Detection of Orbital Foreign Bodies with Computed Tomography: Current Limits

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Detection of Orbital Foreign Bodies with Computed Tomography: Current Limits

Emmett Tate¹
Howard Cupples²

Detection and localization of known orbital foreign bodies with computed tomography was evaluated using a model that simulates as closely as possible in vivo conditions. The GE 8800 scanner proved to be an excellent instrument for detection and localization of most orbital or intraocular foreign bodies above certain minimum levels of detectability. The minimum detectable size varied according to the material, for example, 0.06 mm³ for steel, 1.82 mm³ for auto window glass in intraocular position, and slightly larger sizes for extraocular location. Small wood fragments were not detected.

Perforating wounds make up some 30%–50% of all traumatic eye injuries [1]. The proportion of penetrating eye injuries among the inpatient population of eye hospitals averages some 5%–6% overall [1–3] and is even higher in military facilities [4]. Many radiographic techniques have been developed to detect and localize foreign objects in penetrating eye injuries. These include standard skull radiographs in selected positions, sonography, magnetic localization, and, recently, computed tomography (CT). It has been well recognized that standard and special radiographic techniques as well as sonography have significant limitations. Depending on the material causing the eye injury and its relative position, the smallest fragment that could be reliably resolved was on the order of 1–2 mm on a side [5–7]. With a model duplicating in vivo conditions, the smallest size of several common materials in penetrating eye wounds that could be reliably detected by CT was determined [8]. In addition, any artifactual changes caused by multiple fragments in the same orbit and globe were investigated.

Materials and Methods

A dry, commercially prepared human skull served as the skeletal foundation for the study. The intracranial vault was filled with a paraffin base having an attenuation coefficient similar to cerebral parenchyma. The orbits were filled with a commercial vegetable oil which was warmed to a liquid consistency. Globes harvested from deceased individuals were then imbedded into this gelatinous vegetable material in normal anatomic configuration. Cooling of the vegetable matter then fixed the globes into the desired location. The appropriate foreign bodies were then positioned. The entire assembly was subsequently immersed in a water bath.

Initially, the skull, with globes in place, was scanned in air. However, without the normal facial and scalp soft tissues, the scans were noticeably different from those generated in daily practice. The images had a great deal of "spray" artifact from the angular surfaces of the dried skull. Similarly, the scans had uncharacteristic contrast at the routine level and window settings. By immersing the skull in a water bath only slightly larger than the greatest diameter of the skull, the images were nearly indistinguishable from routine scans at standard settings. The initial purpose of the study centered on reproducing standard scans as closely as possible. Therefore, it was elected to use the water bath for all work, even though this was an artificial condition.
A General Electric CT/T 8800 scanner with 320 x 320 matrix was used. All sections were 5 mm thick. Standard machine settings included 576 angles of measurement per slice. The generator was set to the 600 mA station at 120 kVp. All settings and modes of operation were those used in routine patient scanning, with the exception of the water bath assembly.

For representative foreign material, copper, steel, aluminum, glass, and wood were chosen [8]. The copper and steel were obtained as lengths of small gauge wire filaments. The aluminum was prepared as slivers from beverage cans. Spectacle lens glass and automobile window glass were obtained by choosing appropriate size fragments after pulverizing larger segments. The wood came from splinters of partially dried pine.

Evaluations were performed on both the scanner viewing screen image and on the subsequent films. No magnification was used in the initial screening procedure. All determinations were made by either an experienced ophthalmologist or radiologist. Generally, the observers worked together, simultaneously examining the images. Any suspicious areas discovered on the initial screening were subsequently magnified and closely scrutinized. There were no cases in which both observers could not agree on the presence or absence of the foreign body. Standard viewing settings used included a level of 50 Hounsfield units (H) and a window of 500 H. Much of the evaluation was done in the measure mode as well.

Results

Our observations are offered in table 1 and compared with other investigations in table 2.

Discussion

In the search for a reliable method of detecting an orbital foreign body and its subsequent localization, many methods have been explored. At the present time, CT evaluation of such injuries is being rapidly pursued. It appears to offer the least radiation dose per unit information obtained (about 5 rad [0.05 Gy]), as well as being cost-effective [11–13]. Proper and timely management requires reliable evaluation and specific localization [1, 14]. The CT scanner has the potential for a single, straightforward, non-operator-dependent examination to provide such pertinent anatomic data.

The foreign materials selected for study were those reported to be relatively common in large series [1, 8]. The model used offers anatomic structures with attenuation coefficients similar to those of living tissue. The scans obtained were of similar appearance and quality to those generated in daily operation (figs. 1 and 2).

The results demonstrate that very small slivers of metal can be reliably detected. The lower limit for copper and steel was 0.06 mm³, fragments barely visible even before insertion into the phantom. The minimum volumes for detectable aluminum were some 25 times greater. This is in keeping with the well known difficulty in visualizing aluminum foreign bodies at standard radiography. The wood fragments were never reliably detected.

Whether an object was intra- or extracoccal had little effect on detectability. Several fragments in the same globe provided no additional difficulty. No significant "spray" artifact was generated by the relatively small metal fragments used.

As demonstrated in table 1, the small pieces of wood chosen for this study were never resolved. Attempts were made to insert larger fragments, but once the globe was perforated, its collapse was difficult to prevent. Large wooden fragments could not be positioned without compromising anatomic integrity and loss of the normal tissue configurations.

It is assumed that several factors, including age, state of hydration, type of fiber, and locality of origin, would all contribute to the final attenuation coefficient of any wooden foreign body.

Initially an attempt was made to inject blood into the globes to reproduce the hemorrhage often present with intraocular foreign bodies. It was not technically feasible with the apparatus used to keep the blood and foreign body in physical continuity for reliable interpretation.

Our data compare favorably with that of other authors [9, 10, 15]. The minimum detectable volumes seem slightly smaller than those needed elsewhere (table 2). This may be due to machine difference or inability to measure precisely with such small fragments.

Initially, the attenuation coefficients of the selected foreign bodies were to be cataloged; however, early experience showed that there was such disparity of data that this information was deleted. Only the largest metallic fragments yielded measurements greater than 150 H. The partial volume averaging phenomenon was believed to make analysis of such data unreliable for foreign body content identification.

Other authors have noted that while size, density, and

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**Table 1: Minimum Detectable Volumes for Various Foreign Bodies using 5 mm Slice Thickness**

<table>
<thead>
<tr>
<th>Material</th>
<th>No. Studied</th>
<th>Minimum Detectable Volume (mm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Intracocular</td>
</tr>
<tr>
<td>Steel</td>
<td>5</td>
<td>0.06</td>
</tr>
<tr>
<td>Copper</td>
<td>11</td>
<td>0.06</td>
</tr>
<tr>
<td>Aluminum</td>
<td>13</td>
<td>1.52</td>
</tr>
<tr>
<td>Spectacle lens glass</td>
<td>4</td>
<td>1.34</td>
</tr>
<tr>
<td>Auto window glass</td>
<td>5</td>
<td>1.82</td>
</tr>
<tr>
<td>Wood</td>
<td>7</td>
<td>*</td>
</tr>
</tbody>
</table>

* None were visualized up to 2.44 mm³ (intracocular) and 1.57 mm³ (extracocular).

**Table 2: Comparison of Minimum Detectable Volumes of Foreign Bodies by CT from Different Studies**

<table>
<thead>
<tr>
<th>Material</th>
<th>Minimum Detectable Volume (mm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ref. [9]</td>
</tr>
<tr>
<td>Steel</td>
<td>0.06</td>
</tr>
<tr>
<td>Copper</td>
<td>0.7</td>
</tr>
<tr>
<td>Aluminum</td>
<td>12.0</td>
</tr>
<tr>
<td>Glass</td>
<td>1.27</td>
</tr>
<tr>
<td>Wood</td>
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</tbody>
</table>

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Fig. 1.—Left extraocular foreign body of steel (arrow) measures 0.14 mm². Optic nerve on right side.

Fig. 2.—Left intracocular steel foreign body (curved arrow) measures 0.10 mm². Small amounts of injected air bilaterally (straight arrows).

attenuation coefficient are important determinants of minimum detectability, orientation with respect to the radiation beam can be significant as well [10]. The foreign bodies in this study were placed at random. A follow-up study with orientation as the variable is planned.

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REFERENCES