Temporal Bone Trauma

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Grand Rounds Presentation
October 12, 2005
Temporal Bone Trauma

- Wide spectrum of clinical findings
- Knowledge of the anatomy is vital to proper diagnosis and appropriate management
Incidence and Epidemiology

- **Motorized Transportation**
  - 30-75% of blunt head trauma had associated temporal bone trauma

- **Penetrating Trauma**
  - More dismal prognosis

- **Barotrauma**
  - Inner ear decompression sickness
    - The “bends”
  - Perilymphatic fistula
  - Blast Injuries
Evaluation and Management

- **ATLS**
  - Airway
  - Breathing
  - Circulation

- **H & P**
  - Thorough head & neck examination

- Patients with multiple systems trauma must proceed according to the ATLS protocol and often the otolaryngologist is notified after its been completed, but should not be overlooked in the fundamental approach to evaluation of a trauma patient.
- Of course a thorough H&P consisting of a thorough and well-documented Head and Neck exam is necessary.
- Foreign bodies are more accountable for injuries to the TM, Ossicles and Facial Nerve without temporal bone fractures.
Physical Examination

Basilar Skull Fractures

- Periorbital Ecchymosis (Raccoon’s Eyes)
- Mastoid Ecchymosis (Battle’s Sign)
- Hemotympanum

A complete physical examination will often reveal the type of injury even before radiographic evidence can confirm it.

The classic PE findings of a Basilar skull fracture are Periorbital Ecchymosis (raccoon’s eyes), Mastoid ecchymosis (battle’s sign) and Hemotympanum.

The external canal and TM is more commonly lacerated in Longitudinal fractures which allows for blood or CSF otorrhea.

Whereas the intact external canal assoc w/ transverse fractures may lead to a buildup of blood or CSF behind and intact TM.
Physical Examination

- Tuning Fork exam
- Pneumatic Otoscopy
  - Flaccid TM
  - Nystagmus

- The tuning fork exam is a quick way to evaluate hearing in the emergency room setting.
- Likewise, Pneumatic otoscopy may initiate the nystagmus and vertiginous symptoms of a PLF, or even reveal a subtle fracture of the malleus.
Imaging

- HRCT
- MRI
- Angiography/ MRA

- High resolution CT scanning with bone windows are the standard in diagnosis for identifying and classifying lesions of the middle and inner ear.
- MRI is becoming more prominent in identification of subclinical CNS injuries, especially in patients that are considered for surgical intervention for facial nerve lesions by documenting preexisting CNS injury and determining the risk of potential morbidity in patients undergoing middle cranial fossa approach for facial nerve injury.
- MRI evaluation of the facial nerve has been of interest in Bell’s Palsy, and is gaining some interest in evaluation of nerve edema/compression in trauma evaluation. In a study by Haberkamp, gadolinium enhanced MRI was found to be helpful in accurately predicting the site of facial nerve injury as a result of trauma with focal enhancement of the lesion.
- In the case of penetrating injuries, if there is any concern of risk to the internal Carotid artery, angiography or MRA is necessary.
Longitudinal fractures

- 80% of Temporal Bone Fractures
- Lateral Forces along the petrosquamous suture line
- 15-20% Facial Nerve involvement
- EAC laceration

• The most common temp bone fracture (80%)
• Results from forces applied in the lateral projection, then traveling along the path of least resistance with the petrosquamous suture line anterior to the otic capsule. Sometimes involving the TMJ.
• 15-20% have Facial nerve injuries, and are sometimes often delayed in onset attributed to edema rather than laceration.
• Vestibular and sensorineural deficits are relatively uncommon, and are attributed to concussive effects rather than direct trauma on the labyrinth or cochlea.
• The External Canal is often disrupted.
Transverse fractures

- 20% of Temporal Bone Fractures
- Forces in the Antero-Posterior direction
- 50% Facial Nerve Involvement
- EAC intact

- A much less frequent is the transverse fracture which is generated by forces in the Antero-Posterior axis. These fractures require much more energy and are more commonly associated with more serious or even fatal head injuries.
- The facial nerve is involved in 50% of the cases
- The External canal is usually intact
Temporal Bone Trauma

- Hearing Loss
- Dizziness/Vertigo
- CSF Otorrhea
- Facial Nerve Injuries
Hearing Loss

- Formal Audiometry vs. Tuning Fork
- 71% of patients with Temporal Bone Trauma have hearing loss
- TM Perforations
  - CHL > 40db suspicious for ossicular discontinuity

- Hearing loss is a common compliant of middle and inner ear trauma.
- 71% of temporal bone trauma relate hearing loss.
- Eval of hearing should be done w/ formal audiometry, however in the ER setting tuning fork tests can give preliminary data.
- In general, the larger the TM perforation, the greater the hearing impairment, but this relationship is not constant, seemingly identical perforations in size and location produce different degrees of hearing loss.
- In CHL greater than 40Db, be suspicious for ossicular discontinuity w/ or without TM perforation
Hearing Loss

Longitudinal Fractures
- Conductive or mixed hearing loss
- 80% of CHL resolve spontaneously

Transverse Fractures
- Sensorineural hearing loss
- Less likely to improve

- Longitudinal fractures are more likely to cause conductive or mixed hearing loss.
- Transverse fractures, on the other hand, are more likely to involve the otic capsule and inner ear canal and lead to Sensorineural hearing loss.
- In a review by Tos, 80% of CHL from Temporal bone fractures would spontaneously resolve, whereas none of the sensorineural loss resolved.
Hearing Loss

- Tympanic Membrane Perforations
- Ossicular fracture or discontinuity
- Hemotympanum

Treatment:
- Observation
- Otic solutions may only mask CSF leaks
Dizziness

- Fracture through the otic capsule or a labyrinthine concussion
- Difficult diagnosis - bed rest, obtundation, sedation
- Treatment: reserved for vomiting, limitation of activity
  - Vestibular suppressants
  - Allow for maximal central compensation
Dizziness

Perilymphatic Fistulas

- SCUBA diver with ETD
- Fluctuating dizziness and/or hearing loss
- Tullio’s Phenomenon

Management

- Conservative treatment in first 10-14 days
- 40% spontaneously close
- Surgical management for persistent vertigo or hearing loss
- Regardless of visualization of fistula site, the majority of patients get better

Perilymphatic fistulas may present as fluctuating episodes of dizziness/vertigo with or without hearing loss, lasting a few seconds.

Tullio’s phenomenon may be present

40% should close spontaneously by conservative treatment of light activity, elevating the HOB.

In certain cases such as progressive hearing loss or worsening vertigo beyond an observation period of 10-14 days, surgical options may be considered.

Usually requiring elevation of a tympanomeatal flap, and suspected defects are plugged with fascia, muscle, or fat.

Regardless of visualization of a specific leak site, the majority of patients achieve resolution of their symptoms.
Dizziness

- Inner Ear Decompression Sickness
  - Too rapid an ascent leads to percolation of nitrogen bubbles within the otic capsule.
  - Greater than 30 ft.... Decompression stages upon ascent are needed
Dizziness

**BPPV**

- Acute, latent, and fatiguable vertigo
- Can occur any time following injury
- Dix Hallpike
- Epley Maneuver

- Acute, latent, fatigable vertigo such as BPPV can occur ANY time following trauma.
- Diagnosis is by history and Dix-Hallpike.
- >90% success has been achieved by Epley maneuvers.
CSF Otorrhea

- Acquired
  - Postoperative (58%)
  - Trauma (32%)
  - Nontraumatic (11%)

- Spontaneous
  - Bony defect theory
  - Arachnoid granulation theory
Temporal bone fractures

- Longitudinal
  - 80% of Temp bone fx
  - Anterior to otic capsule
  - Involve the dura of the middle fossa
Temporal bone fractures

- **Transverse**
  - 20% of Temp bone fx
  - High rate of SNHL due to violation of the otic capsule
  - 50% facial nerve involvement
Testing of Nasal Secretions

- Beta-2-transferrin is highly sensitive and specific
  - 1/50th of a drop
  - Gold top tube, may need to send a sample of the patient's serum also.
  - Found in Vitreous Humor, Perilymph, CSF

- Electronic nose has shown early success
  - Faster (<24hrs)
  - Very Accurate
Imaging CSF Otorrhea

- **High resolution CT**
  - Convenience
  - Speed

- **CT Cisternography**

- **MRI**
  - Heavily weighted T2
  - Slow flow MRI
  - MRI cisternography
Imaging

- Slow flow MRI
- Diffusion weighted MRI
- Fluid motion down to 0.5mm/sec
- Ex. MRA/MRV
Treatment of CSF Otorrhea

- **Conservative measures**
  - Bed rest/Elev HOB>30
  - Stool softeners
  - No sneezing/coughing
  - +/- lumbar drains

- **Early failures**
  - Assoc with hydrocephalus
  - Recurrent or persistent leaks
Treatment of CSF Otorrhea

- Brodie and Thompson et al.
- 820 T-bone fractures/122 CSF leaks
- Spontaneous resolution with conservative measures
  - 95/122 (78%): within 7 days
  - 21/122(17%): between 7-14 days
  - 5/122(4%): Persisted beyond 2 weeks
Temporal bone fractures

- **Meningitis**
  - 9/121 (7%) developed meningitis. Found no significant difference in the rate of meningitis in the ABX group versus no ABX group.

- A later meta-analysis by the same author did reveal a statistically significant reduction in the incidence of meningitis with the use of prophylactic antibiotics.
Pediatric temporal bone fractures

- Much lower incidence (10:1, adult:pedi)
  - Undeveloped sinuses, skull flexibility

- otorrhea >> rhinorrhea

- Prophylactic antibiotics did not influence the development of meningitis.
CSF Otorrhea Surgical Management

- Surgical approach
  - Status of hearing
  - Meningocele/encephalocele
  - Fistula location

- Transmastoid

- Middle Cranial Fossa

- The surgical approach depends mainly on the status of hearing, the presence of meningocele or encephalocele, and location of the fistula.
- Defects of the mastoid tegmen can be fixed with a transmastoid approach and plugging with fascia/bone... larger defects or with brain tissue may require a middle cranial fossa approach as well.
- Tegmen tympani defects in an intact hearing ear should be repaired through a middle fossa approach to preserve hearing.
Overlay vs Underlay technique

- Meta-analysis showed that both techniques have similar success rates
- Onlay: adjacent structures at risk, or if the underlay is not possible
Technique of closure

- Muscle, fascia, fat, cartilage, etc..
- The success rate is significantly higher for those patients who undergo primary closure with a multi-layer technique versus those patients who only get single-layer closure.
- Refractory cases may require closure of the EAC and obliteration.
Facial Nerve Injuries

- Loss of forehead wrinkles
- Bell’s Phenomenon
- Nasal tip pointing away
- Flattened Nasofacial groove
The facial nerve begins its course throughout the middle and inner ear as it enters the IAC.
- Runs 8-10mm within the Antero-Superior quadrant.
- To its narrowest labyrinthine portion 2-4mm to the geniculate ganglion.
- The tympanic segment begins just distal to this and turns 40 to 80 degrees at the first genu.
- Then posteroinferiorly across the tympanic cavity to the second genu.
- Turns 90 degrees inferiorly where the mastoid segment travels for 12-14mm in the anterior mastoid to exit the stylomastoid foramen.
Facial Nerve Injuries

- **Initial Evaluation is the most important prognostic factor**
  - Previous status
  - Time
  - Onset and progression
  - Complete vs. Incomplete

- Early evaluation and a careful, thorough history are crucial when evaluating the status of the facial nerve.
- Particular importance to characteristics of onset (sudden vs. delayed) and complete vs. incomplete.
- Care must be taken not to misdiagnose a facial nerve paralysis as a paresis by attributing movement of the levator palpebrae superioris muscle innervated by CNIII.
- Temporal bone fractures are the most common cause of traumatic injury to the facial nerve.
- Fortunately the nerve is fairly robust and has a good regenerative response to mechanical injury.
<table>
<thead>
<tr>
<th>I</th>
<th>Normal</th>
<th>Normal facial function</th>
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</thead>
<tbody>
<tr>
<td>II</td>
<td>Mild</td>
<td>Slight synkinesis/weakness</td>
</tr>
<tr>
<td>III</td>
<td>Moderate</td>
<td>Complete eye closure, noticeable synkinesis, slight forehead movement</td>
</tr>
<tr>
<td>IV</td>
<td>Moderately Severe</td>
<td>Incomplete eye closure, symmetry at rest, no forehead movement, dysfiguring synkinesis</td>
</tr>
<tr>
<td>V</td>
<td>Severe</td>
<td>Assymetry at rest, barely noticeable motion</td>
</tr>
<tr>
<td>VI</td>
<td>Total</td>
<td>No movement</td>
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Electrophysiologic Testing

- NET: Nerve Excitability Test
- MST: Maximal Stimulation Test
- ENoG: Electroneurography

Goal is to determine whether the lesion is partial or complete?

- Neuropraxia: Transient block of axoplasmic flow (no neural atrophy/damage)
- Axonotmesis: Damage to nerve axon with preservation of the epineurium (regrowth)
- Neurotmesis: Complete disruption of the nerve (no chance of organized regrowth)

Electrophysiologic Testing of Facial Nerve Function includes the Nerve Excitability Test, Max Stimulation Test, and ENoG.

Can only be used for unilateral paralysis, results are not valid until >72hrs post injury.
Nerve Excitability Test
Maximal Stimulation Test

- Stimulating electrodes are placed and a gross movement is recorded
  - Not as objective and reliable
- >3.5mA difference suggests a poor prognosis for return of facial function.
  - Correlates with >90% degeneration on ENoG

- NET measures the lowest current necessary to elicit a twitch when stimulating the stylomastoid foramen. Then comparing to the normal side.
- MST is basically a modified NET, by depolarizing all facial nerve branches.
Electroneuronography

- Most accurate, qualitative measurement
- Sensing electrodes are placed, a voluntary response is recorded
- Accurate after 3 days
- Requires an intact side to compare to
- Reduction of >90% amplitude correlates with a poor prognosis for spontaneous recovery

- ENoG is considered to be the most accurate, prognostic test because it provides qualitative, objective measurements of neural degeneration.
- The peak to peak amplitude is measured between an electrode at the stylomastoid foramen and usually the nasolabial groove, then compared to the normal side.
- >90% degeneration correlates with a poor prognosis for spontaneous recovery.
- It should be noted that ENoG data is well known for Bell’s Palsy, however there is limited definitive ENoG data assoc w/ facial nerve injuries due to trauma.
Electromyography

- Electrode is placed within the muscle and voluntary movement is attempted.
- Normal Muscle is electrically silent.
- After 10-14 days, the denervated muscle begins to spontaneously fire:
  - Diphasic/Polyphasic potentials: Good
  - Loss of voluntary potentials: Bad

- Development of muscular degeneration fibrillations does not develop for 10-14 days, therefore making EMG of limited value in early detection.
- Diphasic or Triphasic potential indicate normal voluntary contraction,
- Polyphasic potentials indicate reinervation, which develop 6-12 weeks before clinical return of function, which is useful in the evaluation of patients seen in the late post-traumatic period.
Facial Nerve Injuries

WHO GETS TREATMENT?

- Conservative treatment candidates
- Surgical treatment candidates
Facial Nerve Injuries

Chang & Cass

- Medline search back to 1966
- Individually reviewed each article
- 1) Understand the pathophysiology of facial nerve damage in temporal bone trauma.
- 2) What is the effect of surgical intervention on the ultimate outcome of the facial nerve.
- 3) Propose a rational course for evaluation and treatment.
Facial Nerve Injuries
Chang & Cass

- Pathophysiology based on findings by Fisch and Lambert and Brackmann:

- Where?
  - Perigeniculate, Labyrinthine, and meatal segments
  - Concern over findings of endoneural fibrosis and neural atrophy proximal to the lesions
  - In an untreated human specimen found intraneural edema and demyelinization that extended proximally to the meatal foramen

- How?
  - Longitudinal Fractures
    - 15% transection
    - 33% bony impingement, 43% hematoma
  - Transverse Fractures
    - 92% transection
Does Facial Nerve decompression result in superior functional outcomes compared with no treatment?

- Not enough human data!
- Boyle-monkey: prophylactic epineural decompression in complete paralysis did not improve recovery of facial nerve function after induced complete paralysis
- Kartush: Prophylactic decompression of the meatal segment during acoustic neuroma decreased the incidence of delayed paralysis
- Adour: compared patients with complete paralysis found:
  - Equal outcome with observation vs. decompression without nerve slitting
  - Worse outcome with decompression with nerve slitting
Does Facial Nerve decompression result in superior functional outcomes compared with no treatment?

- Many difficulties in Study designs, controls, etc, but they made some rough estimates:
  - 50% of patients who undergo facial nerve decompression obtain excellent outcomes
  - The true efficacy of facial nerve decompression surgery for trauma remains uncertain
• Conservative Treatment Candidates

  - Chang and Cass
    - Present with **Normal Facial Function** regardless of progression
    - **Incomplete paralysis and no progression** to complete paralysis
    - Less than **95%** degeneration by ENoG
      - Most data comes from Bell’s palsy/tumor studies by Fisch.

  - There is general consensus in the conservative treatment of a patient with an incomplete paralysis.
  - In a large overview by Chang & Cass, it was concluded that surgical treatment was not required in patients who had
    - 1) documented normal facial nerve function after injury regardless of progression.
    - 2) incomplete paralysis as long as there was no progression to complete paralysis
    - 3) less than 95% ENoG
Conservative Treatment Candidates

- Brodie and Thompson
  - All patients that presented with normal facial nerve function initially that progressed to complete paralysis recovered to a HB 1 or 2.
Surgical Candidates

Critical Prognostic factors

- *Immediate* vs. *Delayed*
- *Complete* vs. *Incomplete paralysis*
- *ENoG criteria*

- There are still many unanswered questions and much controversy re: which patients outcome is affected by surgical intervention.
- According to nerve transection cases, Fisch suggested that patients with >95% degeneration by ENoG within 6 days of injury are expected to have poor functional outcome and should be treated.
- Chang and Cass suggest that if decompression surgery is surgery is anticipated, based on animal models by Yamamoto and Fisch, it should be done within a 14 day period.
- In general, patients with acute onset paralysis w/ >95% degeneration and patients whom develop a complete paralysis w/>95% degeneration within a 14 day period may benefit from surgery.
Algorithm for Facial Nerve Injury

Facial nerve injury

- Acute onset
  - Complete paralysis at presentation
  - Incomplete paralysis at presentation
    - Progression
      - Serial ENoG
        - >95% degeneration within 14 days
        - <95% degeneration
        - >14 days elapsed
          - Surgery
            - Facial nerve exploration
          - Observe
- Delayed onset (normal at presentation)
Facial Nerve Injuries
Chang & Cass

What time frame is best to operate?

- Fisch-cats: Decompression of the nerve within a 12 day period resulted in “excellent” functional recovery. Presumption was that it preserved endoneural tubules. (limits the damage to axonotmesis at worst)

- Limits the accuracy of your patient selection because EMG is not reliable until day 10-14.
Surgical Approach

- **Medial to the Geniculate Ganglion**
  - No useful hearing
    - Transmastoid-translabyrinthine
  - Intact hearing
    - Transmastoid-trans-epitympanic
    - Middle Cranial Fossa

- **Lateral to Geniculate Ganglion**
  - Transmastoid

Injuries distal to the Geniculate ganglion can be approached via the transmastoid procedure.
A facial recess approach will help provide examination of the nerve from the geniculate ganglion to the second genu.
Histopathologic case reports of patients with severe facial nerve injuries has shown axonal degeneration takes place to the level of the labyrinthine segment and probably to the meatal segment. Therefore, lesions that are distal to the geniculate ganglion may not adequately be addressed by a transmastoid approach alone. Even though clinically, this is the common route that is chosen.
Chang & Cass

- Histopathologic study
- Severe facial nerve injury results in retrograde axonal degeneration to the level of the labyrinthine and probably meatal segments
Surgical findings of *greater than 50%* nerve transection/damage

- Nerve repair via primary anastomosis or cable graft repair
  - HB 1 or 2: 0%
  - HB 3 or 4: 82%
  - HB 5 or 6: 18%

- If the nerve is found to be intact, decompression proceeds proximally and distally until normal nerve is encountered. In Chang and Cass's review, 50% of decompressed nerves had excellent functional outcomes.
- For transected nerves >50%, nerve repair via direct end to end anastomosis or nerve graft is done. 82% will recover to a HB of 3-4, none have shown to recover to HB 1-2.
- It has not been shown that early vs. delayed repair leads to better functional outcome.
Iatrogenic Facial Nerve Injuries

- Mastoidectomy (55%)
- Tympanoplasty (14%)
- Bony Exostoses (14%)
- Lower tympanic segment is the most common location injury
- 79% were not identified at the time of surgery

- Iatrogenic FN injuries are rare but devastating complications of otologic surgery.
- Most common Mastoidectomy (55%) Tplasty (14%), Bony exostoses (14%)
- Green found that 79% of injuries were not identified at the time of surgery.
Management of Iatrogenic Facial Nerve Injuries

- Green, et al.
- <50% damage: perform decompression
  - 75% had HB of 3 or better!
- >50% damage: perform nerve repair
  - No patients had better than a HB 3
- Beware of local anesthetics
- General consensus: acute, complete, postoperative paralysis should be explored as soon as possible.

- In Green’s review, <50% transection got decompression
  - 75% had a HB of 3 or better
- >50% transection got nerve repair
  - No patients did better than a HB 3
- As with facial nerve injuries from trauma, there is still much controversy.
- However, it is generally agreed upon by otologic surgeons that an acute postoperative facial nerve paralysis should be surgically explored as soon as possible.
- For postoperative delayed onset injuries, serial EPS testing should be performed, and >90% degeneration within one week warrants surgical exploration.
Emergencies

- Brain Herniation
- Massive Hemorrhage
  - Pack the EAC
  - Carotid arteriography with embolization
Bibliography