Conductive Hearing Loss

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Objectives

- To understand the basic functional anatomy of the ear
- To describe components of a comprehensive audiogram and define conductive hearing loss by audiometric and physical exam parameters
- To recall the common causes of conductive hearing loss and appreciate their medical/surgical management
- To describe options for aural rehabilitation in patients with conductive hearing loss

Temporal Bone Anatomy – External Ear

Pinna/Auricle

- Body’s only skin-lined cul-de-sac
- Keratinizing stratified squamous epithelium
- 2.5 cm long
- 1/3 cartilaginous; 2/3 bony
- The cartilaginous ear canal has hair follicles, sebaceous glands, and ceruminous glands
- The bony ear canal has skin directly overlying periosteum
**Temporal Bone Anatomy – External Ear**

**The Tympanic Membrane**

- The tympanic membrane has 3 layers
  - Squamous, fibrous and mucosal layers
- Made up of the pars tensa and pars flaccida
- Visible light reflexes during otoscopy are the primary and secondary light reflex

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**Temporal Bone Anatomy – Middle Ear Space**

- Mesotympanum
- Epitympanum
- Protympanum
- Hypotympanum

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**Temporal Bone Anatomy – Middle Ear Ossicles**

- **Malleus**: umbo, manubrium, head, neck, anterior and lateral processes
- **Incus**: body, short process, long process, and lenticular process
- **Stapes**: head, footplate and two crura

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**Temporal Bone Anatomy – Eustachian Tube**

- Connects protympanum (ME) to nasopharynx (NP)
- Medial 2/3 fibrocartilage; lateral 1/3 bony
- Equalizes ME pressure with atmospheric pressure
- Lined with respiratory epithelium
  - Mucociliary clearance towards the NP
- Usually closed to prevent reflux of NP contents into ME
  - Opens during palate movement
- 13 mm @ birth; 36 mm in adulthood
- More horizontal at birth; elongates and descends over time
Temporal Bone Anatomy – The Mastoid Region

- The mastoid region of the temporal bone is posterior to the bony ear canal
- Surgical landmarks include the tegmen, sinodural angle, sigmoid sinus, horizontal semicircular canal, incus, & the vertical segment of the facial nerve

Temporal Bone Anatomy – The Inner Ear

Hearing mechanism: Cochlea
Balance mechanism: Utricle, saccule, and 3 semicircular canals

Physiology of Hearing

Conductive Hearing Loss!
Sensorineural Hearing Loss!

- PTA (pure tone average): An average for pure tone thresholds at 500, 1000, and 2000Hz
- 4-tone PTA: An average for pure tone thresholds at 500, 1000, 2000, and 3000Hz
- SRT (speech reception threshold): Uses spondee words having equal emphasis on each of 2 syllables
- Threshold should agree within 7 dB of PTA
- Usually lower threshold than PTA (our auditory system is more sensitive to spoken words than to tones)
- WRS (word recognition score): Uses standardized phonemically balanced words representing phonemes in the English language
  - Reported as % correct

Mixed Hearing Loss!

The Normal Audiogram

- PTA (pure tone average): An average for pure tone thresholds at 500, 1000, and 2000Hz
- 4-tone PTA: An average for pure tone thresholds at 500, 1000, 2000, and 3000Hz
- SRT (speech reception threshold): Uses spondee words having equal emphasis on each of 2 syllables
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Audiometry – Conductive Hearing Loss

Air Conduction Stimuli (sounds): delivered by over-the-ear or insert earphones

Bone Conduction Stimuli: delivered through a bone conduction vibrator placed on mastoid region

Audiometry – Sensorineural Hearing Loss

Air Conduction Stimuli (sounds): delivered by over-the-ear or insert earphones

Bone Conduction Stimuli: delivered through a bone conduction vibrator placed on mastoid region

Immittance Testing: Tympanogram

Tuning Fork Tests

- Used to confirm audiogram results (512 Hz tuning fork)
- Weber: Laterizes to the poorer ear with a conductive HL or the better ear with sensorineural hearing loss
- Rinne: A positive Rinne indicates that air conduction is greater than bone conduction. A negative Rinne indicates that bone conduction is greater than air conduction
Causes of Conductive Hearing Loss

Diseases of the External Auditory Canal

Foreign Bodies in the Ear Canal
- Objects
  - Plastic toys or beads; Cotton, paper
  - Insects
  - Organic material (popcorn kernels or vegetable material)
  - Button batteries (caustic!)
  - Ear wax (cerumen impaction)
- Symptoms: pain, ear drainage, conductive hearing loss
- Treatment: Removal
  - Risks tympanic membrane injury
  - Kill live insects rubbing alcohol or mineral oil
  - Use otologic microscopes with microinstruments and suction
  - Ear irrigation (do not use if organic foreign body or button battery)
  - Otic antibiotic drops

Otitis Externa
- Inflammation of the external auditory canal
  - acute and chronic types
- Ear canal defenses
  - Cerumen
    - Acidic
      - Contains lysozyme and immunoglobulins
      - Lipid rich and forms a moisture barrier for underlying skin
    - Epithelial migration from center of tympanic membrane outward (0.07 mm/day) to meatus
    - Curvature of the ear canal
- Excessive moisture predisposes OE
  - Elevates can pH
  - Removes ear wax
  - Keratin debris absorbs moisture and creates medium for microbial growth
Otitis Externa

- Majority of OE is bacterial but OE can also be fungal
  - Staphylococcus aureus and Pseudomonas aeruginosa – common bacteria
  - Candida and aspergillus – common fungi
- Presenting symptoms: pruritis to severe pain; ear drainage; conductive hearing loss
  - Can require narcotics to control the pain
- Treatment
  - Aural debridement +/- ear wick
  - Ototopical antibiotic/antifungal drops
  - Systemic antibiotics for immunocompromised patients
  - Do not irrigate the ear canal if the status of the ear drum is unknown

Keratosis Obturans

- Disruption of normal epithelial migration in the ear canal
- Results in a cast of skin debris and wax
- Can cause remodeling/erosion of underlying bone
- Results in aural fullness, conductive hearing loss, and can otitis externa

Otitis Externa - Treatment

- Frequent aural debridement
- STRICT dry ear precautions
- Treat underlying infections
  - Ototopical antibiotic/antifungal drops
- Treat underlying skin conditions
  - Eczema
  - Atopic dermatitis
  - Seborrheic dermatitis
  - Psoriasis
Acquired Ear Canal Stenosis
- Formation of a fibrous plug in the ear canal with recurrent ear drainage and progressive conductive hearing loss
- Etiology unknown
  - Dermatologic condition
  - Fungal infection
  - Abnormal wound healing response
- Treatment options
  - Non-intervention
  - Conventional hearing aids
  - Bone anchored hearing aids
  - Surgical excision of scar with canal reconstruction

Congenital Ear Canal Atresia
- Failure in development of the external auditory canal
- Spectrum of severity
  - Complete
  - Stenosis (narrow canal)
- Epidemiology
  - 1:10,000-20,000
  - 3-6:1 Unilateral
  - R > L
  - M > F
- Etiology unknown
- Adjacent regions may be affected
  - Syndromes: Goldenhar, Treacher-Collins, Hemifacial microsomia

Tympanoplasty with canalplasty and split thickness skin grafting

Congenital Atresia Surgery
### Congenital Atresia Surgery: Pearls

- Stay anterior (near TMJ) and superior (near tegmen/ middle fossa dura) when drilling open the ear canal
- Avoid entering mastoid air cells
- Careful dissection of atretic plate (without drill) after indentifying incus
- Avoid prosthetics if possible
- Fashion 1.5 cm diameter canal
- Silastic button to prevent lateralization of ear drum reconstruction
- Center meatus by mobilizing the auricle as needed

### Atresia Surgery: Complications

- Re-stenosis – 4-12%
- Infection
- Facial nerve injury
- Hearing loss – 12-28%
  - Scar, lateralization, OCR, OM

### Atresia Surgery: Outcomes

- Goal - restore hearing to an SRT (speech reception threshold) of 15-25 dB.
- Approximately 50% of patients have an SRT less than 25 dB after surgery.
- 1/3 of patients require revision surgery for hearing loss
  - Approximately 50% obtain an SRT of ≤ 25 dB
  - Approximately 66% obtain an SRT of ≤ 30 dB

### Tympanic Membrane and/or Middle Ear Pathology
The Middle Ear Impedance Matching System

• The impedance of fluid in the cochlea is 30 times that of air
• If sound were applied directly to the oval window (at the stapes footplate), about 97% would be reflected.
• The lever formed by the malleus and incus has a pivot point farther from the tympanic membrane than from the stapes at a ratio of 1.3:1.
• The area of the pars tensa is 0.55 cm², whereas that of the oval window is only 0.032 cm².
• The area difference (16x) and the lever arm (1.3), create a 21-fold (about 13 dB) increase in pressure from tympanic membrane to the oval window membrane (under the stapes footplate).
• With an ear drum and intact ossicular chain, 60% of the signal is transmitted as compared to 3% transmission without a tympanic membrane and ossicles.

Chronic Granular Myringitis

• Inflammation with mucosalization of the ear drum surface
  ➢ Can have progressive involvement of the ear canal
  ➢ Leads to chronic canal wetness and pruritis
• Progressive tympanic membrane thickening impedes vibration
  ➢ Leads to conductive hearing loss
• Treatment: similar to otitis externa; may require surgical excision

Tympanosclerosis

• Hyalinization of the middle layer of the ear drum and/or the middle ear mucosa
  ✔ Analogous to scarring
• Common in patients with recurrent otitis media and patients with history of tubes
• Stiffens the tympanic membrane, impairing vibration
  ✔ Can result in mild conductive hearing loss
• Easily distinguished from cholesteatoma when examiner has 3-D view using a binocular otologic microscope
• No treatment required

Tympanic Membrane Perforation

• Variable degrees of conductive hearing loss
  ✔ Typically 20-30 dB
• Large perforation or anterior/marginal perforations are more difficult to repair
• Treatment: Tympanoplasty
Tympanic Membrane Repair

- Paper patch myringoplasty
- Fat myringoplasty
- Underlay tympanoplasty (medial graft technique)

Eustachian Tube Dysfunction (ETD)

- ETD is central to the development of middle ear pathology
  - Lack of middle ear ventilation
- Specific diseases caused by ETD
  - Acute otitis media
  - Recurrent acute otitis media (ROM)
  - Otitis media with effusion
  - Middle ear atelectasis
  - Chronic suppurative otitis media with and without cholesteatoma
    - Ossicular erosion or discontinuity

Underlay Tympanoplasty

Acute Otitis Media (AOM)

- Between 1993 and 1995, OM was the most common diagnosis at physician visits in the US (>10,000,000 visits for 1-4 yr olds)
- The diagnosis of AOM requires
  - History of acute onset signs and symptoms
  - Presence of middle ear effusion (MEE)
  - Signs and symptoms of middle ear inflammation
- The presence of MEE is indicated by
  - A bulging tympanic membrane
  - Limited or absent tympanic membrane mobility
  - Air-fluid level behind the TM
  - Otorrhea (drainage from the ear)
- Signs of middle ear inflammation include:
  - Erythema of the tympanic membrane
  - Otalgia (ear pain)
Recurrent Acute Otitis Media

- Multiple bouts of acute otitis media with complete resolution between episodes

Otitis Media with Effusion (OME)

- Middle ear filled with serous or mucoid fluid
- No purulence
- Often present after acute otitis media is treated appropriately with antibiotics
- Most middle ear effusions will clear within 3 months

Etiology of Acute & Recurrent Acute Otitis Media

- S. pneumoniae 25-50%
- H. influenzae 20-25%
- M. catarrhalis 10-20%
- S. pyogenes (gr. A) 2-5%
- S. aureus 1%
- Other 6%
- No growth up to 35%

Etiology of OME

- 50% sterile to culture
  - Molecular techniques find bacterial products
- When culture +, similar to AOM
**Risk Factors for Otitis Media**

- **Host**
  - Race or ethnic group
  - Age, age at onset
  - Family history, genes
  - Male gender
  - Lower socioeconomic status
  - Low antibody levels
  - Low birth weight or prematurity
  - Anatomical (Eustachian tube, cleft palate, Down syndrome)
  - Male ≠ female rates for OM, OME

- **Environment**
  - Day care, exposure to children
  - Formula feeding, supine feeding
  - Exposure to smokers
  - Supine sleeping
  - Pacifier use
  - Season, season of birth
  - Nutrition

**Antibiotic Treatment: Consensus Recommendations**

- **1st line**: amoxicillin at 80-90 mg/kg/day (given BID)
- **2nd line**: high dose amoxicillin/clav (90 mg/kg)
- **3rd line**: ceftriaxone
- Encourage tympanocentesis
- Prevnar (PCV7) for all children < 2 and older children at risk

**Tympanostomy Tubes**

- 4 episodes of AOM in 6 months or 6-7 episodes in 1 year
- In the US, chronic OME > 3 mos with hearing loss and/or speech delay is an indication for tympanostomy tube placement
- Suppurative complications of otitis media
- Special populations at increased risk for speech/language delay
- Consider adenoidectomy at 2nd set of tubes, not primary treatment
  - Except with concurrent nasal disease

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**Medical Management of Acute Otitis Media**

**TABLE 4. Criteria for Initial Antibacterial Therapy or Observation in Children With Acute Otitis Media**

<table>
<thead>
<tr>
<th>Age</th>
<th>Certain Diagnosis</th>
<th>Excepted Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 3 mo</td>
<td>Antibacterial therapy</td>
<td>Antibacterial therapy</td>
</tr>
<tr>
<td>4 mo – 2 y</td>
<td>Antibacterial therapy</td>
<td>Antibacterial therapy or severe illness, observation option*</td>
</tr>
<tr>
<td>≥ 2 y</td>
<td>Antibacterial therapy or severe illness, observation option*</td>
<td>Observation option*</td>
</tr>
</tbody>
</table>

*The table was adapted from recommendations from the American Academy of Pediatrics. Instructions and the New York Academy of Ophthalmology. Observation is an appropriate option only when follow-up care is ensured and antibiotic agents are not if potential patients or women.

**Tympanostomy Tubes**

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- Consider adenoidectomy at 2nd set of tubes, not primary treatment
  - Except with concurrent nasal disease
Risk Factors for additional tube insertions

- Age under 18 months at initial surgery
  - 26% reinsertion rate vs. 16%; p<0.05
- Craniofacial deformity
- Family history of ENT surgery
- Concurrent adenoïdectomy at 2nd set of tubes reduced need for additional tubes by 3-fold (8% vs 42%), p<0.001

Boston M et al., Arch OTO-HNS. 2003

Middle Ear Atelectasis

- Results from eustachian tube dysfunction
- Negative pressure (vacuum) in the middle ear
- Tympanic membrane becomes flaccid and drapes onto underlying structures
  - Can be mis-diagnosed as a perforation when using handheld otoscope (with a one-eyed, 2-D view)
- Causes variable degrees of conductive hearing loss

- Patient is at risk for cholesteatoma due to skin accumulation within retraction pockets
- Drum contact with the incus and/or stapes results in progressive incudostapedial (IS) joint erosion
- TM is flaccid and non-vibratory – causes variable degrees of conductive hearing loss
- Treatment
  - Early ME atelectasis may be treatable with tympanostomy tubes
  - Severe atelectasis requires removal of the flaccid ear drum and replacement using cartilage (cartilage tympanoplasty)
  - This adds rigidity to the drum but at the expense of vibratory capacity (as compared with a normal ear drum)
### Cartilage Tympanoplasty

- Skin incision on the medial side of tragus - leaving 2 mm of tragal cartilage lateral to cartilage incision
- Can get > 1 cm of flat cartilage
- Can be thinned as needed with a KURZ cartilage-cutting knife
- Can be harvested with or without perichondrium
- Cartilage pallisade technique – precise placement of cartilage to prevent atelectasis and ear drum retraction

### Cholesteatoma

- **Term** “cholesteatoma” coined by Johannes Muller in 1838
- ✓ Misnomer because the cysts don’t contain cholesterol
- **Cholesteatomas** are epidermal inclusion cysts of the ear canal, middle ear and/or mastoid with a squamous epithelial lining
  ✓ Contain keratin and desquamated epithelium
- **Natural history** is progressive growth with erosion of surrounding bone due to pressure effects, enzymatic activity, and osteoclast activation

### Cholesteatoma

- **Annual incidence** is unknown
  ✓ In 1978, there were 4.2 hospital discharges per 100,000 with cholesteatoma
  ✓ Harker and coworkers estimated the incidence at 6/100,000
  ✓ Tos and colleagues found 3/100,000 in children and 12.6 per 100,000 in adults
### Congenital Cholesteatoma

- Rare
- Likely due to epithelial remnants trapped within the temporal bone during fetal development
  - [Michaels L: An epidermoid formation in the developing middle ear: possible source of cholesteatoma, Otolaryngol 15:169, 1986](#)
- Diagnosed as a pearly white mass behind an intact tympanic membrane in a child who does not have a history of chronic ear disease
- Often occur in the anterior superior quadrant of the middle ear near the Eustachian tube orifice

### Acquired Cholesteatoma - Pathogenesis

- Skin cysts originating from the tympanic membrane
- Mechanism (theories):
  - Invagination
  - Basal cell hyperplasia
  - Migration (through a perforation)
  - Squamous metaplasia

### Primary Acquired Cholesteatoma

- Secondary to ETD (vacuum in the middle ear)
- Retraction pocket develops within the pars flaccida or the posterior superior tympanic membrane
- Skin debris collects within the retraction pocket, resulting in the formation of a keratin cyst (cholesteatoma)

### Secondary Acquired Cholesteatoma

- Originates from a tympanic membrane perforation
- As the edges of the TM try to heal, the squamous epithelium migrates into the middle ear
**Treatment of Cholesteatoma**

- Control infection with Ototopical antibiotics +/- oral antibiotics
- Surgical repair of the tympanic membrane
- Repair of the ossicular chain if necessary
- Often requires a mastoidectomy

**Mastoidectomy**

- Intact (bony ear) canal wall mastoidectomy
- Canal wall down mastoidectomy
  - Radical Mastoidectomy
  - Modified Radical Mastoidectomy

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**Intact-Canal-Wall Mastoidectomy**

- Ototopical antibiotics +/- oral antibiotics to control infection
- Tympanoplasty +/- mastoidectomy
  - Surgical repair of the TM perforation
  - Repair of the ossicular chain if necessary
  - Often requires a mastoidectomy

- Tympanoplasty with mastoidectomy and hydroxyapatite bone cement ossicular reconstruction
Canal-Wall-Down Mastoidectomy

Ossicular Chain Reconstruction

- PORP: partial ossicular reconstruction prosthesis
- TORP: total ossicular reconstruction prosthesis

Otosclerosis

- Unique bone disease affecting the human temporal bone
- Characterized by foci of bone resorption and foci of bone deposition
- Decreased mobility of stapes footplate causes conductive hearing loss
- Incidence
  - Autopsy studies: 10% of Caucasians
  - Symptomatic otosclerosis: 0.5-1% of Caucasians
  - Less common in Blacks and Asians
  - Genetic component: 60% of patients have an identifiable family member with otosclerosis
Otosclerosis - Diagnosis

- Physical exam: normal tympanic membrane with dry middle ear
- Audiogram: conductive hearing loss
- Tympanogram: normal middle ear pressure but shallow configuration

Otosclerosis – Stapedectomy/Stapedotomy

- > 90% success in eliminating otosclerosis-related conductive hearing loss
- 0.5-1% chance of profound hearing loss from surgery

Conventional Amplification with Hearing Aids
### Hearing Aid Basics

- **Analog Hearing Aids**
  - Basic analog circuitry
  - Single-band amplification with possible high-low pass filtering
  - Limited audiological manipulation
  - User-operated volume control
  - Most beneficial when used in quiet listening environments
- **Digital Hearing Aids**
  - Fully digital circuitry and sound processing
  - Programmed via computer
  - Multiple frequency bands for discreet frequency manipulation
  - Multiple memory capabilities
  - Advanced digital - speech vs. noise algorithm
- **Higher-end analog hearing aids can be "programmable"**

### Open Fit Hearing Aids

- Primarily used for mid and high frequency amplification
- Appropriate for hearing that is normal/mild hearing loss in the low frequencies.
- Inappropriate if much gain is needed at 250-500Hz
- Designed to eliminate the occlusion effect

### Styles of Hearing Aids

- Primarily used for mid and high frequency amplification
- Appropriate for hearing that is normal/mild hearing loss in the low frequencies.
- Inappropriate if much gain is needed at 250-500Hz
- Designed to eliminate the occlusion effect

### CROS and BiCROS SYSTEMS

- Used in patients with single sided deafness or poor word recognition ability in one ear
- CROS (contralateral routing of signal) systems have a microphone/FM transmitter worn on the non-hearing side and a receiver worn on the hearing side
  - Used when hearing in the better ear is normal and does not require amplification
  - Everything is heard in one ear
- The BiCROS system has a microphone/FM transmitter worn on the non-hearing side and a hearing aid on the better hearing side that also acts as an FM receiver
The BAHA® System

- Conductive/Mixed HL
  - > 5 years of age
  - < 45 dB HL BC PTA
  - ≥ 60% speech discrimination scores
  - For bilateral fitting - Symmetric bone conduction thresholds
- Single Sided Deafness
  - > 5 years of age
  - Normal hearing in contralateral ear defined as 4-frequency AC PTA ≥ 20 dB
  - Functions by trans-cranial routing of the signal

BAHA® The Bone Anchored Hearing Aid

- > 800,000 potential Baha candidates in the United States
  - Adults and Children >5 years of age
  - Mixed/Conductive Hearing Loss
  - Single Sided Deafness (SSD)
- Each year it is estimated that between 25,000 and 30,000 new patients develop hearing loss that are treatable with the Baha system
- We have treated less than 1% of the patients who could benefit

BAHA® Indications

Concluding Thoughts

- Conductive hearing loss results from impaired transmission of sound through the ear canal, tympanic membrane, and middle ear
- Divergent causes
- Medical/surgical options for treatment
- Numerous modalities for aural rehabilitation
- New technologies on the horizon
- Ask your patients about their hearing during your review of systems!!!