Detection of Metallic Ocular Foreign Bodies With Handheld Sonography in a Porcine Model

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Objective. Eye conditions are common in emergency departments. Intraocular foreign bodies (IOFBs) are a frequent concern. Orbital computed tomography (CT) is traditionally used for evaluation. We sought to evaluate bedside ocular sonography for detecting metallic IOFBs. Methods. A pig model was chosen. A micrometer was used to create 3 precise metallic fragments: 0.012 × 0.012 × 0.012, 0.025 × 0.025 × 0.012, and 0.05 × 0.05 × 0.012 in. Individual eyes were randomized to the presence or absence of a foreign body. Randomization was also used to determine the specific size of any given IOFB. A standard 18-gauge spinal needle was used to puncture the sclera and introduce the IOFB into the vitreous. Each eye was then evaluated by 2 sonologists for the presence or absence of an IOFB. Results. A total of 28 eyes were used; 12 (43%) were randomized to no IOFB and 16 (57%) to the presence of an IOFB. Of the 16 eyes that received IOFBs, 8 (50%) were 0.012 × 0.012 × 0.012 in; 5 (31%) were 0.025 × 0.025 × 0.012 in; and 3 (19%) were 0.05 × 0.05 × 0.012 in. Sensitivity was 87.5% and specificity 95.8%. Positive predictive value (PPV) and negative predictive value (NPV) were 96.5% and 85.2%, respectively. Conclusions. Bedside sonography may identify the presence of metallic IOFBs. The PPV allows a high degree of certainty that an IOFB is actually present if seen and may negate the need for unfused orbital CT. The NPV was 85.2%. Given the potential grave consequences of a missed IOFB, sonography cannot be used as the definitive test to rule out the presence of a metallic IOFB. In the presence of negative findings, further imaging is warranted. Key words: emergency medicine; emergency sonography; portable sonography; ocular foreign bodies; ocular sonography; sonography.
out contrast has been used to evaluate these patients. However, orbital CT may not be available in all instances and does deliver a dose of radiation to some of the more sensitive tissues in the human body. Recent concerns over radiation doses from CT and other procedures stress the need for judicious use of imaging applications that use ionizing radiation.

Sonography has been used for many ocular conditions, including retinal detachment, lens dislocation, globe disruption, and even foreign body detection. Advantages of sonographic evaluation of the eye include little to no safety risk. American Institute of Ultrasound in Medicine guidelines specify exposure standards for ophthalmic ultrasound and suggest that the maximum attainable value for the thermal index should be less than or equal to 1; the maximum attainable value of the mechanical index should be less than or equal to 0.23; and the maximum attainable value of the derated spatial-peak time-average intensity should be less than or equal to 50 mW/cm². Recent work has shown that even a combination of high-energy ultrasound imaging with power and pulsed wave Doppler imaging caused no retinal damage after 30 minutes in an animal model. Furthermore, sonography has the distinct advantage of being highly mobile and even portable, something CT is unlikely to attain in the near future. We sought to evaluate the sensitivity of bedside ocular sonography with a handheld sonography machine in detection of metallic IOFBs in a porcine model.

Materials and Methods

This was a prospective randomized blinded controlled trial using mature freshly harvested adult articulated swine eyes. Foreign bodies made of steel were placed into the pig eyes randomly, and portable sonography was used to detect these objects. This study was Institutional Review Board exempt because of the use of commercially available dead animal tissue.

Mature freshly harvested adult articulated swine eyes were used because of the similar size to human eyes. Twenty pig heads were obtained, resulting in a total of 40 eyes. All experiments were performed in a closed-door room used for laboratory procedure sessions in medical student and resident education. The foreign bodies consisted of metal shavings created by drilling a solid piece of steel. Shavings produced from each of 3 different thickness steel samples were collected and sorted. With the use of a micrometer, 3 different uniform sizes of particles were isolated, 0.012 × 0.012 × 0.012, 0.025 × 0.025 × 0.012, and 0.05 × 0.05 × 0.012 in (Figure 1).

All metal fragments were placed intraocularly via an 18-gauge spinal needle with the stylet being used as a plunger to eject the fragment from the needle (Figure 2). Introduction occurred through the sclera lateral to the iris. The depth of placement was not controlled. In the control eyes, the sclera was punctured in the same manner and location with the same spinal needle, but no foreign body was placed. A random number generator was used to determine the presence or absence of a foreign placement as well as the specific size of foreign body to be placed in each eye.

Using a Sonosite Titan sonography system (Sonosite, Inc, Bothell, WA) with a broadband linear array transducer (5–10 MHz), 2 physicians, both with hospital credentials for the use of ultrasound, examined each eye to determine the presence of a foreign body. No attempt was made to estimate the size of the foreign body. The sonologists were allowed to use the color and power Doppler settings as well as manipulate the other settings of the ultrasound as desired to find and interrogate the foreign body. Each sonologist entered the room, made observations, and then left the room without having contact with the other sonologist. There was no time limit placed on the examination.

Figure 1. Small metal fragments, the measurement tool used, and the needle and stylet used for insertion.
on the sonologists. The sonologists marked the presence or absence of the foreign body, which was then entered into a computerized database. Statistical analysis included descriptive statistics and a paired t test with 95% confidence intervals. Data were analyzed with statistical calculators from a commercially available software package (StatsDirect Ltd, Sale, Cheshire, England).

Results

The 40 porcine eyes were evaluated for damage during transportation or animal harvesting. On initial assessment of the eyes, 12 were determined to be in too damaged a condition to be used effectively. Thus, a total of 28 eyes were used for data collection. Of these, 12 (43%) were randomized to no foreign body, and 16 (57%) were randomized to foreign body placement. Of the 16 eyes that received foreign body, 8 (50%) had $0.012 \times 0.012 \times 0.012$-in pieces; 5 (31%) had $0.025 \times 0.025 \times 0.012$-in pieces; and 3 (19%) had $0.05 \times 0.05 \times 0.012$-in pieces.

The sensitivity of detecting a foreign body was 87.5% (28 of 32). There were 4 false-negative findings, 3 of which were $0.012 \times 0.012 \times 0.012$-in pieces and 1 of which was a $0.025 \times 0.025 \times 0.012$-in piece. No foreign body was located in 23 of the 24 control eyes, with a resulting specificity of 95.8%. Positive and negative predictive values were 96.5% and 85.2%, respectively.

Discussion

History and physical examination are the clinician’s primary tools for discovering an IOFB. In many situations, however, small foreign bodies cannot be detected because of haziness of the optical media, poor patient cooperation, subconjunctival hemorrhage, cataract formation, which may take only hours to develop, or inflammation caused by the foreign body.\(^7,8\) In clinical practice, it is the normal-appearing eyes that can be deceiving and, hence, most troubling. As with foreign bodies resulting from hammering or grinding metal, which produce high-speed, small, sharp fragments, small IOFBs can leave little or no evidence of ocular penetration.\(^2\)

Although small, these IOFBs are as likely to produce vision loss from scarring of the cornea, cataract formation, endophthalmitis, and retinal detachment as the larger more obvious foreign bodies.\(^2,4\) If the clinical examination is indicative of a possible foreign body, it is left up to an imaging modality to rule out or rule in its presence.

Although CT is the reference standard for the evaluation of potential IOFB’s, some clinicians may be reluctant to obtain CT in patients with equivocal examination results or a poor history because of expense, involvement of additional personnel, or lack of time in a busy hospital setting. Furthermore, although CT can show steel and copper objects as small as 0.06 mm\(^3\), other metallic objects and glass up to 25 times larger can be missed.\(^7\) Additionally, CT is occasionally misleading in that extraocular foreign bodies can be seen as intraocular if they are in the vicinity of the scleral wall.\(^7\)

The application of ultrasound in ophthalmologic diagnosis is not a new phenomenon. Much of the pioneering work was performed before 1960. Mundt and Hughes\(^9\) published “Ultrasonics in Ocular Diagnosis” in 1956. This article presented, among other things, the finding that intraocular tumors could be successfully identified by sonography.\(^9\) The early work in the field was based on A-mode techniques. Gilbert Baum, MD, and Ivan Greenwood would later introduce 2-dimensional B-mode scanning for ophthalmologic purposes. Early techniques were cumbersome, requiring a water bath coupling between the eye and the transducer. A handheld contact B-mode transducer was developed by Bronson in 1972, and this facilitated further work in the field.\(^10\) The con-
continued improvement in ultrasound technology with regard to image quality and portability has made the bedside use of sonography a reality in many areas of medicine.

Sonography is well known to be a useful imaging study after ocular trauma. It has been shown to be helpful in the diagnosis of vitreous hemorrhage, retinal detachment, ruptured globe, and IOFB. Reports vary on the reliability of sonography in the diagnosis of IOFB, and numerous examples of missed foreign bodies exist in the literature. However, several studies have shown a greater than 95% correlation between sonographic findings and surgical findings for IOFBs. To our knowledge, no study has specifically assessed the ability of bedside, hand-carried sonography to identify metallic objects of varying sizes.

The results of our study indicate that bedside sonography is useful in determining the presence or absence of small metallic IOFBs. There was only 1 false-positive finding in our study, with a resultant positive predictive value of 96.5%. When there is ocular opacity or poor patient cooperation, bedside sonographic evaluation can provide evidence of actual globe perforation, leading to faster implementation of vision-saving measures and CT evaluation. In the normal-appearing eye in which a foreign body is more likely to be missed, bedside sonography provides an easy, time-effective method for ocular interrogation before CT. Although in this in vitro experiment the sensitivity for detecting IOFBs was only 87.5%, other concomitant injuries such as vitreous hemorrhage and lens dislocation can add to the sensitivity of the sonographic examination. Unfortunately because the model used was one of dead swine, these conditions could not be simulated.

Metal was chosen for this experiment because it is the most common (86%) IOFB encountered in the emergency setting. Frequently, IOFBs consisting of small pieces of metal are difficult to detect by physical examination because only a small tear is produced in the cornea. Hence, there may be no change in vision or vitreous hemorrhage, and fluorescein uptake could easily be confused with a corneal abrasion instead of the classic Seidel sign. Prior studies have shown that IOFBs are located in the vitreous, retina, or choroid in 88% of the cases. Our goal was to reproduce these types of injuries in a manner that would not be readily evident on physical examination; that is, the perforation occurred lateral to the iris in the sclera. Of a total of 4 missed foreign bodies, 3 were the smallest size (0.012 × 0.012 × 0.012 in), and 1 was of intermediate size (0.025 × 0.025 × 0.012 in). None of the largest size (0.05 × 0.05 × 0.012 in) were missed. This observation agrees with the intuitive notion that smaller objects will be more difficult to visualize with sonography. However, the randomization process resulted in most of the foreign bodies being the smallest size (0.012 × 0.012 × 0.012 in) and only 3 being the largest size (0.05 × 0.05 × 0.012 in), which may be responsible for bias in the above findings. The objects missed were ones randomly placed very close to the wall of the globe, in a posterior location; as a result, the bright echo from the foreign body was mistaken for a wall irregularity.

The foreign bodies appeared as a bright linear reflection with an artifact posteriorly (Figure 3). Although no air was introduced into the experimental eyes, air introduced intraocularly by the foreign body would have a less dense shadow than the metallic foreign body, that is, a dirty shadow. Color Doppler sonography was used for confirmation on several of the foreign bodies. With the addition of the color Doppler imaging, the metal object resonated and resulted in color over the object on the screen (Figure 4). Most of the foreign bodies present in this study were readily visible because of the high reflectivity of the metal.

![Figure 3. Large metallic foreign body (arrow). An artifact is shown posteriorly (arrowheads).](image-url)
Because this was not living tissue, there were several changes in the eyes noted on sonography. Primarily, some of the eyes were partially collapsed. These eyes were removed from the study. However, some of the eyes showed an irregular interior wall surface that is not present in living eyes. This led to 2 of the wrong observations by the sonologists. In living eyes, this effect would not be present; hence, the results may differ.

In conclusion, bedside handheld sonography can be used to identify the presence of metallic IOFBs with a high positive predictive value. This can be an important adjunct to the physical examination in cases of suspected foreign bodies.

**References**


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Figure 4. Color Doppler imaging applied to a suspected foreign body highlights the object and gives an artifact posteriorly.


