Penetrating intracranial wood wounds: clinical limitations of computerized tomography

JAMES E. HANSEN, M.D., STEVEN K. GUDEMAN, M.D., RICHARD C. HOLGATE, M.D., AND RICHARD A. SAUNDERS, M.D.

Departments of Neurosurgery, Radiology, and Ophthalmology, Medical University of South Carolina, Charleston, South Carolina

The case history of a patient with a periorbital penetrating wooden foreign body is presented. The computerized tomography (CT) densities of several different sources of wood were compared using an experimental model. The clinical usefulness and practical limitations of CT in the evaluation of intracranial foreign bodies is discussed, and the management of this type of injury is reviewed.

Key Words · head injury · computerized tomography · intracranial foreign bodies · orbital wounds · wood density

Transcranial penetration by a wooden foreign body is relatively rare, especially by one acting as a missile with a high kinetic energy content. The comparatively thin orbital roof, temporal squama, and cribriform plate allow access to the intracranial cavity for objects not usually strong enough to penetrate other regions of the skull. Periorbital penetration by wooden foreign bodies usually occurs in young children from a low-velocity puncture wound with a sharp wooden object. These wounds may appear deceptively minor and superficial, are often not accompanied by major symptomatology, and may be considered trivial by parents and examining physicians. Serious sequelae may occur days, months, or even years after the initial trauma.

The inherent nature of wood as a foreign body makes it an especially dangerous wounding agent. Its porous organic material provides a natural reservoir for microbial agents. It is soft and can fragment with minimal force and is often not detected by routine x-ray examination. These qualities make wood a potentially lethal substance.

We encountered a case of an orbital injury by a wooden stick with intracranial penetration. To study the ability of current computerized tomography (CT) technology to differentiate wood from brain, bone, and surrounding tissues, a model was constructed to measure the comparative densities of different types of wood. The clinical usefulness and practical limitations of CT as an aid in the detection and localization of intracranial foreign bodies is discussed, and the management of this type of injury is reviewed.

Case Report

This 7-year-old boy was struck by a tree branch in the left eye while playing near his home. He fell backwards, striking his occiput on the ground. There was no history of loss of consciousness. He was transported to a local emergency department where he was reported to be lethargic and unable to move his left eye. He was transferred to the Medical University of South Carolina Medical Center.

Examination. On physical examination, the patient was lethargic, but awake and able to follow commands. A small puncture wound was present just inferior to the medial canthus of the left eye. The patient was able to count fingers at 5 ft with each eye, but was too lethargic for formal testing. There was mild swelling and erythema of the lids and periorbital soft tissues of the left eye. Tension of the globe was normal to finger palpation. Levator palpebrae function was absent on the left side. Corneal sensitivity was intact bilaterally. Pupillary diameters were 3 mm in the right eye and 6 mm in the left. The left eye was nonreactive to light, but consensual reflex on the right was normal. Extraocular motions were intact on the right, but absent on the left. The remainder of the ocular and physical examination was unremarkable.

Anteroposterior and lateral skull films revealed no...
Penetrating intracranial wood wounds

Fig. 1. Left and Center: Axial computerized tomography (CT) cuts through the orbits. A low-density linear abnormality is seen passing through the superior orbital fissure and into the region of the left cavernous sinus. Right: Coronal CT cut illustrating the relationship of the foreign body to the cavernous sinus.

abnormality. A Water’s view showed a vague lucency over the superomedial aspect of the left orbit which was thought most likely to represent a small amount of subcutaneous emphysema. No fractures were seen.

The patient was placed on intravenous antibiotic prophylaxis using nafcillin and chloramphenicol. On the day following admission, he was more alert. His vision was 20/25 on the right and 20/70 on the left. His temperature had risen to 100°F orally, and the edema and erythema of his left eyelid and periorbital soft tissues had increased. The left eye appeared mildly proptotic. A CT scan through the orbits and parasellar region with coronal slices was obtained (Fig. 1). A linear abnormality of very low density, measuring approximately 3 x 50 mm, was seen lying along the medial aspect of the left orbit and passing through the superior orbital fissure and into the region of the left cavernous sinus. The most posterior portion of this area was in a plane with the dorsum sellae at the junction of the cavernous sinus and superior petrosal sinus. The attenuation coefficient of this abnormality varied from −100 to −424 Hounsfield units (HU). Carotid arteriography revealed thrombosis of the left carotid sinus.

Operation. A decision was made to explore the left orbit in an attempt to identify the foreign body. If one were found, direct anterior removal through the wound was planned. If necessary, a craniotomy would be performed. On the day after admission, a transconjunctival medial orbitotomy was performed. A foreign body was found protruding from the region of the superior orbital fissure and was removed with gentle traction. It was a hard, cylindrical woody substance with a central lumen, measuring 3 by 52 mm (Fig. 2). No bleeding followed its removal, and cultures were taken from the foreign body and wound track.

Postoperative Course. After removal of the foreign body, the patient became afebrile and his proptosis and erythema steadily diminished. The cultures grew out a bacillus species. Postoperatively, intravenous nafcillin and chloramphenicol were continued for 7 days and the patient was discharged on a 10-day course of erythromycin. Six months later, a follow-up CT scan was unremarkable. His visual acuity had returned to normal and the ophthalmoplegia had cleared. His only residua were mild anisocoria and a Marcus-Gunn pupil.

CT Characteristics of Wood

Materials and Methods

To study the CT characteristics of wood, a model was constructed to allow scanning of six wooden substances in an aqueous environment. Two plastic cylindrical specimen containers measuring 18 by 21 cm were

Fig. 2. Intraoperative photograph just after removal of foreign body, illustrating the cylindrical woody “stick” lying across the patient’s face.
each fitted with a 2 cm-thick Styrofoam disc placed inside near and parallel with the container's base. Five varieties of wood and a No. 2 graphite pencil were placed through the styrofoam discs. The woods used were oak, pine, wax myrtle, dogwood, and cedar. The sections were taken from twigs with diameters of approximately 5 to 7 mm. The specimen in each container was taken from an adjacent portion of the same branch. A pencil was included in the array because of its frequent involvement as an intracranial foreign body. A barium wire was used as a marker. Two groups of wood were utilized: the wood of one group was "water-logged" by soaking in water for 60 hours then placed in one container; the other group was placed dry in the other container. Both containers were filled with water and sealed, then immediately placed in the scanner with its axis perpendicular to the plane of scanning. Each array of woods was scanned with cuts 3 mm thick (Fig. 3). Density measurements of the woods were made with a General Electric 9800 CT scanner (Table 1).

Results

Table 1 indicates the highly variable density of the woods tested. The differences in measurements between soft and hard woods can be quite marked (for example, dry pine has a mean of -461.2 HU and dry oak a mean of -88.2 HU). The lack of homogeneity within the same piece of wood is illustrated by the wet pine sample, with a minimum value of -644 HU and a maximum of -61 HU. All woods became denser (obtained more positive values) upon soaking in water. This could be quite striking as illustrated by the difference in the mean density values of dry and wet wax myrtle, -327.8 HU and 65.7 HU, respectively. The graphite in the pencil was considerably denser than any of the woods.

Discussion

All periorbital puncture wounds should be treated for possible intracranial penetration. Although wounds in and about the orbit without intracranial penetration are much more common, the consequences of retained intracranial foreign bodies can be disastrous. Miller, et al.,\(^8\) reported that infection was a complication in 64% of their 42 cases of intracranial wooden foreign bodies, in spite of the use of antibiotic agents. Brain abscess occurred in 48%, and the total mortality rate was 25%. Orbito-facial-cranial wounds are thought by some to be more hazardous than penetrating intracranial wounds at other sites. A mortality rate of 12.5% was reported by Webster, et al.,\(^2\) in a review of 40 cases of orbito-cranial wounds suffered during World War II from all causes. This is half of the 25% mortality rate due to wooden foreign bodies cited by Miller, et al. Webster,
Penetrating intracranial wood wounds

et al., noted that the mortality rate from orbitocranial wounds was almost twice that associated with missiles entering the vault directly, perhaps due to the close proximity of the perinasal sinuses to the orbits.

The structural characteristics of the orbit play an important role in the pathogenesis of orbital injuries with intracranial penetration. The orbit is in a shape of a horizontal pyramid on a postremedial axis. This shape tends to deflect objects entering the orbit toward the apex where the superior orbital fissure and optic foramen may provide a passage to the intracranial contents. The superior orbital plate of the frontal bone is another vulnerable orbital structure. Freeman has shown how easy it is to penetrate the roof of the orbits with a sharp object in order to reach the frontal lobes of the brain in the performance of transorbital prefrontal leukotomies. In the child, not only is this structure very thin, but the lack of development of the supraciliary ridges makes it particularly vulnerable. This plate may be further exposed during a reflex retroflexion of the head at the time of injury. The globe is seated amidst the periorbital fat and is rarely ruptured, as the scleral covering is quite strong and the globe is readily displaceable. Also, the blink reflex covers the globe with a tough layer of skin, effectively blunting the stabbing instrument. The resilience of the globe is a self-protective feature, but its shape and position further tend to direct objects entering the orbit either through the superior orbital plate or down the cone of the orbit to the foramen.

Bard and Jarrett recommend that intensive antibiotic therapy be started immediately for all perforating orbital wounds, even in the absence of signs of intracranial penetration. The role of wood as the nidus of infection is well documented. Adequate tetanus immunization should be established since wood is the risk of tetanus.

J. Neurosurg. / Volume 68/May, 1988

TABLE 1
Density measurements of woods*

<table>
<thead>
<tr>
<th></th>
<th>Pine</th>
<th>Live Oak</th>
<th>Red Cedar</th>
<th>Dogwood</th>
<th>Wax Myrtle</th>
<th>Pencil Wood</th>
<th>Graphite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>Wet</td>
<td>Dry</td>
<td>Wet</td>
<td>Dry</td>
<td>Wet</td>
<td>Dry</td>
<td>Wet</td>
</tr>
<tr>
<td>maximum</td>
<td>-136</td>
<td>-61</td>
<td>-13</td>
<td>198</td>
<td>-129</td>
<td>-79</td>
<td>-102</td>
</tr>
<tr>
<td>mean</td>
<td>-461.2</td>
<td>-376.3</td>
<td>-88.2</td>
<td>68.6</td>
<td>-319.5</td>
<td>-218.2</td>
<td>-198.1</td>
</tr>
<tr>
<td>SD</td>
<td>118.4</td>
<td>152.9</td>
<td>35.3</td>
<td>80.5</td>
<td>82.2</td>
<td>54.4</td>
<td>59.1</td>
</tr>
</tbody>
</table>

* Values are expressed in Hounsfield units. Dry denotes wood placed in aqueous media and immediately scanned; wet denotes wood soaked in water 60 hours before being placed in aqueous media for scanning. SD = standard deviation.

Although CT has been shown to detect steel particles as small as 0.06 cu mm, wood may not be distinguished from surrounding tissues, regardless of the splinter size. Our case report and experimental study illustrate that wood can have a surprisingly low density as measured by CT, and care must be taken not to misinterpret a low-density wooden foreign body as a localized region of pneumocephalus or air in the sinuses or orbit. The experimental study indicates that the CT appearance of wood can be highly variable. Kuhns, et al., have shown that, after 48 hours in an aqueous environment, the wooden foreign body absorbs water and becomes even closer to tissue density. This was confirmed in our study where all of the woods became denser upon soaking in water. Tate and Cupples reported that the partial-volume averaging phenomenon of CT produced disparities in the attenuation coefficients of the selected foreign bodies studied. With the current CT technology, accurate foreign body content identification is not always possible, considering the wide range of densities found within specific woods and the partial-volume averaging phenomenon. When clinical suspicion warrants, additional CT maneuvers are necessary including the introduction of contrast media, dynamic contrast-enhanced scans, delayed contrast-enhanced scans, angling of axial cuts, coronal cuts, tangential cuts, sagittal and coronal cuts, reconstruction, and use of metrizamide in addition to various CT windows (especially bone windows). Despite its limitations, however, CT is currently the single most effective test and should be the primary diagnostic examination in suspected penetrating orbital and cranial wounds.

Neurosurgical exploration must be considered for all cases of intracranial injury or penetration by a foreign body.
body. This is especially important if the wounding agent is of a friable nature or of organic origin. There is a high incidence of retained pencil tips and brain abscess formation with intracranial pencil injuries.\[2,4,6,7,9,11,18\]

In their detailed review of penetrating intracranial foreign bodies, Miller, et al.,\[18\] found a 33% morbidity rate in all patients who underwent immediate operation in the post-antibiotic era; the morbidity rate rose to 50% if the patient underwent surgery at a later time. The mortality rate was 10% in the group undergoing surgery (early or late), whereas the mortality rate was 62% in the nonoperated group. It should be noted that CT evaluation was not performed on any patient reported by Miller, et al. Deeply embedded foreign bodies should not be removed except in a controlled operating room environment. Any bone fragments should be carefully removed and a thorough search made for all possible fragments of foreign body. This may necessitate use of the operative microscope. Aerobic, anaerobic, and fungal cultures of any foreign material or suppuration should be made. All cerebrospinal fluid leaks and dural tears must be repaired, with closure of the dura in a watertight fashion.

The case described here represents one of the few situations permitting an extracranial approach for removal of an established intracranial foreign body. The intraorbital location of the foreign body was clearly identified by CT, supporting the feasibility of an intraorbital surgical approach. The scan demonstrated the foreign body to be of small diameter, cylindrical, and regular in shape. It showed the foreign body passing through the superior orbital fissure with no evidence of any fractures or bone fragments. Cerebral angiography clearly documented the status of the intracranial vascular structures. The involved cavernous sinus was thrombosed. Upon withdrawal of the foreign body, no hemorrhage occurred along its track and no fragmentation of the foreign body was seen. Its length was measured and found to correspond to the dimensions calculated in the CT scanner. Obviously, a minute fragment could go undetected in spite of these methods, but close follow-up monitoring with interval CT will detect a foreign body granuloma or brain abscess formation should it develop.

References


Manuscript received March 16, 1987.
Accepted in final form October 30, 1987.
Address reprint requests to: Steven K. Gudeman, M.D., Department of Neurosurgery, Medical University of South Carolina, 171 Ashley Avenue, Charleston, South Carolina 29425.