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Do Contemporary Temporal Bone Fracture Classification Systems Reflect Concurrent Intracranial and Cervical Spine Injuries?

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Objectives/Hypothesis: Temporal bone fractures (TBFs) are a frequent manifestation of head trauma. We investigated the prevalence of concurrent intracranial injuries (ICIs) and cervical spine injuries (CSIs) in a series of patients with TBFs and attempted to identify significant associations between current TBF classification systems and either ICI or CSI.

Study Design: Retrospective case series with chart review.

Methods: The records of all patients ≥18 years of age diagnosed with a basilar skull fracture, including TBF, at a level I trauma center from 2004 to 2009 were reviewed. Patient demographics, mechanism of injury, and Glasgow Coma Scale (GCS) scores were collected. Imaging studies were reviewed to classify TBF using the traditional longitudinal-transverse-mixed and otic capsule–sparing versus –involving systems and identify concurrent ICI and CSI.

Results: Of 1,279 patients, 202 (15.8%) met inclusion criteria. There were 160 (79.2%) males. Sixteen (7.9%) patients had bilateral TBFs. Falls (n = 66, 32.7%) represented the most common mechanism for TBF. Longitudinal (n = 96, 44.0%) and otic capsule–sparing (n = 209, 95.9%) fractures were the most prevalent subtypes. There were 184 (91.1%) patients who sustained ICI and 18 (8.9%) who demonstrated CSI. Longitudinal, transverse, mixed, otic capsule–sparing, or otic capsule–involving TBF subtypes had no statistically significant associations with mechanism of injury, GCS score, or concomitant ICI or CSI.

Conclusions: More than 90% of patients sustaining TBF presented with concomitant ICI, and 9% sustained CSI. Current TBF classification systems do not correlate with these outcomes. A more sophisticated, multidisciplinary classification system encompassing radiographic and clinical findings may better predict neurologic, neuro-otologic, and skull base complications.

Key Words: Temporal bone fracture, intracranial, cervical spine, head injury, otic capsule, Glasgow Coma Scale, complication.

Level of Evidence: 4.

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INTRODUCTION

The original temporal bone fracture (TBF) classification system, which was based on pathologic observations made as early as 1926, classified fractures by their orientation relative to the petrous ridge (longitudinal vs. transverse).[1] However, this historic TBF classification system has been increasingly criticized for its limited value in predicting potential complications and clinical outcomes, despite the introduction of a third category of oblique or mixed fractures by Ghorayeb and Yeakley.[2] The otic capsule system, which assesses whether fractures spare or violate the otic capsule, has been described by Brodie and Thompson as an alternative for both succinctly describing TBFs and predicting complications.[3] In a retrospective series of 699 patients with 820 TBFs, the authors identified a significant correlation between otic capsule violation and facial nerve injury. However, although both classification systems possess an elegant simplicity in their anatomic descriptions of temporal bone trauma, with the otic capsule system in particular demonstrating a strong correlation with otologic sequelae, their value in predicting neurologic complications has not been firmly established. Alvi and Bereliani reported an 84% rate of intracranial injury (ICI) in a series of 43 patients with TBFs, including cerebral midline shift, subarachnoid, subdural, and intraparenchymal hemorrhage, cerebral edema, contusions, and more.[4] A 1-year retrospective review of 1,309 patients with head trauma in Malaysia demonstrated that 61 (4.7%) individuals in the cohort had sustained TBFs, with 13 deaths related to the severity of head injury.[5] However, neither study attempted to correlate these neurologic outcomes with the subtypes of a particular TBF classification system.

The large amount of force required to fracture the temporal bone likely explains their high association with head trauma and intracranial injuries. As such, sound knowledge of the mechanisms of TBFs, the relevance of

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key diagnostic tools, and effective management algorithms of these fractures and their complications should be of critical importance to all clinicians caring for head trauma victims. A recent epidemiologic study of the National Trauma Data Bank (NTDB) performed by Mulligan et al. captured data from the United States and Puerto Rico from 2002 to 2006, revealing 334,864 cases of head injury with a 21.7% incidence of concomitant facial fractures and 7.0% incidence of cervical spine injury (CSI).[6] TBFs account for 18% to 22% of all skull fractures in general[7] and 18% to 40% of all head injuries involving the cranial base.[1] Exadaktylos et al. reported a TBF incidence of 10.9% in a prospective series of 350 patients with head trauma at a level I trauma center.[8] Separately, Elahi et al. reported a 3.69% incidence of CSI in a cohort of 3,356 Canadian patients with craniomaxillofacial fractures from 1994 to 2003, although in that study the fractures were categorized into skull and upper, middle, and lower facial thirds; TBFs were not specifically analyzed.[9]

The first objective of the current study was to identify a regional series of trauma patients presenting with TBF and categorize these fractures by using both the historic and otic capsule TBF classification systems. Secondarily, we determined the prevalence of concurrent ICI and CSI in this population and established whether any TBF subtype, using either classification system, demonstrated significant associations with concomitant ICI or CSI.

MATERIALS AND METHODS

The University Hospital Trauma Registry is a database serving the University Hospital of Cincinnati, a tertiary-care level I trauma center in Ohio. Using the *International Classification of Diseases, Ninth Revision* (ICD-9) codes 801 (fracture of base of skull) and 804 (multiple fractures involving skull or face with other bones), we searched this database for all patients diagnosed with a basilar skull fracture between January 1, 2004, and January 1, 2009. All records then were systematically reviewed to identify patients with TBF. Exclusion criteria included all patients less than 18 years of age and those who died during initial hospitalization at the study institution.

Demographic information, mechanism of injury, Glasgow Coma Scale (GCS) scores, and serum alcohol and urine toxicology data were gathered. Computed tomography (CT) scans of the head and temporal bones were examined by two neuroradiologists (R.S.C., B.L.K.) to locate and classify TBFs. Fractures were classified by using the traditional (longitudinal, transverse, and mixed) and otic capsule (sparing and involving) systems. Longitudinal fractures were specifically defined as those coursing parallel to the axis of the petrous ridge. Transverse fractures coursed perpendicular to the petrous ridge. Mixed fractures were defined as either TBF with both longitudinal and transverse components or comminuted fractures of the petrous ridge. A fourth "miscellaneous" category was created for this study, incorporating TBFs that were localized to isolated segments of the temporal bone (squamous, petrous, mastoid, tympanic, or styloid), not otherwise conforming to the descriptions of the other three primary categories.

All other available imaging studies, including head CT, cervical spine plain radiography, and cervical spine magnetic resonance imaging (MRI), were reviewed to identify evidence of both ICI and CSI. CSI was defined as radiographic evidence of cervical spine fractures, dislocation, and spinal cord injury. ICI was defined as radiographic evidence of intracranial injury, including intracranial contusion, laceration, shear injury, and hemorrhage. Linear regression and χ^2 analyses were performed by using SPSS version 16.0 (IBM; Chicago, IL). Statistical significance was defined as $P \leq .05$.

TABLE I.
Patient Demographics (N = 202).

Characteristic	Frequency, No. (%)
Sex	
Male	160 (79.2)
Female	42 (20.8)
Race/ethnicity	
White	167 (82.7)
Black	22 (10.9)
Hispanic	10 (5.0)
Other	3 (1.5)
Mechanism of injury	
Fall	66 (32.7)
Motor-vehicle collision	56 (27.7)
Assault or gunshot wound	30 (14.9)
Motorcycle collision	22 (10.9)
Pedestrian versus motor vehicle	12 (5.9)
Falling object	6 (3.0)
Bicycle collision	4 (2.0)
Other trauma	5 (2.5)
Unknown	1 (0.5)

Percentages may not add up to 100% because of rounding.

RESULTS

The initial database search yielded 1,279 consecutive patients who sustained a basilar skull fracture; 202 (15.8%) adult patients were found to have at least one TBF. Mean age was 41.0 ± 16.4 years (median, 38.5 years). Mean GCS score was 11.5 among 186 patients with available data. Seventy (34.7%) patients had detectable serum alcohol levels, and 23 (11.4%) demonstrated a positive urine toxicology result. Table I summarizes other patient demographic information and mechanism of injury in all patients. Sixteen (7.3%) patients had bilateral TBF, for a total of 218 fractures. Of patients with unilateral TBF, 82 (40.6%) patients had a left-sided fracture, and 104 (51.5%) patients had a right-sided fracture. Bilateral fractures had statistically significant associations with both otic capsule involvement (P = .002) and detectable serum alcohol (P = .02), but not mechanism of injury, GCS score, positive serum alcohol, or positive urine toxicology screen. Table II summarizes the distribution of TBF using the traditional and otic capsule–involvement classification systems. When the traditional TBF classification scheme was used, 60 patients had unclassifiable or "miscellaneous" TBF, with 48 (80.0%) fractures isolated to the squamous portion of the temporal bone.

A total of 184 (91.1%) patients demonstrated findings consistent with ICI. Among 183 patients with available cervical spine imaging studies, 18 had

TABLE II.
Characteristics of Temporal Bone Fractures (N = 218).

Characteristic	Frequency, No. (%)
Laterality	
Left	98 (45.0)
Right	120 (55.0)
Traditional classification	
Longitudinal	96 (44.0)
Transverse	19 (8.7)
Mixed	43 (19.7)
Miscellaneous	60 (27.5)
Squamous only	48 (22.0)
Mastoid only	5 (2.3)
Petrous only	5 (2.3)
Squamous + mastoid	1 (0.5)
Tympanic + mastoid	1 (0.5)
Otic capsule classification	
Otic capsule-sparing	209 (95.9)
Otic capsule-involving	9 (4.1)

Percentages may not add up to 100% because of rounding.

radiographic evidence of CSI. Chart review of all patients without cervical spine imaging demonstrated that none had clinical evidence of CSI. Therefore, 18 of the 202 (8.9%) patients in the current study sustained CSI. Table III summarizes the prevalence of ICI and CSI in each fracture subtype, including all fractures that could not be classified by using the traditional TBFs system. All nine patients with otic capsule–involving fractures had associated ICI, and none sustained CSI. The highest rate of CSI (16.7%) was found in the subset of patients with isolated squamous TBFs. There were no statistically significant associations between any of the four traditional and two otic capsule TBF subtypes and mechanism of injury, positive alcohol and urine toxicology results, GCS scores, ICI, and CSI. The sole exception was found in the miscellaneous category specifically created for this study, where there was a statistically significant correlation with CSI ($P = .002$). However, individually, none of the temporal bone subunits within this category significantly correlated with either ICI or CSI.

DISCUSSION

Because of changes in injury trends, advances in high-resolution imaging technology, and a greater focus on clinical relevance, there has been a growing interest during the last two decades in developing trauma-related classification schemes that incorporate additional TBF radiographic findings other than orientation relative to the petrous axis, such as the system assessing involvement of the otic capsule. Following the study by Brodie and Thompson, subsequent retrospective series showed that in addition to facial nerve paresis, otic capsule violation also correlated strongly with cerebrospinal fluid (CSF) otorrhea and hearing loss.[10–12] Ishman and Friedland proposed an alternative classification system that categorized TBFs by petrous (otic capsule or petrous apex) or nonpetrous (mastoid, middle ear, and external auditory canal) involvement, showing improved strength of clinical correlations with CSF leakage, facial nerve injury, and sensorineural and conductive hearing loss as compared with the traditional TBF classification system.[13]

However, despite better prediction of otologic complications with modern TBF classification systems, their effectiveness in predicting ICI is unclear. Reviews by Amin et al.[5] and Alvi and Bereliani[4] established important relationships between traumatic head injuries and TBFs but did not distinguish among TBF subtypes. A prospective study by Jones et al. used both CT and MRI studies to analyze 27 patients with longitudinal TBFs, finding a 46% incidence of temporal lobe injury.[14] Dahiya et al. identified statistically significant correlations between otic capsule–violating fractures and both epidural hematoma and subarachnoid hemorrhage ($P < .05$), but not with subdural hematoma or cerebral contusion.[10] Dahiya et al. also showed a trend whereby GCS scores were lower in TBF patients compared to patients with general closed head injuries, although the trend was not statistically significant. Rafferty et al. did not detect significant differences in the distribution of concurrent brain injury among TBF patients by using either the traditional and otic capsule–involvement classification systems.[12]

To date, no study has established any correlation between TBF subtypes and CSI. Diaz et al. reported a prospective unblinded series of 1,006 individuals presenting with blunt head trauma and either altered mental status or other distracting injuries, identifying 116 (11.5%) patients with 172 acute CSIs, or roughly double the 2% to 6% incidence of CSI in all patients with blunt trauma.[15] Although the proportion of patients with TBF was not reported, the notable increase in incidence of CSI in their study serves as an important reminder that evaluation of TBFs should include adherence to cervical spine precautions.[1]

The current study is the first to attempt to identify significant associations between two common TBF classification systems and both ICI and CSI. The paucity of statistically significant relationships is unlikely to be related to the demographic makeup of the study cohort.

TABLE III.
Prevalence of Intracranial and Cervical Spine Injury, Based on Temporal Bone Fracture Subtype.

Temporal Bone Fracture Subtype	N	Intracranial Injury, No. (%)	Cervical Spine Injury, No. (%)
Longitudinal	96	87 (90.6)	8 (8.3)
Transverse	19	18 (94.7)	3 (15.8)
Mixed	43	41 (95.3)	2 (4.7)
Miscellaneous	60	53 (88.3)	8 (13.3)*
Squamous only	48	43 (89.6)	8 (16.7)
Mastoid only	5	4 (80.0)	–
Petrous only	5	5 (100)	–
Squamous + mastoid	1	1 (100)	–
Tympanic + mastoid	1	–	–
Otic capsule-sparing	209	190 (90.9)	21 (10.0)
Otic capsule-involving	9	9 (100)	–

*Statistically significant relationship ($P \leq .05$).

Our series, on the basis of age, sex, mechanism of injury, and fracture laterality, is comparable to previously published TBF series.[3,10–13] Our rate of fractures involving the otic capsule of 4.1% is within the 2.5% to 7% range described in most prior studies as well.[3,10,12] The distribution of fractures using traditional criteria does differ substantially from previous reports, likely owing to our inclusion of a fourth subtype encompassing fractures that do not have a clear fracture pattern. However, it should be noted that this particular category was the second largest subgroup of "traditional" fractures and that of all subtypes, this was the only one to demonstrate any significant correlation with either ICI or CSI. These findings undermine one of the major criticisms of the traditional system, in that the classic descriptions of its subtypes are less frequently encountered in the modern era, where complex head injuries are increasingly commonplace.

Although modern TBF classification systems were not specifically designed to predict neurologic outcomes resulting from ICI and CSI, it nevertheless holds true that patients with TBF are at high risk of sustaining multiple other injuries to the head and neck. Travis et al. demonstrated in 1977 that at an average speed of 25 miles per hour, an average of 1,875 pounds of force was required to produce a TBF.[16] This force also was sufficient to produce ICI in all cadavers studied. The interrelationships between ICI, CSI, and facial fractures have been powerfully delineated in the NTDB study by Mulligan et al.[6] Our study further demonstrates a very high coprevalence of ICI (>90%), similar to the 84% ICI rate reported by Alvi and Bereliani and higher than the 55% cited by Rafferty et al.[4,12] Our concurrent CSI rate of nearly 9% is slightly less than the 11.5% figure cited by Diaz et al., which may be due to our exclusion of patients with head trauma but no diagnosis of TBF.[15] Given these findings, it may be prudent to create a new classification system that has predictive value not only for otologic and neuro-otologic sequelae but also for neurologic complications. Like other complex medical entities, head trauma management requires a multidisciplinary approach for optimal results. A novel TBF classification system that is applicable across multiple surgical and medical specialties, building on the best predictors from existing classification schemes, could improve the management of acute head trauma and its varied sequelae and help standardize descriptions of TBF severity across institutions.

CONCLUSION

More than 90% of patients sustaining TBF presented with concomitant ICI, and 9% of patients had evidence of CSI. The traditional and otic capsule–involvement TBF classification systems do not significantly correlate with these neurologic outcomes. Research into an alternative classification system that encompasses both radiographic and clinical findings and accurately predicts both neurologic and neuro-otologic complications is warranted.

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