



Paediatric petrous temporal bone fractures: a 5-year experience at an Australian paediatric trauma centre

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Background: Petrous temporal bone (PTB) fractures are often associated with otological and neurological injuries, all of which can have functional, developmental and social implications in the paediatric population. Therefore, appropriate and timely management is required to ensure optimal outcomes. The aims of this study were to investigate the prevalence of PTB fractures in children who presented with a skull fracture and their associated complications, and to provide general recommendations on the early management of PTB fractures in the paediatric population.

Methods: A 5-year retrospective cohort study of children with a skull fracture admitted to a tertiary referral paediatric trauma centre (The Royal Children's Hospital, Melbourne).

Results: Five hundred and twenty-eight patients were admitted with a skull fracture between 2013 and 2017. Ninety (17%) patients were diagnosed with a temporal bone fracture, of which 36 (7%) involved the PTB. The most common mechanism of injury was a fall from height (69%). 63% of PTB fractures occurred in males and 78% were associated with an intracranial injury. With regards to complications, 8% had a transient facial nerve palsy (FNP), 8% had a cerebrospinal fluid leak and 19% had persistent hearing loss at 3 months.

Conclusions: PTB fractures are uncommon but are frequently associated with intracranial complications and should be managed at a tertiary paediatric trauma centre. FNP and persistent hearing loss are infrequent debilitating complications of PTB fractures. Specific attention to the management of FNP and hearing loss are critical in the care of the child with a PTB fracture.

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Introduction

The temporal bone forms part of the lateral skull base and is made up of the squamous, styloid, tympanic, mastoid and petrous segments (1). The petrous temporal bone (PTB) is one of the hardest bones in the body and therefore a significant amount of force must be applied to result in a fracture (2). The PTB contains essential anatomical structures including the facial nerve, internal carotid artery,

the cochlea and vestibule, which are responsible for hearing and balance respectively (3).

A PTB fracture can result in significant immediate and long-term complications including facial nerve palsy (FNP), conductive and/or sensorineural hearing loss, cerebrospinal fluid (CSF) leak and related neurological injuries (4). Early childhood hearing loss has been clearly shown to result in poorer outcomes in a multitude of important developmental skills such as communication, language, cognition and

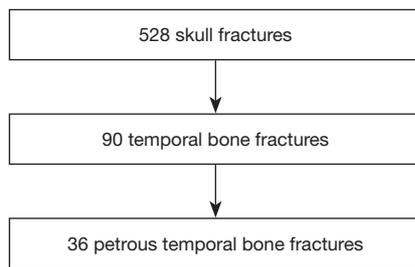


Figure 1 The number of skull fractures, temporal bone fractures and PTB fractures admitted to RCH over a 5-year period between 2013 and 2017.

motor skills (5-7). Facial expression plays an important role in conveying emotions, which is critical in the social development of children (8). A FNP can be extremely disfiguring and can result in severe stigmatization and social isolation, especially in the paediatric population (9). This in turn has been shown to increase the prevalence of anxiety and depression in those with a FNP (10). Complications associated with PTB fractures can have enormous functional, developmental and social implications in the paediatric population and therefore, appropriate and timely management is required to ensure optimal outcomes.

There are currently no studies that look exclusively at PTB fractures in an Australian paediatric population. The primary aim of this study was to investigate the prevalence of PTB fractures in children who presented with a traumatic skull fracture and the prevalence of associated otological and neurological complications. The secondary aim of this project was to provide general recommendations on the early management of paediatric PTB fractures based on regional data.

Methods

This retrospective cohort study was conducted at a tertiary referral paediatric trauma centre, The Royal Children's Hospital (RCH), Melbourne. The RCH is the primary paediatric trauma centre in Victoria, Australia. This study included all paediatric patients admitted to the RCH over a 5-year period between January 2013 and December 2017 with a traumatic skull fracture. This study was approved by the Royal Children's Hospital Ethics Committee as a low-risk project and the requirement for consent was waived.

Data was extracted from the Royal Children's Hospital electronic medical records (EPIC) and pre-established trauma databases. Outcome measures included age, sex,

mechanism of injury, type of PTB fracture, otological and neurological deficits, other associated injuries, and mortality.

The sequelae of petrous temporal fractures were specifically collected, and included presence of CSF leak, presence and grade of facial nerve injury, and presence, type and grade of hearing loss at time of 3-month follow-up. PTB fractures were classified using both the conventional 'longitudinal *vs.* transverse' system and the newer 'otic capsule sparing *vs.* otic capsule violating' system. FNP was graded in this study using the House Brackmann scale (HB). HB 2 was classified as mild, HB 3 or 4 as moderate, and HB 5 or 6 as severe FNP.

It is standard practice at our institution that all PTB fractures are reviewed on admission, treated accordingly and then followed up with an audiogram and by the Otolaryngology, Head and Neck unit at 3 months. Severity of conductive or sensorineural hearing loss was classified as normal (audiometry ISO ≤ 20 dB), mild (audiometry ISO 21-40dB), moderate (audiometry ISO 40-70 dB), severe (audiometry ISO 70-90 dB), and profound (audiometry ISO ≥ 90 dB).

Results

Five hundred and twenty-eight patients were admitted to our institution with a diagnosis of a traumatic skull fracture between January 2013 and December 2017. Ninety patients (17%) were diagnosed with a temporal bone fracture, of which 36 (7%) specifically involved the PTB. The median age was 7 years old and 63% of PTB fractures occurred in males. Two patients had bilateral PTB fractures (*Figure 1*).

With regards to temporal bone fracture classifications, 28 (78%) had longitudinal fractures and 32 (88%) had otic capsule sparing fractures. All subjects with an otic capsule violating fracture ($n=4$) had at least one direct otological or neurological complication. The most common mechanism of injury was a fall from height (69%) followed by motor vehicle accidents (17%) and blunt trauma (*Table 1*).

Twenty-eight (78%) petrous temporal fractures were associated with an intracranial injury. These included pneumocephalus, extra-axial haemorrhage and traumatic brain injury. In this cohort, there were multiple associated injuries necessitating involvement from other surgical specialities including orthopaedic (6%), cardiothoracic (3%), oral & maxillofacial (6%), plastic & reconstructive (6%), and paediatric surgery (3%).

Of the 36 patients with PTB fractures, nine (25%)

Table 1 Subject demographics and mechanisms of injuries

Characteristics	Values
Subject	N=36
Sex (male)	23 (63%)
Age range	13 months to 15 years old
Median age (years)	7
Longitudinal PTB fractures	28 (78%)
Otic capsule sparing PTB fractures	32 (89%)
Bilateral PTB fractures	2 (6%)
Mortality	0
Mechanisms of injury	
Fall from height	25 (69%)
Motor vehicle accident	6 (17%)
Blunt trauma	5 (14%)

Table 2 Complications resulting from PTB fractures

Complications	Values
Subjects (n)	N=36
FNP	3 (8%)
CSF leak	3 (8%)
Hearing loss at 3 months	7 (19%)
Conductive hearing loss	2 (6%)
Sensorineural hearing loss	4 (11%)
Mixed hearing loss	1 (3%)
Associated intracranial injury	28 (78%)

patients had at least one direct otological or neurological complication from their fracture, which consisted of FNP, CSF leak and/or hearing loss. Three (8%) had a transient FNP, two of which were moderate (HB 3 or 4), and one was mild (HB 2). All patients were initially treated with intravenous and subsequently oral steroids and had resolved at time of 3-month review. Three (8%) had biochemically proven CSF otorrhea, two of which spontaneously resolved within 1 week with non-surgical therapy. One patient with CSF otorrhea required the insertion of a lumbar drain and their CSF otorrhea subsequently resolved within 24 hours.

Seven patients (19%) had persistent hearing loss at 3 months proven with an audiogram. Two (6%) had a purely conductive hearing loss (CHL), four (11%) had a purely

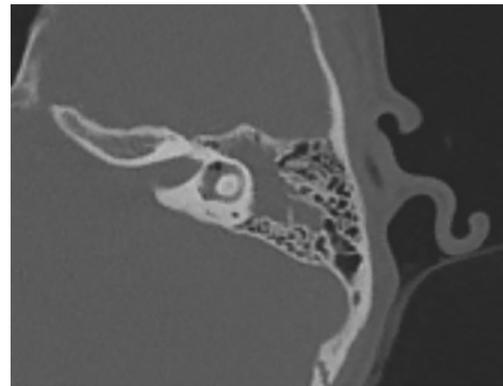


Figure 2 Axial CT image demonstrates an otic capsule violating left PTB fracture. Free gas is within the vestibule indicating pneumolabyrinth.

sensorineural hearing loss (SNHL) and one (3%) had a severe to profound mixed hearing loss. For the two who had purely CHL, neither were severe enough to necessitate any surgical intervention and one declined the offer of a hearing aid. Three patients with a unilateral SNHL, which included the patient with mixed hearing loss, were referred for consideration for a cochlear implantation. Of note, all patients with a CSF leak at time of injury were recorded to have a persistent SNHL at time of audiometric testing (Table 2, Figure 2).

Discussion

This is the first paper to our knowledge to investigate PTB fractures in an Australian paediatric population. The overall prevalence of PTB fractures in paediatric patients who presented with a skull fracture was 7% in this study. The most common mechanism of injury was fall from height. This differs from previous studies that report motor vehicle accidents (MVAs) account for the most common cause of paediatric temporal bone fractures (3,11-13). A study by Weissbluth *et al.* found that MVAs made up the majority cause for temporal bone fractures and in particular, a large proportion was made up of uncommon vehicles types such as All-Terrain Vehicles (3). This was not apparent in our study and may relate to increased Australian public awareness about helmet use, road safety, and the dangers of quadbikes and farming equipment from national public health initiatives such as the Farmsafe guidelines on “*Safety of quad bikes and side-by-side vehicles on Australian farms: a practical management guide*” and the Royal Australasian

College of Surgeons “*Quad Bikes—Trauma prevention*” position paper (14,15).

The majority of patients in our study had longitudinal PTB fractures and otic capsule sparing fractures. This is consistent with current literature (12,16). All the patients with otic capsule violating PTB fractures suffered at least one direct otological or neurological complication. This is similar to previous studies by Little *et al.* and Frisenda *et al.*, who described that those with otic capsule violating fractures were more likely to develop SNHL, facial nerve injury and CSF otorrhea (4,17).

Only seven subjects (19%) were noted to have hearing loss at 3 months post injury in our study. This is lower than previously reported studies. Sheehan *et al.* previously showed that temporal bone fractures caused by MVA in recreational vehicles were associated with higher rates of otic capsule violation (21% *vs.* 5%) and hearing loss (30% *vs.* 16%) compared to other causes of head trauma (18). Therefore, the lack of MVAs accounting for injury mechanisms in this study may be a reason for our lower prevalence of hearing loss.

Bowman *et al.* showed that hearing loss in children was strongly associated with a temporal bone fracture compared to other head trauma, and suggested that any child with head trauma and clinical or radiological evidence of temporal bone fracture should have early hearing evaluation (19). It is currently not routine practice at our institution to get an audiogram in the acute setting of a PTB fracture. This is due to several reasons. Firstly, many of these patients have an associated neurological injury and therefore they are not clinically appropriate to participate in audiometric testing. Secondly, of those who are clinically appropriate in the acute setting, the observation has been that the majority of acute paediatric trauma patients are unwilling to actively engage in audiometric testing. It is standard practice at our institution for all paediatric patients with a PTB fracture to be given a course of intravenous and oral steroids. This practice has been extrapolated from studies which have shown that steroids help to reduce long term risk of SNHL in other forms of labyrinthine trauma such as cochlear implantation and sudden SNHL (20-23). Our institution also aims for patients with a PTB fracture to be seen within 3 months by the Otolaryngology, Head and Neck unit with audiometric testing. This is ideally followed audiometric testing at 6 and 12 months to ensure hearing remains stable. The low prevalence of hearing loss at 3 months in our study may stand to show that although hearing loss may be observed acutely, as seen with previous studies, that long

term hearing outcomes in paediatric patients are good, the majority are self-resolving, and that empirical treatment with steroids may be beneficial. However, of the seven patients who did have a persistent hearing loss, three had a sensorineural hearing loss significant enough to warrant referral for a cochlear implant.

All patients with a FNP in this study were acutely treated with empirical steroids, as part of our institution's standard practice of steroid use for sensorineural hearing preservation. There were no complete facial nerve palsies observed in our cohort and all facial nerve palsies had resolved at time of outpatient review. The use of steroids is likely to be useful in the setting of FNP based on its anti-inflammatory effect and the assumption that neural swelling is the primary driver for FNP in the traumatised but intact nerve (24). However, there is currently no strong evidence to substantiate this management in paediatric PTB fractures.

A study by Adepoju *et al.* reported a CSF leak rate of 2.3% in the setting of paediatric skull fractures (not specific to PTBs), whereas the prevalence of CSF leak in this study specific to PTBs was 8% (25). There are two potential reasons for this higher prevalence in our study. Firstly, the petrous portion of the temporal bone forms the majority of the lateral skull base and therefore a fracture running through this region is more likely to result in direct communication between the ear and the subarachnoid space compared to fractures going through any other portion of the temporal bone. The second reason is related to the density of the PTB and the large force required resulting in a significant fracture (2). This reason may also account for the large proportion of associated intracranial injuries seen in this study (78%), which is consistent with a previous study by Ort *et al.*, who showed that the prevalence of concomitant intracranial injury was 75% (26). Despite the higher prevalence of CSF leaks in our study, all resolved over a short time period with either close clinical observation or insertion of a lumbar drain. No otological surgery was required for any patient with a CSF leak. The findings of this study appear to reflect current literature in that CSF otorrhea caused by temporal bone trauma usually resolves within 2 weeks without intervention and that surgical exploration is rarely required (27).

Based on the results of this study, we found that PTBs fractures are uncommon in children, but when present, they are a hallmark for a high-energy mechanism of trauma. They do not commonly occur in isolation, but rather are likely to be associated with a multisystem injury, in

Table 3 Recommendations for the early management of paediatric PTB fractures

General recommendations for the early management of paediatric PTB fractures

- A paediatric PTB fracture is a hallmark for high energy trauma, and other associated injuries should be identified early, in particular intracranial complications;
- Early collaborative multidisciplinary management by trauma, neurosurgical and Otolaryngology, Head & Neck services are essential for appropriate and timely management of paediatric PTB fractures;
- Empirical steroids may be beneficial in reducing the risk of long term SNHL.
- Most complications directly related to a PTB fracture in paediatric patients will not require any acute surgical intervention;
- Follow up with an Otolaryngology, Head & Neck unit with audiometric testing is essential in paediatric patients with a PTB fracture;
- All paediatric PTB fractures should be managed at a tertiary paediatric trauma centre given the association with intracranial complications and the need for multidisciplinary team input.

particular, intracranial injuries. As such, we recommend that all paediatric PTB fractures should be managed at a tertiary paediatric trauma centre. The direct complications associated with paediatric PTB fractures are overall uncommon, but when present, can have serious lifelong morbidity, and therefore early referral and multidisciplinary care is recommended (*Table 3*).

Limitations

The main limitation to this study was the small sample size. The small sample size was not conducive to any meaningful statistical analyses and therefore, it is difficult to draw definitive conclusions. A multi-centre study and a larger sample size over a longer time period would allow for greater analysis of the long term sequelae of paediatric PTB fractures and a better understanding of their true implications in the paediatric population.

Conclusions

PTB fractures are uncommon but are likely to be associated with intracranial complications, when observed in paediatric trauma. FNP and persistent hearing loss are infrequent debilitating complications of PTB fractures. Most otologic and neurologic complications directly related to PTB fractures will resolve with non-surgical management. No patients in our study population required otological surgery in the acute setting. Specific attention to the management of FNP and hearing loss are critical in the care of the child with a PTB fracture. Multidisciplinary care of the child with PTB fracture is recommended due to the significant related multisystem complications, and therefore all paediatric PTB fractures should be managed at a tertiary paediatric trauma

centre.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was approved by the Royal Children's Hospital Ethics Committee as a low-risk project and the requirement for consent was waived.

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