High-Resolution CT of Temporal Bone Trauma

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Computed tomographic (CT) findings in 18 patients with temporal bone trauma were reviewed. Eight patients suffered longitudinal fractures of the petrous bone, which were associated with ossicular dislocation in two patients. Transverse fractures were detected in six patients, with a contralateral mastoid fracture in one patient. In four patients, the fractures were restricted to the mastoid region. Of the 14 patients in whom adequate neurologic evaluation was available, seven had a permanent facial nerve or hearing deficit while five suffered at least a transient neurologic deficit related to the temporal bone trauma. Routine head CT (10 mm sections) demonstrated only eight of 19 petrous bone injuries. Clues to such injury included opacification of the mastoid air cells (10 patients), sphenoid sinus (11 patients), external canal and middle ear air space (10 patients), and local pneumocephalus (five patients). Evidence of brain trauma or extra-axial hematoma was seen in 12 patients. In 13 cases, high-resolution CT was also performed, demonstrating temporal bone injuries in all. This latter technique allows rapid and detailed evaluation of temporal bone trauma. Reports of radiographic evaluation of temporal bone trauma tend to deal with a somewhat skewed population, selected on the basis of clinical symptomatology. In a major trauma center equipped with high-resolution CT, it was found that temporal bone fractures may be seen incidentally, or in patients in whom symptomatology related to temporal fracture is obscured by much more serious neurologic compromise.

The complications of temporal bone trauma—facial nerve paresis, conductive hearing loss, cochlear and vestibular dysfunction, and leakage of cerebrospinal fluid (CSF)—constitute an important group of delayed sequelae of head injury. Appropriate and timely therapy may, in some cases, improve or prevent permanent deficits related to such complications. Therefore, expedient radiologic recognition of temporal bone fracture, with accurate delineation of the fracture plane and assessment of associated soft-tissue injury, is warranted [1-3].

Plain radiography displays only 17%-30% of temporal bone fractures [4, 5]. Consequently pluridirectional tomography has been the method of choice for the investigation of suspected otologic trauma [4, 6, 7]. However, complex motion tomography is both difficult to perform, particularly in the acutely ill patient, and less than satisfactory for the demonstration of fine fractures [8]. Recent advances in computed tomographic (CT) technology, including very thin-section scanning with special reconstruction software specific for bone imaging, have allowed spatial resolution of fine bony detail comparable to that attainable by conventional tomography [9-11] (fig. 1). Furthermore, high-resolution CT images are obtained more efficiently and with less radiation, and can be reformatted in multiple projections, regardless of the original plane of scanning. We report our experience with high-resolution CT in the evaluation of temporal bone trauma.

Materials and Methods

We reviewed the clinical records and head CT scans of 18 patients admitted for head...
trauma during a 2 year period who had evidence of acute trauma of the temporal bone. All CT scans were obtained with a GE 8800 CT scanner. Five patients were evaluated by routine head CT alone. Thirteen patients had both routine head CT and high-resolution CT of the temporal bone. These CT studies were performed by obtaining contiguous 10 mm axial slices through the cranial vault with a 9.6 sec scan time.

High-resolution CT scans were obtained on patients with symptoms of temporal bone trauma, including otorrhea, or seventh or eighth cranial nerve dysfunction. These contiguous 1.5 mm CT sections had exposure factors of 120 kVp and 200-500 mAs and scan speeds of 9.6 sec. Target reconstruction was performed, yielding pixels of 0.25 mm in diameter. The CT number range was expanded to 4000 H. In the more recent cases, dynamic sequential scanning was performed using a software package provided by G.E. (Dynapak, G.E. Medical Systems, Milwaukee). Most scans were obtained in the axial plane. In all cases, image reformation in multiple planes was done. Information in the clinical records, including operative reports, was correlated with the CT findings.

Results

The 18 patients (12 males, six females) were 2½–77 years old; most were in the second to third decade. Eight patients suffered their fracture from blunt trauma; six, from a motor vehicle accident; and four, from a vertical fall. Eight patients suffered fractures directed longitudinally along the axis of the petrous ridge. Of these eight patients, definite and probable associated ossicular dislocations were identified in one patient each (fig. 2). In six others, transverse fractures occurred, with
a contralateral mastoid fracture in one case. Four fractures were restricted to the mastoid region; one of them involved only the styloid process. Bleeding from the external auditory canal was observed in 11 cases (including all longitudinal fractures); otorrhea and hemotympanum, in six each; rhinorrhea, in one.

In four of the 18 patients, rapidly deteriorating clinical status prevented extensive neurologic examination. In seven of the other 14 patients, a lasting facial nerve or hearing deficit associated with the temporal bone fracture was seen. Four patients suffered a seventh nerve paresis, one immediate in onset (associated with a longitudinal fracture) and three delayed (associated with a transverse fracture in two and a styloid process fracture in one). Three patients experienced unilateral deafness, conductive in two (associated with a middle ear hemorrhage in one; an ossicular dislocation in another) and sensorineural in one (associated with a transverse fracture) (fig. 1). A transient deficit was noted in five of the 14 patients.

Mental status was initially abnormal in 17 patients, characterized by alteration of consciousness in seven and complete loss of consciousness in 10. The information was not available in one case initially seen elsewhere.

Routine head CT (10 mm sections) demonstrated only eight of 19 petrous bone injuries. High-resolution CT, performed in 13 cases, demonstrated temporal bone injuries in all. Of these 13 patients, routine head CT had documented a temporal bone fracture in only three, with 10 false-negative studies. In these cases high-resolution studies were prompted by clinical signs including CSF otorrhea and facial or cochlear nerve paresis. High-resolution CT showed not only a greater number but also a greater variety of injuries. Whereas fractures demonstrated by routine CT were primarily restricted to the transverse or longitudinal plane, high-resolution CT detected mastoid and styloid process fractures as well as an ossicular dislocation, in addition to the more conventional fracture types.

The CT findings of temporal bone trauma in our patients are summarized in Table 1. Calvarial fractures including facial fractures and other fractures of the skull base were often associated with the temporal fractures (fig. 2). Opacification of mastoid, sphenoid, external canal, and middle ear spaces was noted as was local pneumocephalus. Most patients had evidence of brain trauma or extraaxial hematoma.

### Table 1: CT Findings Associated with Temporal Bone Trauma

<table>
<thead>
<tr>
<th>Associated Findings</th>
<th>No. Patients (n = 18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinus opacification (n = 16):</td>
<td></td>
</tr>
<tr>
<td>Mastoid</td>
<td>10</td>
</tr>
<tr>
<td>Sphenoid</td>
<td>11</td>
</tr>
<tr>
<td>Ethmoid</td>
<td>9</td>
</tr>
<tr>
<td>Maxillary</td>
<td>7</td>
</tr>
<tr>
<td>Frontal</td>
<td>3</td>
</tr>
<tr>
<td>Opacification of external canal/middle ear</td>
<td></td>
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<tr>
<td>(n = 10)</td>
<td></td>
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<tr>
<td>Other fractures (n = 11):</td>
<td></td>
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<tr>
<td>Calvarial</td>
<td>8</td>
</tr>
<tr>
<td>Facial</td>
<td>7</td>
</tr>
<tr>
<td>Sphenoid</td>
<td>4</td>
</tr>
<tr>
<td>Cerebral contusion (n = 12):</td>
<td></td>
</tr>
<tr>
<td>Ipsilateral to fracture</td>
<td>6</td>
</tr>
<tr>
<td>Contralateral to fracture</td>
<td>5</td>
</tr>
<tr>
<td>Bifrontal</td>
<td>1</td>
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<tr>
<td>Local pneumocephalus (n = 5)</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 4.—Sagittal reformation of left temporal bone through lateral aspect of tympanic cavity. "Molar tooth" appearance of malleus and incus in lateral view (open arrow) rules out ossicular dislocation; facial nerve canal (closed arrows). Middle ear fluid (presumably blood) accounted for conductive hearing loss.

Fig. 5.—Longitudinal fracture. High-resolution axial scan shows longitudinal fracture extending from mastoid antrum through posterior part of middle ear into middle cranial fossa (arrows). Malleus and incus are normal in position (arrowhead). Conductive hearing loss is explained by fluid in middle ear.

Fig. 6.—Atypical transverse fracture. Axial high-resolution CT scan shows transverse fracture (open arrow) far medial to otic capsule in patient without symptoms referable to temporal bone trauma. Also shown are fracture through right frontozygomatic suture (closed arrow) and fluid within ethmoid and sphenoid sinuses.
Discussion

Anecdotal reports on the use of high-resolution CT in the evaluation of the temporal bone have described the detection of subtle petrous bone fractures and more thorough evaluation of associated findings than was possible with multidirectional tomography [12, 13]. Our experience with a larger series of cases corroborates these earlier reports. High-resolution CT accurately images the site of fractures, with fine bony detail sufficient to detect even small fracture lines in the region of the genu of the facial nerve. In addition, soft-tissue findings, such as blood in the middle ear or mastoid sinus and CSF leakage associated with fracture, can be assessed (figs. 2 and 3).

The three-dimensional capability of CT also offers increased flexibility in the evaluation of the plane and course of fractures. Scans obtained in the axial plane can be reformatted in multiple projections. This allows the assessment of vertically oriented structures such as the descending part of the facial canal (fig. 4), difficult to evaluate on axial sections. Because the resolution of reformatted images is limited to 1.5–2.0 mm, some degradation of the image is inevitable in comparison with the direct sagittal or coronal scans [14]; however, such scans may be impossible to obtain in the acutely injured patient. Dynamic sequential scanning with automatic table incrementation and low-milliamper-second technique may be performed, resulting in markedly shortened examination time and further lowering the radiation dose [15]. Consequently, high-resolution CT is the imaging method of choice in patients suspected of temporal bone injury, including all those presenting with posttraumatic seventh or eighth cranial nerve dysfunction or CSF otorrhea.

In contradistinction to high-resolution CT, routine head CT (10 mm sections) obtained for head trauma may be inadequate not only for the definitive evaluation of, but even for the routine screening for, petrous bone trauma. Only eight of 19 temporal bone fractures were identified by such scans, despite the use of wide windows. Furthermore, routine CT scans failed to demonstrate 10 of 13 temporal bone injuries documented by high-resolution scans. However, although the resolution is inadequate for the reliable diagnosis of temporal bone fracture, routine head CT may provide clues that should arouse the suspicion of such an injury, such as air-space opacification in or near the temporal bone or local pneumocephalus. Evidence of brain trauma or extraaxial hematoma, frequently contralateral to the temporal bone, is common, and may distract clinical and radiographic attention away from the temporal bone itself. It should be noted that in five of the cases in this series, routine scans detected signs of petrous bone fractures incidentally in patients in whom symptomatology related to such an injury was absent or obscured by more serious neurologic compromise.

The previously reported incidence of the different types of fracture may well reflect the selection of patients for radiographic study based on specific clinical signs. Historically, temporal bone fractures are categorized with respect to the long axis of the temporal bone as either longitudinal, transverse, or mixed. However, this rigid scheme of classification is somewhat artificial, as many fractures may follow a multiplanar or oblique course [1, 5, 16].

Longitudinal fractures have been reported as constituting 70%–80% of temporal bone fractures. They begin in the squama, extend medially across the posterior superior external bony canal wall, involve the roof of the middle ear, and run along the surface of the petrous pyramid anterior to the labyrinth capsule, finally terminating near the foramina spinosum and lacerum in the middle cranial fossa (fig. 5). Bleeding from the ear occurs in almost all cases due to injury to the lining of the external auditory canal and tympanic membrane. Otorrhea may be seen in up to 50% of these cases due to fracture of the tegmen tympani [16]. This fracture results in a conductive deafness in up to 65% of such cases, largely transient [17]. However, in 15%–20% of these patients, severe disruption of the ossicles may occur [16]. A component of concussive sensorineural impairment may occasionally be detected. Facial nerve injuries occur in 20% of longitudinal fractures, most commonly in the horizontal part just distal to the geniculate ganglion [2]. In most, the facial paralysis is delayed in onset and results from perineural edema. Complete recovery occurs in about 75%, with permanent paralysis in 10% [17].

Transverse fractures are said to constitute about 20% of temporal bone fractures. These fractures constituted a higher percentage in the present series in which the diagnosis was based solely on CT demonstration of temporal bone trauma, whereas in previous reports patients were selected for conventional tomography based solely on clinical criteria of inner ear damage, which need not occur with such fractures. Transverse fractures are more often associated with blows to the occipital or less frequently frontal areas, unlike longitudinal fractures, which are associated with direct blows to the petrous bone. The fracture line most commonly follows the internal auditory canal, extending across the pyramidal process of the temporal bone, or through the labyrinth capsule, including both the cochlea and vestibule (fig. 1) [5]. In addition, transverse fractures can extend through the temporal bone more medially (fig. 6), or laterally through the middle ear and external auditory canal [16]. Obviously, clinical symptoms and the development of neurologic deficits depend on the fracture site. Bleeding from the external canal or hemotympanum is detected in roughly one-half of patients. Deafness, reported in over 50% of cases, is associated with disruption of the cochlea. Predictably, vertigo with spontaneous nystagmus is also a common feature. Facial paralysis occurs in 40%–50% of transverse fractures, and, unlike that in longitudinal fractures, is usually immediate and permanent due to extensive damage to the nerve itself [1, 18].

Fractures restricted to the mastoid, although reportedly uncommon, may open into the external auditory canal and middle ear, and may involve the vertical part of the facial nerve. Fractures of the styloid process may result in contusion injuries of the facial nerve. In addition, as demonstrated in this series, there is a frequent association of mastoid fractures with additional fractures to the skull base.

Ossicular dislocation (fig. 2) may follow relatively minor head
trauma, though most patients have an associated fracture of the temporal bone [1]. Incostapedial joint separation is seen at surgery in most cases, with gross dislocation of the incus in most. One-third of patients have predisposing middle ear disorders such as chronic otitis media or cholesteatoma, congenital defects, or tympano- or otosclerosis [1].

As some of the complications of temporal bone fracture are potentially surgically remediable, the more precise and complete delineation of fracture planes, associated bone fragments, and soft-tissue pathology is of considerable practical clinical importance. In cases of facial nerve paralysis, although the decision to intervene surgically is usually based on clinical criteria, the operative approach depends on the anatomic location of nerve damage [19]. Because determinations of the site of injury using topognostic testing may be misleading [8], the more refined imaging of temporal bone injury along the course of the facial nerve, possible with high-resolution CT, may allow more informed preoperative planning. In cases of traumatic conductive hearing loss, detailed middle ear imaging may affect not only the timing of surgery but the decision to operate [19].

REFERENCES