Audiometric Outcomes in Pediatric Temporal Bone Trauma

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Abstract

Objective. To characterize pediatric temporal bone trauma, focusing on audiometric outcomes.

Study Design. Case series with chart review.


Subjects and Methods. Cases were reviewed of children (<18 years) presenting over a 3-year period with computed tomography–proven temporal bone fracture and audiology examination. All scans were read by a neuroradiologist and reviewed by a pediatric otolaryngologist. Demographics, fracture pattern, and audiometric data were recorded.

Results. Fifty-eight patients (60 fractures) met inclusion criteria. The majority (93%) were otic capsule–sparing fractures. The types and severity of hearing loss were significantly different between the 2 fracture patterns. Based on pure-tone average, all otic capsule–violating fractures had abnormal initial audiograms; 75% of these losses were severe. Approximately half (54%) of otic capsule–sparing fractures had abnormal initial audiograms; a majority were mild losses (85%). All classifiable losses in otic capsule–violating cases were of mixed type, whereas the majority (75%) of losses in otic capsule–sparing cases were conductive. Regardless of classification, 72% of patients with otic capsule–sparing fractures and initially abnormal audiograms improved to normal levels at a mean of 48 days posttrauma; this increased to 83% when only conductive losses were considered.

Conclusions. Hearing loss type and severity differ in otic capsule–sparing and otic capsule–violating temporal bone fractures. A majority of children with otic capsule–sparing fractures and associated hearing loss improve to normal levels in about 6 weeks, especially if the original loss is classified as solely conductive. Children who do not improve within this time frame may warrant early investigation into surgically correctable causes.

Keywords
temporal bone fracture, otic capsule–violating, otic capsule–sparing, conductive hearing loss, sensorineural hearing loss, mixed hearing loss

Temporal bone fractures are the most common type of skull base fracture in pediatric trauma.¹ The potential complications associated with temporal bone fractures are myriad, including facial nerve paresis and other cranial nerve palsies, sensorineural hearing loss (SNHL), conductive hearing loss (CHL), balance disturbances, tinnitus, cerebrospinal fluid leaks, meningocoele, ependymocele, cholesteatoma, and meningitis.² Additionally, fractures of the skull base are potentially fatal. Head injury is one of the leading causes of death in the pediatric age group.³

Although temporal bone trauma and its related effects are common among pediatric patients, literature regarding audiometric outcomes in this age group is lacking. Additionally, many protocols used to manage the aforementioned complications are derived from adult patient experience.¹ Aspects of temporal bone and other skull base trauma may be fundamentally different among younger patients due to differing skull flexibility.³

Hearing loss is a common consequence of temporal bone trauma that may have special implications in the pediatric population. Thirty-one percent of children with even unilateral SNHL have been shown to “experience scholastic or behavioral problems at school.”⁴ Early recognition of hearing loss, especially in children, is imperative and can greatly decrease associated morbidity.⁵

Historically, temporal bone fractures have been described in terms of the fracture axis in relation to the long axis of the petrous bone, as either transverse or longitudinal. Even when an oblique category is included, this system insufficiently describes many clinically observed fractures.⁶ Additionally, this system correlates poorly with clinical outcomes.⁷,⁸ For these reasons, multiple other classification

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schemes have been proposed. Kelly and Tami introduced “otic capsule–violating” (OCV) versus “otic capsule–sparing” (OCS) terminology in 1994 (Figures 1 and 2). In multiple studies, this classification scheme has been more predictive of several fracture-associated deficits, including facial nerve injury, SNHL, and cerebrospinal fluid leak.

Early recognition of temporal bone trauma and its potential otologic complications are essential, especially in the pediatric population. Despite its importance, there is a relative paucity of literature on the subject. This study seeks to characterize pediatric temporal bone trauma with a focus on the natural history of associated audiometric outcomes.

Methods

Ethical Considerations

This study was approved by the University of Pittsburgh Institutional Review Board (protocol PRO13050454).

Study Cohort

We conducted a retrospective analysis of medical records and computed tomography images at a tertiary care academic children’s hospital. Potential subjects included all children aged 1 month to 17 years presenting from 2010 to 2013 with maxillofacial trauma. Patients were included if they had temporal bone fracture on computed tomography and at least 1 posttrauma audiometric examination. Clinical data collected included baseline demographics, mechanism of injury, fracture pattern, audiometric data (posttrauma and follow-up, if available), and time to follow-up. All computed tomography scans were read by a neuroradiologist and reviewed by a pediatric otolaryngologist to confirm the presence of temporal bone fracture and classify the fracture(s) if present. Fracture pattern classification was based on OCS versus OCV scheme.9

An audiogram or otoacoustic emission (OAE) examination was performed on all patients included in this study. OAE examination was performed on children who could not undergo traditional audiogram due to young age or severity of injury and associated mental status changes. From raw audiometric data, hearing loss was categorized as sensorineural, conductive, mixed, or unclassified. Hearing loss was categorized as unclassified if only OAE data or only air thresholds were available. A pure-tone average (PTA) was recorded on all patients when possible; this was calculated by obtaining the mean value of air and/or bone thresholds at 500, 1000, and 2000 Hz. An air-bone gap >10 dB between air and bone PTA levels was considered abnormal. Hearing loss was deemed mild (PTA, 16-40 dB), moderate (PTA, 40-60 dB), or severe (PTA, >60 dB).

Statistical Analysis

Categorical variables were described as proportions, and continuous variables were described with mean and standard deviation. Measures of association between categorical variables were completed via Fisher’s exact test. One-way analysis of variance was used to test continuous variables. Statistical significance was considered at P < .05. All tests were 2-sided.

Results

Demographics

There were 280 patients with maxillofacial trauma considered for inclusion. Of these, 58 patients (60 fractures) met inclusion criteria. Most patients who were excluded had other craniofacial fractures but not temporal bone fractures. The majority (62%, n = 36) were male, and most (86%, n = 50) were Caucasian. The mean age of our population was 8.6 ± 4.9 years (Table 1). The most common mechanism of injury was fall (47%; Figure 3).

Nearly all fractures were OCS (93%, n = 56), while the remainder (7%, n = 4) were OCV. All OCV fractures in this series violated the cochlea. Three fractures involved the vestibule and basal turn of the cochlea and round window. The fourth OCV fracture transected the cochlea. Almost all
patients (97%, n = 56) had unilateral fractures; 2 patients (3%) had bilateral fractures. Of the unilateral fractures, 22 (38%) were left-sided, and 34 (59%) were right-sided. Each patient with bilateral fractures showed only OCS fracture patterns (Table 1).

Audiometric Data
Based on PTA or OAM testing, 34 (57%) of the initial post-trauma audiometric evaluations were abnormal. Approximately half (54%, n = 30) of the OCS fractures were associated with abnormal audiometric evaluations, while all 4 OCV fractures had abnormal initial audiograms (100%, n = 4; Table 2).

The most common hearing loss type in OCS fractures was CHL (47%, n = 14), followed by unclassified (40%, n = 12), SNHL (10%, n = 3), and mixed (3%, n = 1). In contrast, OCV fractures were associated with mixed losses (50%, n = 2) and unclassified losses (50%, n = 2). The proportion of mixed losses seen in OCS and OCV fractures was significantly different (P = .031; Table 2, Figure 4).

A majority (73%, n = 22) of losses associated with OCS fractures were mild, followed by moderate (10%, n = 3) and severe (3%, n = 1). Only OAE data were available for 13% (n = 4); thus, the severity of the associated hearing losses was unclassified. Only 1 (25%) OCV fracture was associated with a mild hearing loss. The remaining 3 (75%) OCV fractures were associated with severe losses. The proportion of severe hearing losses seen in OCS and OCV fractures varied significantly (P = .0026; Table 2, Figure 4).

Follow-up Data
Follow-up audiometric data were available for 25 fractures (23 patients). Two fractures were OCV and 23 were OCS, yielding a follow-up rate of 41% for OCS fractures and 50% for OCV. A large proportion of patients with initially abnormal audiograms were lost to follow-up (41%, n = 14), including 2 patients with initially severe losses. Neither of the OCV fractures had hearing improvement on follow-up testing. In fact, hearing declined for both these patients. In contrast, a majority of losses associated with OCS fractures were noted to improve to normal levels. Of the 23 OCS fractures for which follow-up data were available, 18 were associated with initially abnormal audiologic examination. The majority (72%, n = 13) improved to PTA ≤20 in a mean of 46.0 ± 15.9 days. When only conductive losses were considered, 10 of 12 (83%) of those with initially abnormal examination results improved to PTA ≤20 in that same time frame (Table 2).

Discussion
In this retrospective analysis of pediatric trauma patients at a tertiary referral center, we identified that the type and severity of hearing loss differ in OCS and OCV temporal bone fractures. OCV fractures tend to be associated with
severe, mixed hearing losses. Although OCS fractures are often associated with no measureable hearing loss, those that are tend to be associated with mild, conductive losses. Hearing losses, especially conductive losses, associated with OCS fractures tend to resolve over the course of about 6 weeks (Table 2).

In this study, most fractures were unilateral and OCS (Table 1). In adult population reports, 9% to 20% of temporal bone fractures are bilateral. The bilateral prevalence is lower here (3%). In the same vein, the prevalence of all skull base and maxillofacial fractures seems to be lower in children than adults. Though speculation, this may be related to greater skull flexibility and impact absorption in children. Pediatric craniofacial anatomy is fundamentally different, with developing paranasal sinuses and prominent buccal fat pads. Varying fracture rates between pediatric and adult populations may also relate to a different mechanism of injury pattern in children.

The mechanism of injury distribution in this study was similar to that seen in prior pediatric skull base trauma literature, with falls as the leading cause (Figure 3). A majority of patients in this study were Caucasian males, reflecting a possible tendency for males to engage in more active and reckless behavior (Table 1). Motor vehicle accidents are still the leading cause of adult temporal bone fractures, but that prevalence is decreasing. It has been postulated that this decrease may be related to stricter safety regulations involving airbags and seatbelts. There may be a similar and stronger effect in the pediatric population given rigorous standards for car seats and child restraint devices.

Similar to this study, a previous work showed that most hearing losses associated with OCS fractures were conductive. Whereas a majority of OCV fracture-associated hearing losses were classified as sensorineural in a prior study, we found that most classifiable losses in OCV fractures are mixed (Table 2, Figure 4).

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related to the difficulty in obtaining bone conduction data in this population; it is possible that some conductive components are missed when bone lines cannot be obtained due to patient cooperation or altered mental status associated with injury. Additionally, the mechanisms of injury associated with the OCV fractures in this study tended to be more severe. It seems reasonable to suspect that bloody debris in the canal or hemotympanum could have accounted for some of the CHL in the setting of the overall severity of these patients’ injuries. The small number of OCV fractures in this study, however, prohibits drawing any conclusions about this finding of mixed hearing loss.

It has been generally concluded that most trauma-associated CHLs resolve with time. In 1 study, 77% of adults with traumatic CHL improved without surgical intervention.13 Our findings confirm this and extend to a pediatric population. A majority of the persistent CHLs resulting from temporal bone trauma are reportedly related to ossicular injury or discontinuity.6 In fact, 1 of the patients in our review who had persistent CHL following OCS temporal bone fracture had documented ossicular discontinuity requiring eventual tympanoplasty. Regarding potential operative intervention for traumatic CHL, it has been suggested in the adult literature that conservative management is appropriate initially and that surgical exploration is indicated only when the loss persists for 4 to 6 months.2,13 In the pediatric population studied here, we found that a majority of CHLs associated with temporal bone fracture improved to normal levels within 6 weeks (Table 2). Given this finding, it could be argued that those children who do not improve to near-normal hearing levels within that time frame warrant further investigation into potential issues that may be surgically corrected. These patients may benefit from intervention earlier than the 4- to 6-month time point suggested in the adult literature.

**Limitations**

There are several limitations to this study. First, our sample size is relatively small, likely due to the rare incidence of temporal bone fractures. Furthermore, the tertiary referral setting in a single geographic location limits generalizability to other health care settings. There were a large number of unclassified hearing losses in this study. Occasionally, young age or clinical condition precluded the ability to obtain a traditional audiogram. With OAE data in these cases, we were unable to determine the severity or type of loss, unlikely affecting the overall results, as the number of OAE examinations in this study was small. More frequently, however, the available traditional audiograms were missing bone conduction data, presumably due to a lack of cooperation among many of the young patients as well as periaural tenderness resulting from the trauma. Furthermore, the child’s clinical condition may have precluded complete audiologic evaluation, particularly if there was neurologic injury. In these instances, the type of hearing loss could not be defined. Finally, a large portion of our population was lost to follow-up. Many of these patients had more devastating, concurrent neurologic injury that could explain some of the poor follow-up. Additionally, this could be related to more local follow-up for referred patients or simply due to resolution of symptoms.

**Conclusions**

Although audiometric outcomes are difficult to study in the pediatric population, this study suggests that hearing loss type and severity differ in pediatric OCS and OCV temporal bone fractures. Furthermore, the natural history of hearing deficits favor short-term resolution, and those with persisting deficits should be evaluated for surgically amenable causes. Patients and families should be counseled about the strict need for further follow-up given the potential long-term consequences of neglected hearing losses.

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**Author Contributions**

Amy Schell, study design, data collection, analysis and interpretation of data, drafting of manuscript; Dennis Kitsko, study design, data collection, manuscript revision.

**Disclosures**

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