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Temporal bone fracture: Evaluation in the era of modern computed tomography

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ABSTRACT

Background: Temporal bone fractures (TBFs) are harbingers of high energy head trauma that can result in a variety of significant complications of the auditory, vestibular, nervous, and vascular systems. Multiple cohort studies have identified the incidence and proper evaluation of these fractures. We hypothesize that these have changed with the advent of modern high resolution computer tomography (CT) imaging.
Methods: We performed a retrospective review of all TBFs admitted to an urban level one trauma center between June 1, 2011 and May 31, 2015. A database was compiled including demographics, physical exam findings, imaging performed and results, morphology and directionality of fracture as well as outcomes and follow-up.
Results: One hundred thirteen patients were identified, representing 4.7% of skull fractures and 35.9% of skull base fractures. Most were subsequent to falls (41.6%) followed by pedestrian vehicular trauma (19.5%). The majority of TBF patients (67.3%) had additional fractures of the skull and 77.9% of TBF patients also had some kind of intracranial hemorrhage. The morphology of TBF and the overall mortality (7.9%) was consistent with previous reports. The incidence of facial nerve paralysis (1.6%), CSF leak (1.7%), and hearing loss (18.6%) were all lower than previously reported. Trauma imaging was able to identify 98.6% of TBF, calling the utility of routine temporal bone CT imaging into question.
Conclusion: TBFs are less common than they once were and though they still carry a mortality rate similar to previously reported cohorts, the incidence of complications among survivors has dramatically improved. Additionally, modern CT imaging is very capable of identifying these injuries and dedicated temporal bone CT may only be of utility in cases where facial nerve injury or vascular injury is suspected.
Level of evidence: Epidemiologic study, Level III.

Background

The temporal bone, the most morphologically complex bone in the human body, consists of five fused elements: the styloid process, tympanic ring, squamous, mastoid and petrous bones. The squamous portion is essentially diploic bone and forms the most superior and lateral aspect, while the mastoid bone is mostly pneumatized. The petrous pyramid is the medial component of the temporal bone which sits intracranially and divides the middle cranial fossa from the posterior fossa. In the center of the petrous bone is the otic capsule which is highly dense, mineralized bone that houses the cochlear and vestibular apparatus.

The complex anatomy of the temporal bone can be further appreciated by mentioning a few of the structures that lie near or course through it. The internal carotid artery is encased within the petrous portion of the temporal bone. The internal auditory canal transmits cranial nerves VII and VIII. The greater and lesser petrosal nerves, chorda tympani, cochlea and vestibular apparatus, middle ear space, ossicles, tympanic membrane, and the external auditory canal are all enclosed within the temporal bone. Due to this complex arrangement of solid and pneumatized bones along with the number of vascular, nervous, and specialized sensory structures housed within, a myriad of possible fault lines exist for forces to be transmitted through the structure, leading to an abundance of fracture patterns and classification systems. Additionally, cadaveric experiments show that enormous force

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is required to fracture this bone; in cadaveric research models a strike averaging 1,875lbs at a speed of 25 mph against the temporoparietal region of human skull is needed to break the temporal bone [17,18]. As such, temporal bone fractures (TBFs) rarely occur in isolation and are often encountered amidst other life threatening injuries.

There are many potential complications of a TBF, and the incidence of long term deficits has been variably reported in greater than half of patients. These complications include, but are not limited to: facial nerve injuries, cerebrospinal fluid (CSF) leaks, meningitis, devastating cranial vascular injuries, hearing loss, tympanic membrane tears, ossicular injuries, tinnitus, vestibular pathologies, hemotympanum, and bloody otorrhea. Since the development of multi-detector array computed tomography (MDCT) scanners, most fractures are evaluated with a dedicated temporal bone CT (CT-TB) after a thorough exam of the head, neck, and ear has been performed and earlier CT scans have identified the fracture. In the acute setting, transections of the facial nerve and injuries to the internal carotid artery need to be rapidly identified and addressed, the former surgically and the latter depending on the level of the injury with various modalities. The most common symptom of TBF is hearing abnormality, and most patients with this fracture are evaluated with audiology examinations after their acute trauma issues have resolved.

We hypothesized that the most modern MDCT have increased the sensitivity for detecting sub-clinical temporal bone fractures and that dedicated CT-TB may not be necessary in all patients with temporal bone fractures that have undergone CT of the head (CT-H), maxillofacial region (CT-MF), and cervical spine (CT-CS).

Methods

Subsequent to approval by the Jamaica Hospital Medical Center Investigational Review Board, we identified patients admitted to the trauma service at an urban Level I Trauma Center in New York City, selecting all adults (age ≥ 18) who had a TBF between June 1, 2011 and May 31, 2015 utilizing a prospectively maintained trauma registry. Skull fracture was defined as International Classification of Diseases-9th Rev. (ICD-9) 800–804.3; skull base fracture as ICD-9 801–801.3; and facial fracture as ICD-9 802–802.9. All medical records were reviewed to verify injuries, clinical and radiologic data, and outcomes. Variables collected included demographics, mechanism of injury, location and direction of TBF, injury severity score (ISS; calculated using AIS-98 methodology), Glasgow Coma Scale (GCS), imaging performed and results, presence of neurologic deficits upon arrival, physical exam results, and mortality. Injury severity score (ISS) was stratified into categories as either mild (ISS ≤ 4), moderate (ISS $\geq 5 \leq 9$), or severe (ISS ≥ 10). GCS was stratified similarly into three categories with GCS ≥ 13 indicating mild; GCS $\geq 9 \leq 12$ indicating moderate, and GCS ≤ 8 severe. All CT imaging was performed using a 32-slice GE Optima CT 660, and all imaging studies identifying a TBF were re-read by the chief neuroradiologist to classify the location and direction of the fracture. All scans were performed and stored for up to one month at 0.625 mm cuts. CT-H and CT-CS were reformatted at 2.5 mm cuts for interpretation, CT-MF and CT-TB were reformatted at 1.25 mm cuts and delivered to the radiologists. In all cases and at the request of the radiologist, the images could be reformatted as finely as 0.625 mm if there was a question of a fracture. Generally, CT-MF and CT-CS did not include the entirety of the temporal bone though CT-H always encompassed the whole bone.

Data are presented as median (IQR) for continuous and ordinal variables, and frequency (percentage) for categorical variables. Comparisons of categorical variables were performed using Fisher's exact test or a single sample test of proportions as appropriate, presented with 95% confidence intervals. All statistical analyses were performed using R [15], and statistical significance was defined as $p < 0.05$.

Results

Between June 1, 2011 and May 31, 2015 there were 4354 patients admitted with head injuries, of which 2383 (54.7%) sustained a fracture of the skull. Of those with skull fracture, 2065 (86.7%) patients had facial bone fractures while 315 (13.2%) had skull base fractures. TBFs were present in 113 patients, representing 4.7% of skull fractures and 35.9% of skull base fractures. There were 118 TBF among the 113 patients, corresponding to a bilateral TBF incidence of 4.4% ($n = 5$). The sample was predominantly male (82%), with a median age of 45 (IQR: 27–58) years. At initial evaluation, a minority of patients were obtunded (32.7%; $\chi^2_{(1)} = 13.0$; 95% CI = [24.4%, 42.3%]; $p = 0.004$) despite the majority reporting a loss of consciousness (61.1%; $\chi^2_{(2)} = 47.0$; $p < 0.001$; Table 1). The median ISS was 16 (IQR: 10–25), with 79.7% of patients having injuries classified as either mild or moderate in severity ($\chi^2_{(2)} = 8.6$; $p = 0.01$). Most patients had a mild GCS (63.7%; $\chi^2_{(2)} = 49$; $p < 0.001$), and the median GCS at admission was 14 [IQR: 9–15].

The mechanisms of injury (MOI) were predominantly falls at 41.6% and pedestrians struck by motor vehicles at 19.5%; the remaining MOI can be seen in Table 1. The overall mortality rate was 7.9%, and just under half of all patients were discharged directly home, with the remainder to other facilities. Unsurprisingly, 77.9% of TBF patients also had some kind of intracranial hemorrhage (ICH; Table 2); the most common being subarachnoid hemorrhage in 31% of patients with an ICH, followed by subdural hemorrhage in 24.8%, and epidural hemorrhage in 4.4%. There were

Table 1
Demographic Data for All TBF Patients. Percentages based on $N = 113$ patients.

Variable	*n* (%)
Gender	
Male	93 (82.3)
Female	20 (17.7)
Age (Median, IQR)	45 (27.0–58.0)
Obtunded	37 (32.7)
Head Strike	86 (76.1)
LOC	69 (61.1)
ISS (Median, IQR)	16 (10.0–25.0)
Mild	46 (40.7)
Moderate	44 (38.9)
Severe	23 (20.4)
GCS (Median, IQR)	14 (9–15)
Mild	72 (63.7)
Moderate	15 (13.3)
Severe	26 (23.0)
Mechanism	
Fall	47 (41.6)
Ped/Cyclist struck	22 (19.5)
Assault	18 (16.0)
Found Down	8 (7.1)
Gunshot	4 (3.5)
Stab	1 (0.9)
Other	6 (5.3)
Disposition	
Home	56 (49.6)
Rehab	16 (14.1)
TBI	11 (9.7)
SNF	8 (7.1)
Other	13 (11.5)
Mortality	9 (7.9)

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