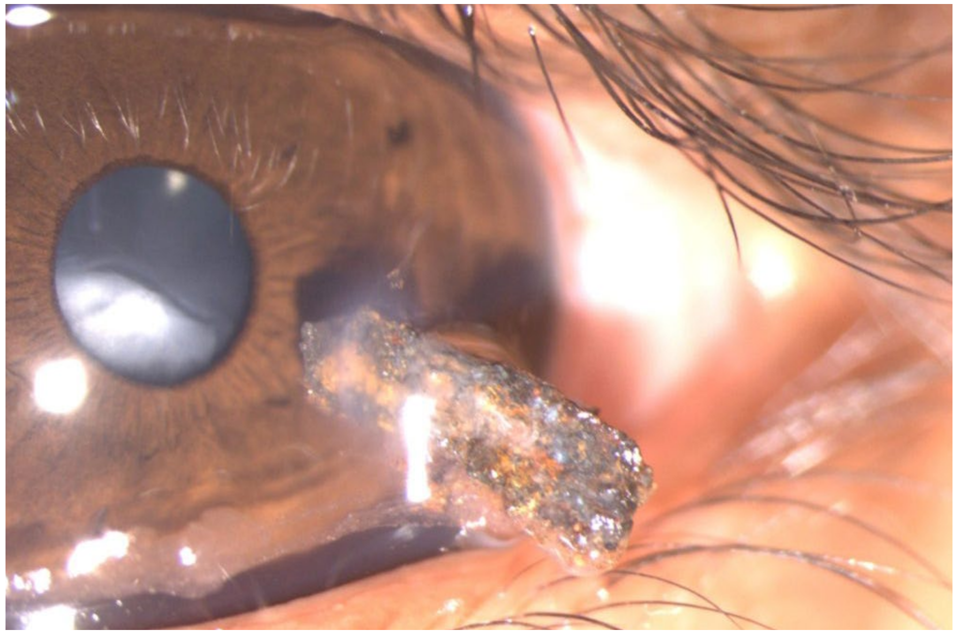
DCO PRINCIPLE 4: Defer removal of IOFBs to a vitreoretinal subspecialist with proper equipment and support.

- Intraocular posterior segment FBs should not be disturbed and should only be managed by a vitreoretinal specialist after closure of the perforating/penetrating scleral laceration
- Information concerning any and all FBs should be documented at Level III and communicated to higher levels of care. If possible, send all FBs with the patient
- A partially embedded eyelid FB that is in contact with the globe should be removed at Level III to prevent further globe injury
- Antibiotic prophylaxis is important for all open globe injuries, particularly those with IOFBs. Start fluoroquinolone antibiotics (e.g., ciprofloxacin, moxifloxacin, or levofloxacin) to prevent infection. Administer an anti-emetic (ondansetron [Zofran]). If necessary, administer acetaminophen, ibuprofen, or aspirin by itself or in combination with opioids for pain management
- Shield and evacuate patients with impaled or difficult to remove IOFBs to a Level IV or V military treatment facility (MTF) with an available vitreoretinal subspecialist

+ **Necessity** – Critical
+ **Urgency** – As soon as possible
+ **Adequacy** – Administer fluoroquinolone antibiotics (e.g., ciprofloxacin 500 mg BID, moxifloxacin 400 mg PO, or levofloxacin 500 mg IV QD) to prevent infection if an open globe injury is present. Antibiotics should continue through evacuation to Level IV and V facilities. Begin an anti-emetic (ondansetron [Zofran] 4 mg IV). If necessary, administer acetaminophen, ibuprofen, or aspirin by itself or in combination with opioids for pain management
+ **Avoidance** – Avoid removing IOFBs in theater. If possible, defer removal to a more stable, controlled, and efficient environment (Level IV or V MTF)



Corneal perforation with a metallic foreign body. (Source: Community Eye Health)

DCO PRINCIPLE 5: Follow patients carefully and repeat diagnostic studies as necessary, particularly if the clinical status does not improve, remembering that a patient may have multiple FBs in different areas.

+ **Necessity** – Critical
+ **Urgency** – Daily, or more frequently, during the first 96 hours
+ **Adequacy** – Must be carefully conducted. Repeat imaging as necessary to ensure all FBs have been identified
+ **Avoidance** – N/A

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Conference Presentations and Publications

The following presentations and publications highlight contributions from VCE staff and collaborators.

Recent Conferences

2017 International Blast Injury State of the Science Meeting - The Neurological Effects of Repeated Exposure to Military Occupational Blast: Implications for Prevention and Health

12–14 March 2018, RAND Pentagon City Office, Arlington, VA | https://blastinjuryresearch.amedd.army.mil/

National Capital Area TBI Research Symposium 2018

6–7 March 2018, Natcher Conference Center, National Institutes of Health, Bethesda, MD | https://hjf.cvent.com/events/national-capital-area-tbi-research-symposium-2018

Upcoming Conferences

The Association for Research in Vision and Ophthalmology (ARVO)

29 April–3 May 2018, Hawaii Convention Center, Honolulu, HI | https://www.arvo.org/

Presentations

Special Session:

Santullo O, et al. **Military Relevant Priorities and Strategies for Injury Diagnostics and Treatments.**

30 April 2018

Special Interest Group, Ocular Trauma:

Rex T, Blanch R, Coats B, Purdue M, Thomas CM. **Animal Models of Ocular Trauma.**

2 May 2018

Poster Presentations

Mazzoli RA, Snider M, Lewin-Smith M, Merezhinskaya N, et al. **The DoD Joint Pathology Center (JPC)/ Vision Center of Excellence (VCE) Ocular Foreign Body Compositional Analysis Program.**

Recent Publications

Reynolds ME, Hoover C, Riesberg JC, Mazzoli RA, Colyer MH, Barnes S, Calvano CJ, Karesh JW, Murray CK, Butler FK, Keenan S, Shackelford S. **Evaluation and Treatment of Ocular Injuries and Vision-Threatening Conditions in Prolonged Field Care**. *Journal of Special Operations Medicine*. 2017;17(4):115-126. **(See article summary on Page 12)**

Calvano CJ, Enzenauer RW, Eisnor DL, Mazzoli RA. **Atropine Eye Drops: A Proposed Field Expedient Substitute in the Absence of Atropine Autoinjectors.** *Journal of Special Operations Medicine*. 2017;17(3):81-83.