

Everything you wanted know
about the temporal bone and
might notice on CT cspine but
didn't learn in residency and
were afraid to ask

Stephen Haltom

4/15/2011

Outline

External Auditory Canal (EAC)

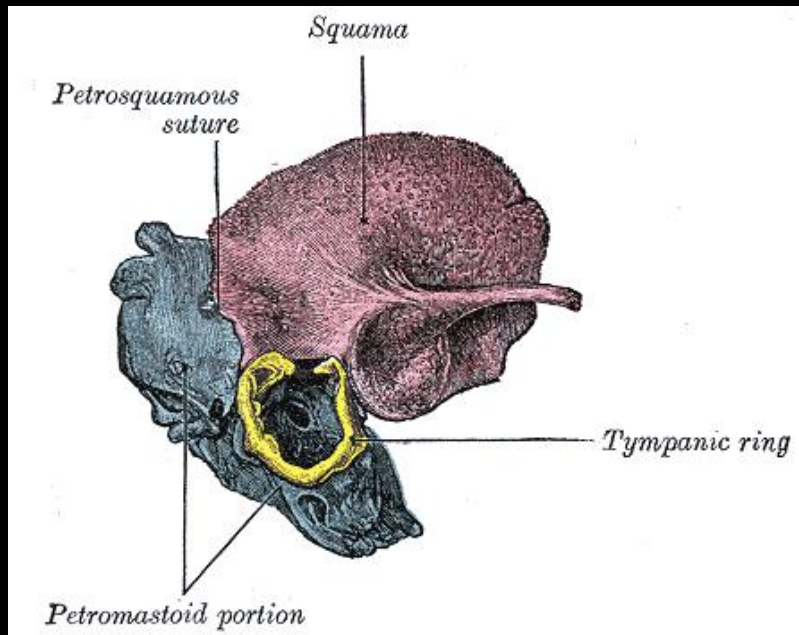
Middle Ear

Inner Ear

- Normal anatomy
- Congenital anomalies
- Inflammatory lesions
- Benign neoplasms
- Malignant lesions
- Trauma



Temporal bone gross anatomy



Formed from eight ossification centers (not including ossicles and inner ear)

At end of fetal life consists of three principle parts

- Squamosal
- Petromastoid
- Tympanic ring

The External Auditory Canal

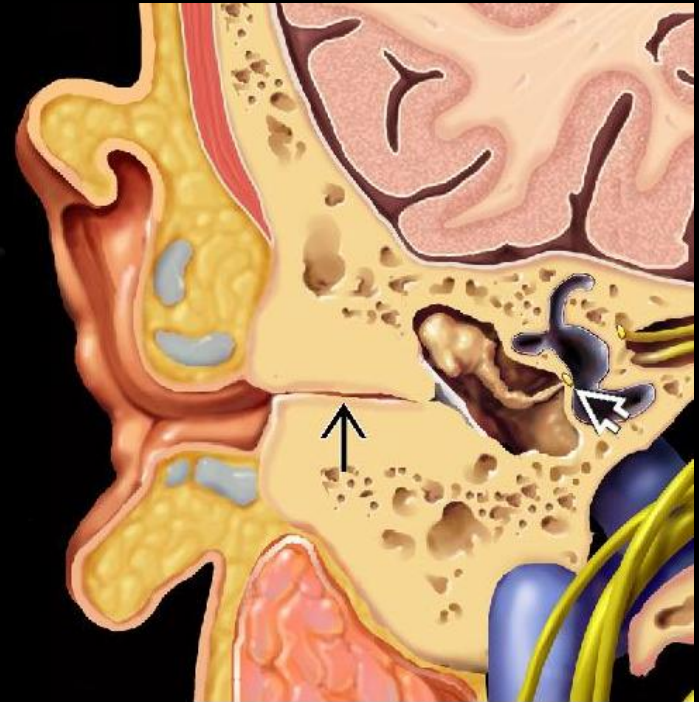
EAC: Congenital Anomalies

Atresia - Bony and/or soft tissue stenosis

- Small dysmorphic pinna
- Narrowed, stenosed, or completely atretic EAC (membranous and bony portions)

Middle ear malformations correlate with severity of pinna deformity

- Small middle ear
- Fusion and rotation of incus and malleolus
- Oval window atresia
- Aberrant course of CN VII common



microtia



Wikipedia

EAC: Congenital Anomalies

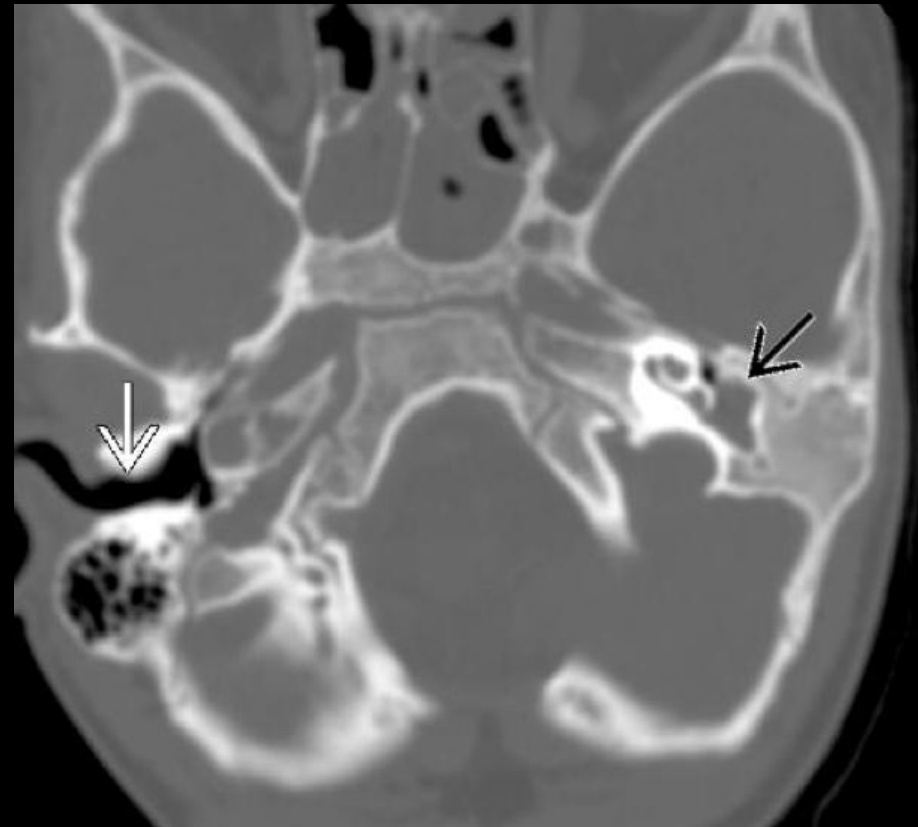
EAC Atresia: Middle ear malformations

Small middle ear

- Reduced pneumatization of mastoid air cells
- small middle ear cavity

1960's: Thalidomide embryopathy -
1 in 900

Today: Congenital Rubella and
inherited syndromes - 1 in
10000



EAC: Congenital Anomalies

EAC Atresia: Middle ear malformations

Ossicle malformation, rotation, fusion, or absence

- Underpneumatized MACs
- Small fused incus and malleus



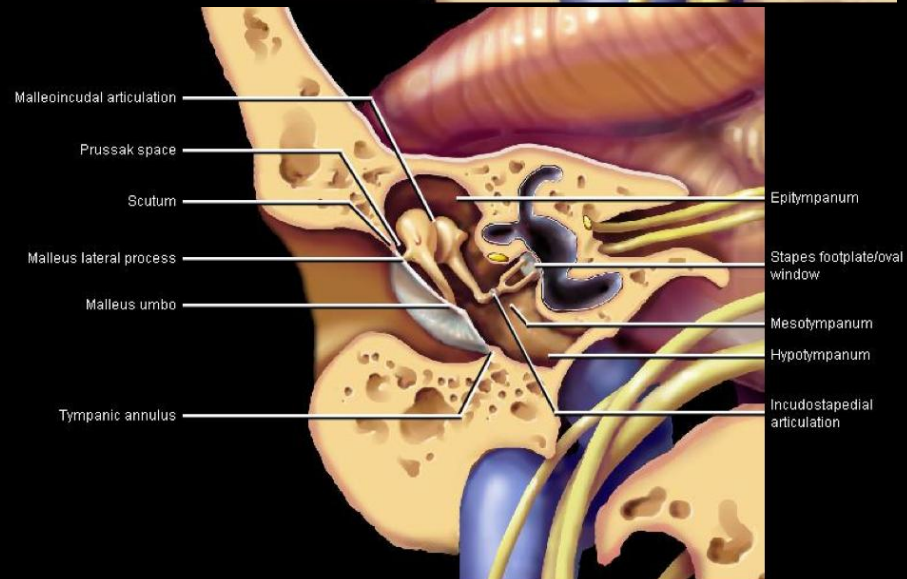
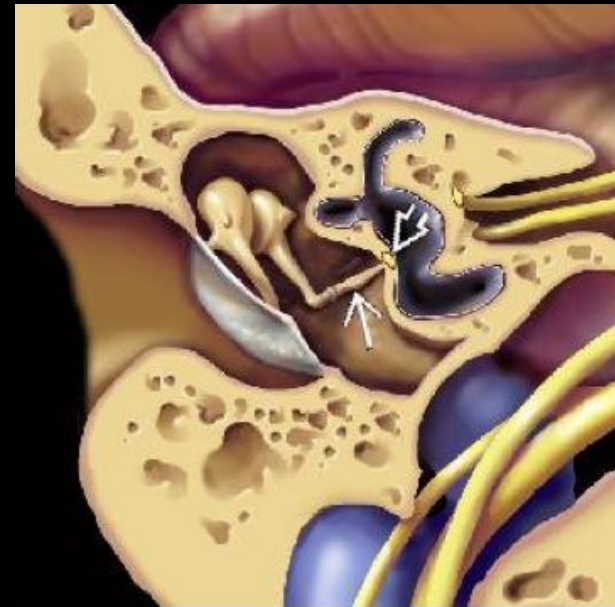
normal

EAC: Congenital Anomalies

EAC Atresia: Middle ear malformations

Oval window atresia

- Oval window replaced by ossified web
- Stapes malformed (arrow)
- Abnormal inferomedial position of CN VII in front of oval window (open arrow)



EAC: Congenital Anomalies

EAC Atresia: abnormal course of CN VII

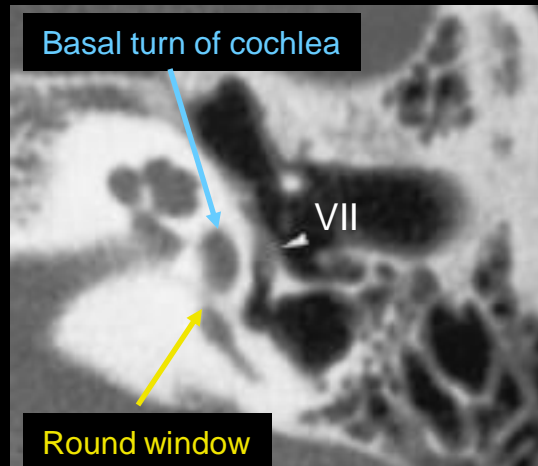
Tympanic portion

- Dehiscent. Crossing over too low, overlying oval or round windows
- ♠ **Important for surgeon to know before repairing EAC and middle ear ossicles.**

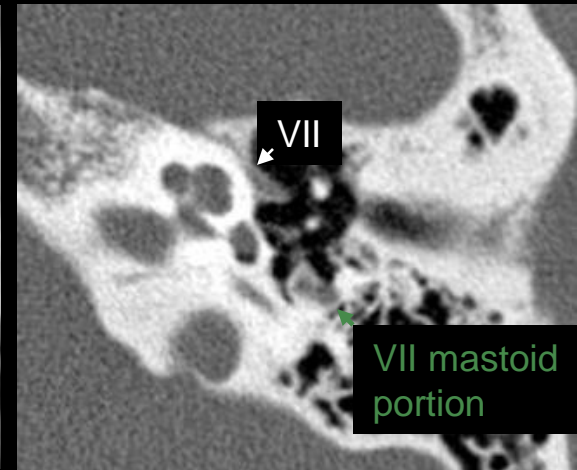
Mastoid portion

- Anteriorly displaced
- May exit into glenoid fossa

abnormal



normal



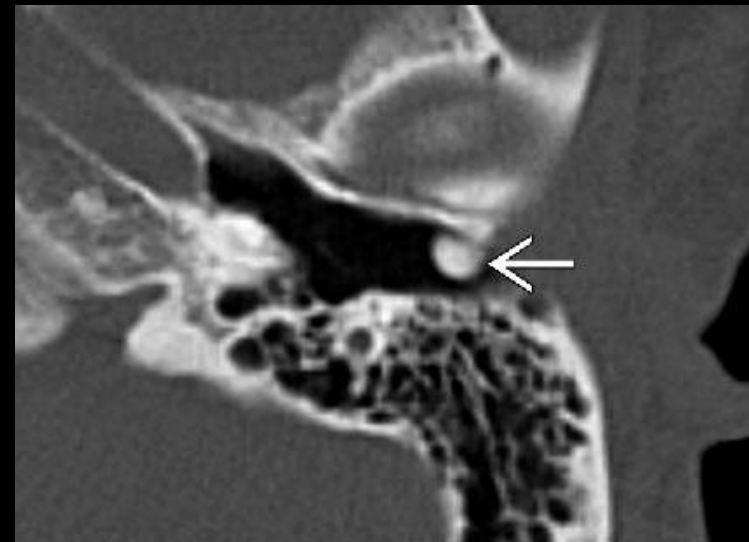
EAC: Congenital Anomalies

EAC Atresia

DDx

- Acquired exostosis (surfer's ear)
 - Cold water exposure - bilateral
 - Benign broad base overgrowth

- Osteoma
 - 20% of cases are surfers
 - Benign, focal, pedunculated. At osteocartilage jcn of EAC



EAC: Congenital Anomalies

First Branchial Cleft Cyst

- 1st BC has ventral and dorsal components.
- Failure of regression of ventral component results in cyst
- **Fistula with EAC at osteocartilagene junction**
 - Type I: near pinna
 - Type II: behind/below mandible

Type I



Khanna, 2006

EAC: Inflammatory Lesions

Malignant otitis externa

Keratitis obturans

- Painful keratin plugs bilaterally in middle aged adult

Surfer's/swimmer's ear

- Acute otitis externa
- Usually pseudomonas infection

EAC: Inflammatory Lesions

Malignant otitis externa

- Pseudomonas infection
 - HIV and diabetic patients
- Clinical symptoms
 - Otagia
 - Temporal headache
 - Cranial neuropathies
- Early findings
 - Bony erosion of EAC floor and skull base

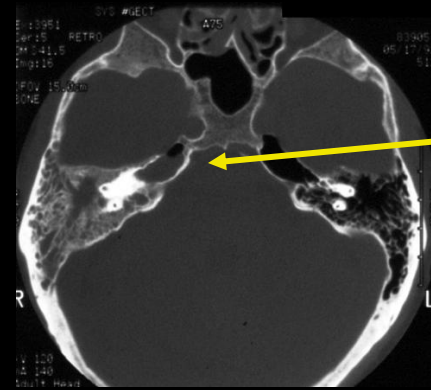
♠ Don't miss sigmoid or cavernous sinus thrombosis. TBD later.

EAC: Inflammatory Lesions

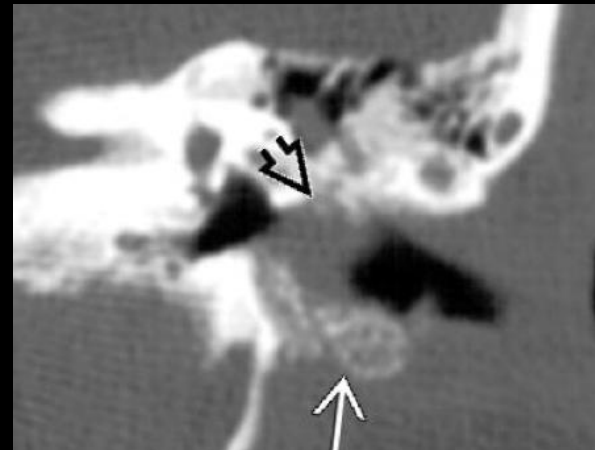
Malignant otitis externa

Begins at junction of cartilaginous and bony EAC

- Vertically oriented fissures in cartilage allow inferior route of infectious spread
- Aggressive spread to:
 - Parotid, masticator, parapharyngeal spaces
 - MACs
 - Middle ear and petrous apex
 - Temporomandibular joint



Air fluid level in right Petrous apex, MAC fluid



Erosion of roof and floor of EAC

Extension into TMJ with anterior Displacement of mandibular condyle



EAC: Inflammatory Lesions

Ossification/Calcification of EAC

Tissue injury

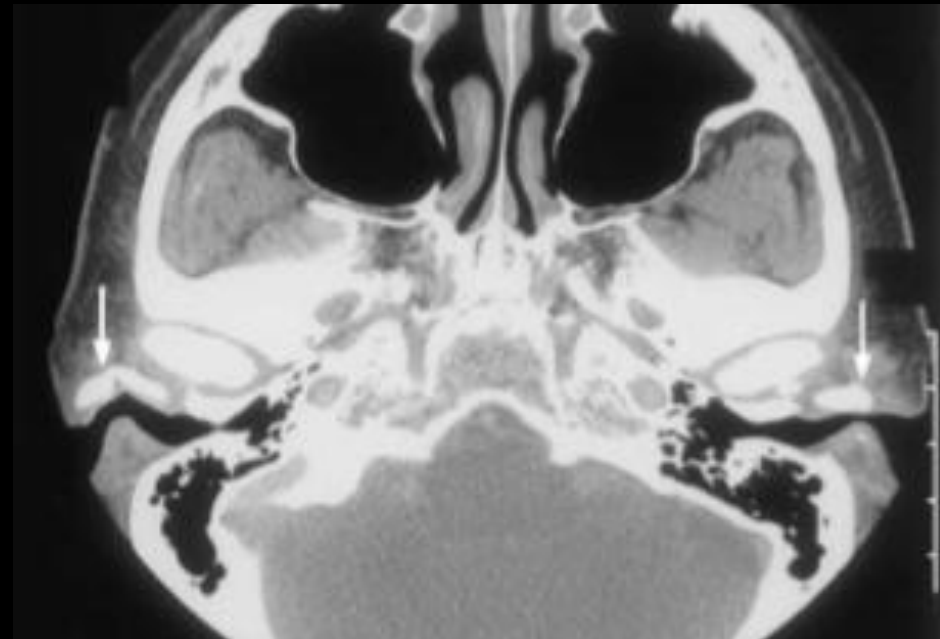
- Frostbite
- Mechanical trauma
- Radiation
- Polychondritis

Metabolic/endocrine

- Hypercalcemia
- Sarcoid
- Hyperparathyroidism
- Milk alkali syndrome
- Vit D intoxication
- Diabetes
- Ochronosis
- Gout
- Adrenal insufficiency

Other

- Syndrome related
- Senile
- idiopathic



EAC: Benign Neoplasms/Masses

Many

Expand EAC without destruction

EAC cholesteatoma - TBD later

Hemangioma

Ceruminoma

Medial canal fibrosis - post surgical/post infectious

Polyp/papilloma

Nevi

Wax ball

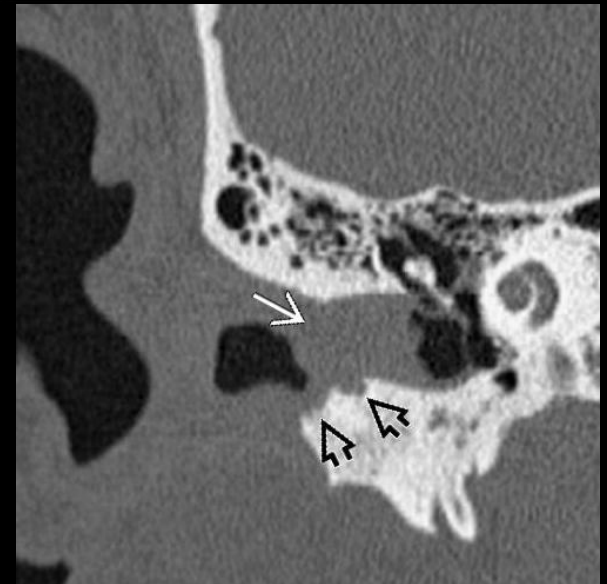
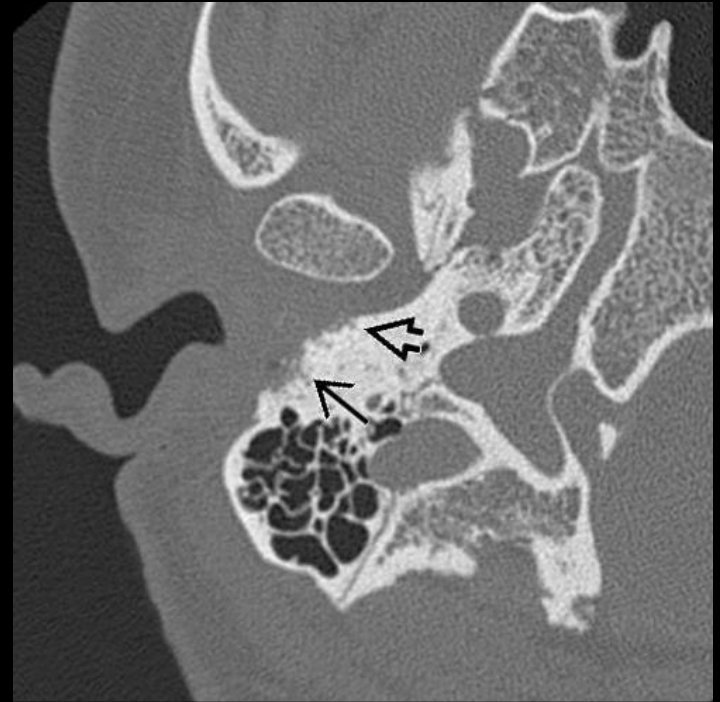
EAC: Malignant Lesions

Squamous Cell Carcinoma

- By far the most common neoplasm.
- Secondary involvement of the EAC by a superficial SCCa is more common than Primary SCCa.
- ♠ Involvement of middle ear and/or TMJ is rare and associated with poor prognosis

Findings

- Unilateral EAC mass with underlying bone erosion



EAC: Malignant Lesions

SCCa DDX:

EAC cholesteatoma, Malignant otitis externa

- Both cause bone erosion and should be considered SCCa until proven otherwise.

Medial canal fibrosis

Post surgical or infectious fibrosis

Often bilateral

No bone destruction

Keratosis obturans

Bilateral

No bone destruction

EAC: Cholesteatoma

- exfoliated keratin within stratified squamous epithelium

Findings

- Focal unilateral mass in EAC
- **Scalloping of bony EAC, most commonly in posterior, inferior aspect**
- Matrix with bony flecks
- Progressive enlargement
- Can demonstrate +CE of rim

Etiology

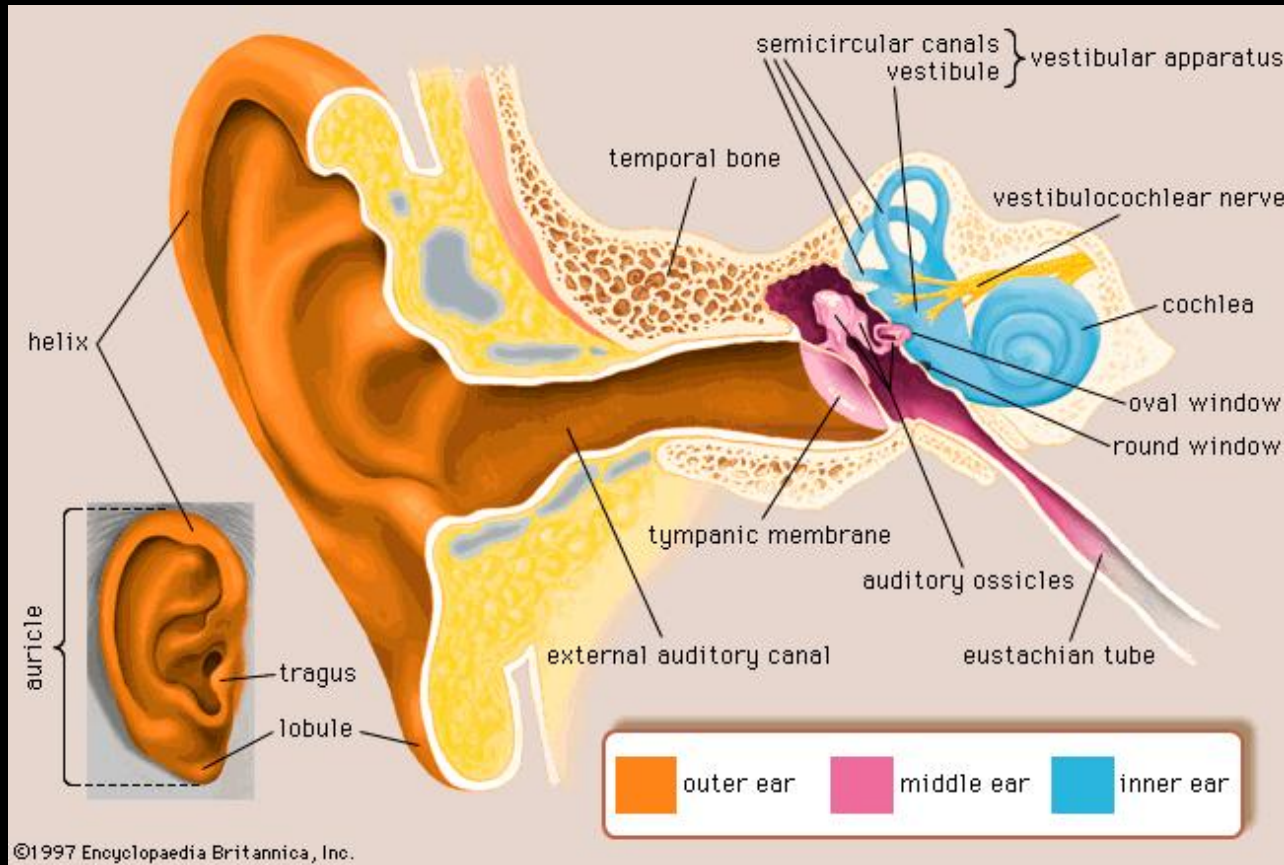
- Congenital - ectodermal rest, rare
- Spontaneous - abnormal migration of ectoderm
- Acquired - postsurgical, post-traumatic





The Middle Ear

Middle Ear: Normal Anatomy



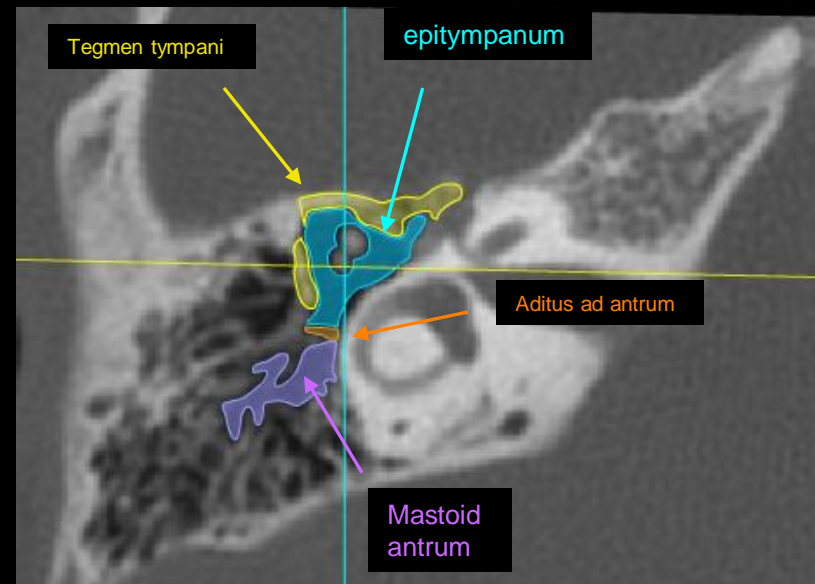
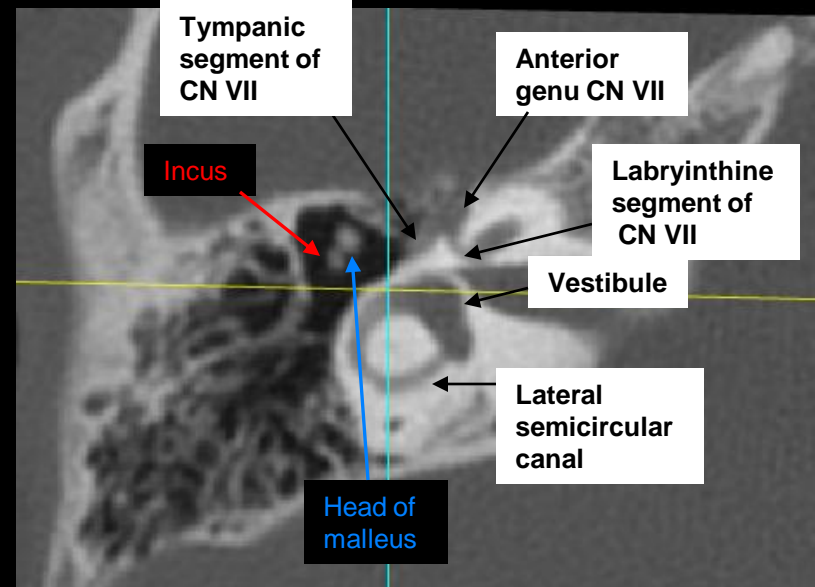
Middle Ear: Anatomy

Overview

- Space containing ossicles and air
- Bounded laterally by the tympanic membrane, medially by inner ear structures
- Connected to other spaces
 - Mastoid air cells
 - Nasopharynx - via eustacian tube

Spaces

- Epitympanum (attic)
 - Roof - tegmen tympani
 - Floor - line between scutum and tympanic portion of facial nerve
 - Lateral - Prussak space
 - Posterior - **Aditus ad antrum** leads to mastoid antrum



Middle Ear: Anatomy

Spaces contin.

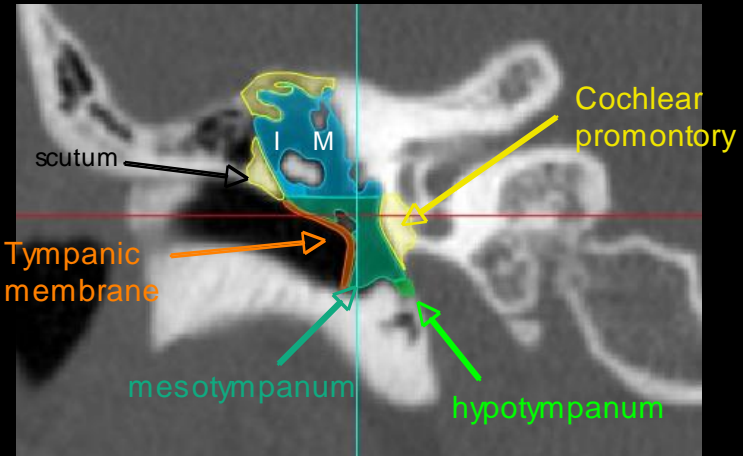
- **Mesotympanum**
 - Roof - epitympanum
 - Floor - line between inferior edge of tympanic membrane and cochlear promontory
 - Anterior - Eustacian tube
 - Posterior - 3 key structures

- Facial nerve recess
- Pyramidal eminence
- Sinus tympani

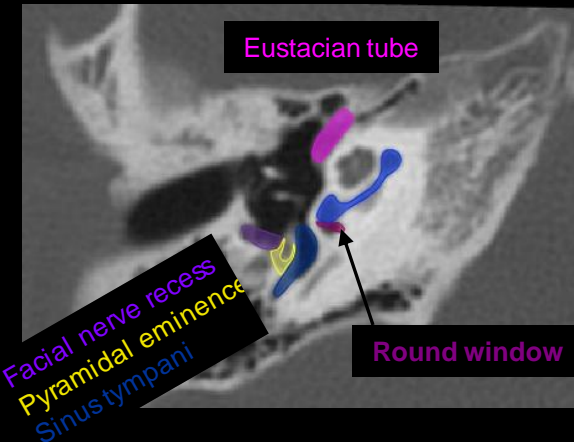
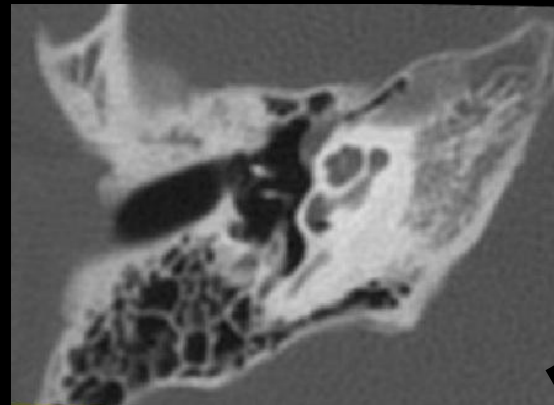
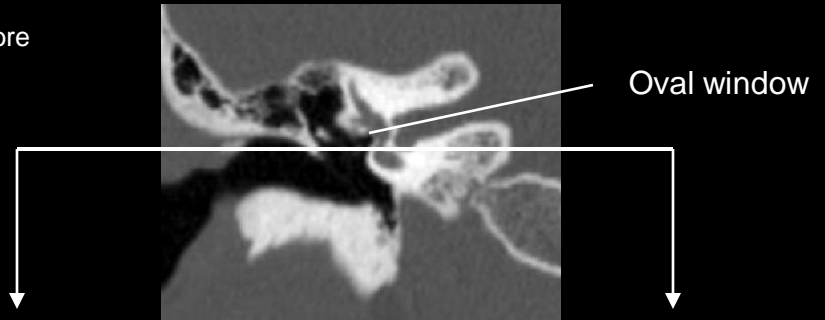
Medial

- Lateral semicircular canal
- Oval and round windows
- Tympanic segment CN VII

- **Hypotympanum**
 - Shallow space in floor of middle ear cavity



Slightly more posterior



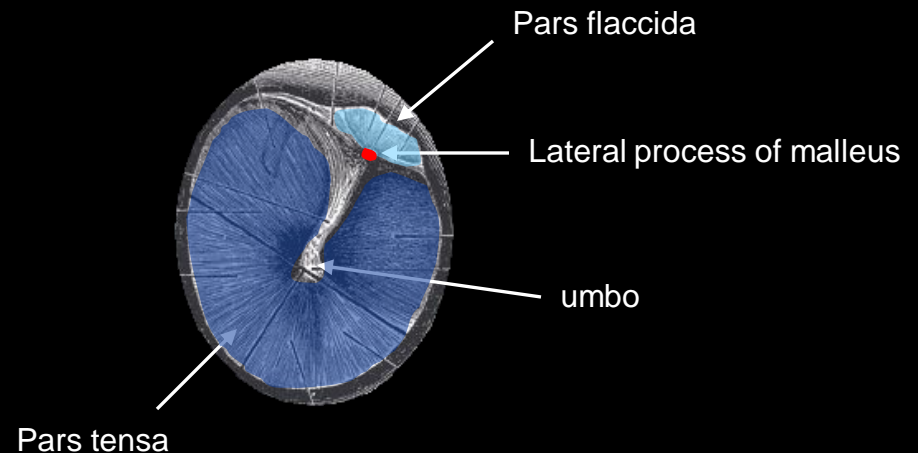
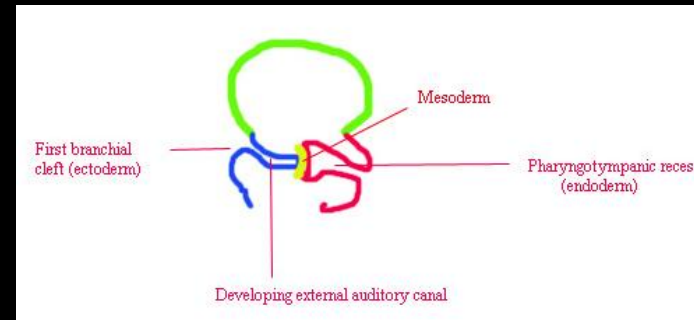
Middle Ear: Anatomy

Conductive chain

Tympanic membrane, ossicles, oval window

Tympanic membrane

- Pars flaccida - upper 1/3
 - Two layers
- Pars tensa - lower 2/3
 - Three layers: ectoderm, mesoderm, and endoderm.
 - More rigid than pars flaccida
 - Conducts vibrations to ossicles



Middle Ear: Anatomy

Conductive chain

Ossicles

Malleus (hammer)

attached to TM at umbo and lateral process

Incus (anvil)

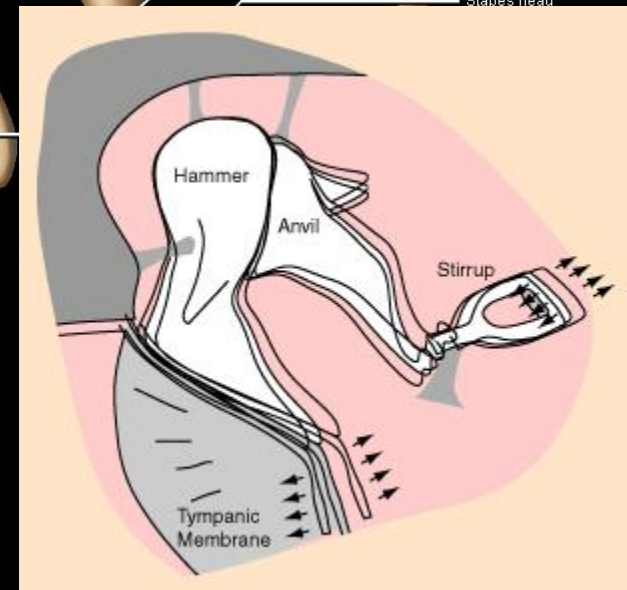
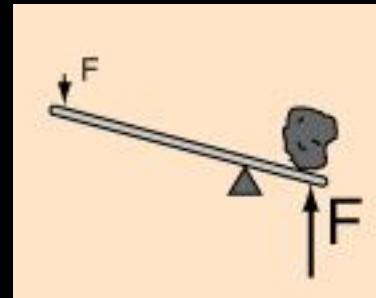
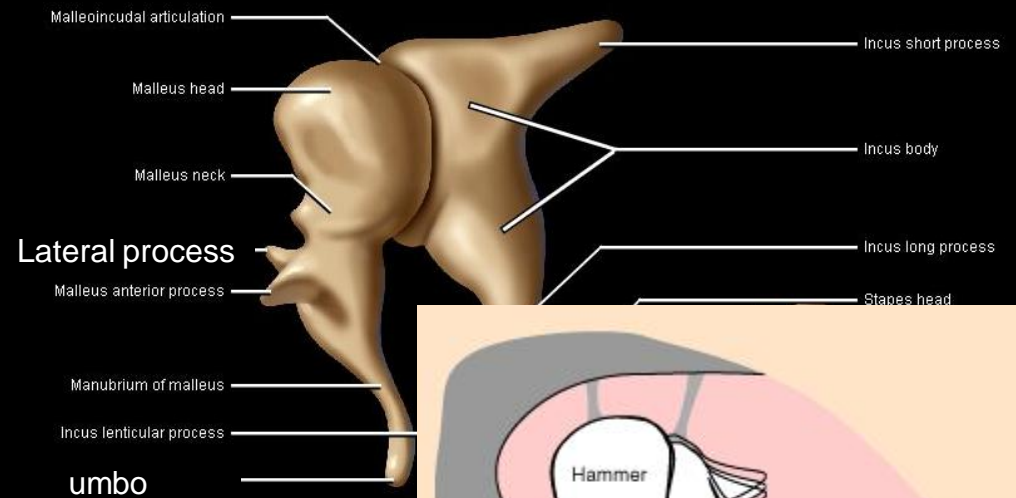
Stapes (stirrup)

Amplify sound pressure by two mechanisms

1. catenary lever - sound energy transmitted to center of TM
2. Force funneling (hydraulic lever)
3. ossicular lever

pressure at oval window is increased by ratio of $(TMsa/OWsa)$ and lever ratio of malleus/incus.

$$P_{ov} = 17 * 1.3 P_{tm} = 22 P_{tm}$$



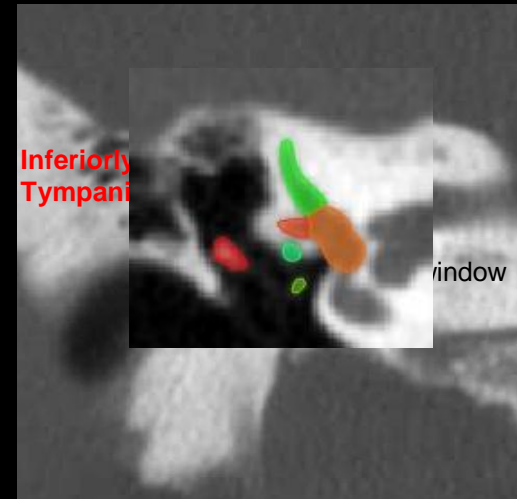
Middle Ear: congenital anomalies

Previously discussed

Ossicular fusion, hypoplasia, maldevelopment

- Most commonly occurring with EAC and external ear anomalies
- Coexisting abnormality of CN VII course in middle ear

Oval window atresia



Congenital Cholesteatoma, aka epidermoid

Usually pediatric population

Arise in variety of places in temporal bone.

Middle ear involvement

- Bone erosion occurs late in disease
- Anterosuperior middle ear, adjacent to eustachian tube & anterior tympanic ring, medial to ossicles

DDx (discussed later)

pars tensa acquired middle ear cholesteatoma

- Ossicles commonly eroded

Glomus tympanicum paraganglioma

- No bony erosion
- +CE on MRI

Scwannoma of tympanic portion of CN VII



Middle Ear: Inflammatory lesions

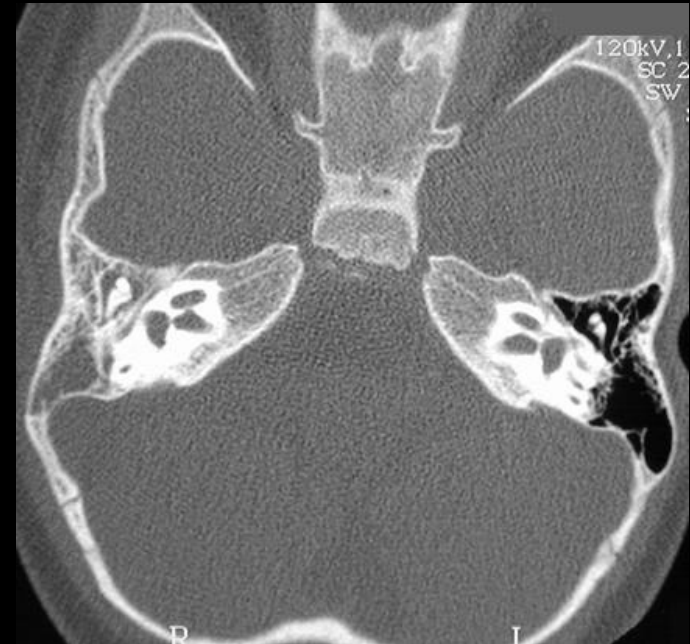
Otitis Media

Opacification of tympanic recess

Bacterial - strep, m.cattarhalis, H flu, pneumoc.

Eustacian tube obstruction by URI in kids

- Acute or Chronic Uncomplicated
 - A/F level in middle ear, +- mastoid air cells



- Coalescent otomastoiditis
- Coalescent otomastoiditis with abscess

Middle Ear: Inflammatory lesions

- Coalescent otomastoiditis
 - Destruction of mastoid trabeculae and cortex

Petrous apicitis

Classic triad - CN6 palsy, deep facial pain, ipsilateral otorrhea (**Gradenigo Syndrome**)



Erosion of lateral cortex and sigmoid plate (check for sigmoid sinus thrombosis)
Floating sequestrum.

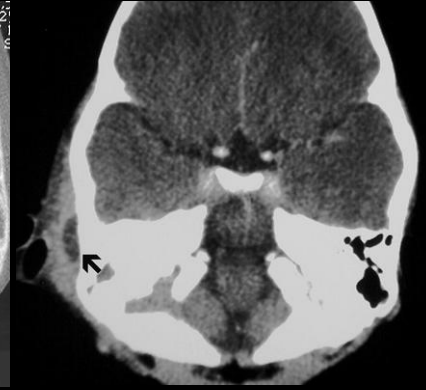
- Coalescent otomastoiditis with abscess



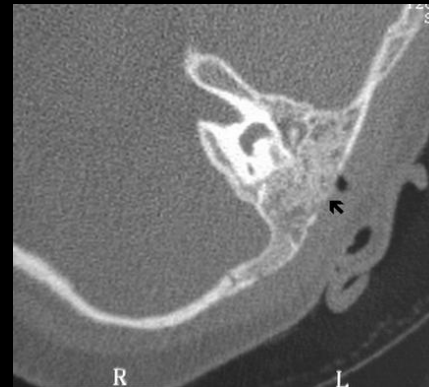
Opacification of middle ear and mastoid air cells. Erosion of right petrous apex

Middle Ear: Inflammatory lesions

- Coalescent otomastoiditis with abscess
 - Extratemporal (subperiosteal, epidural, subdural) abscess/empyema complicating coalescent otomastoiditis



Erosion of cortex with subperiosteal abscess on soft tissue windows



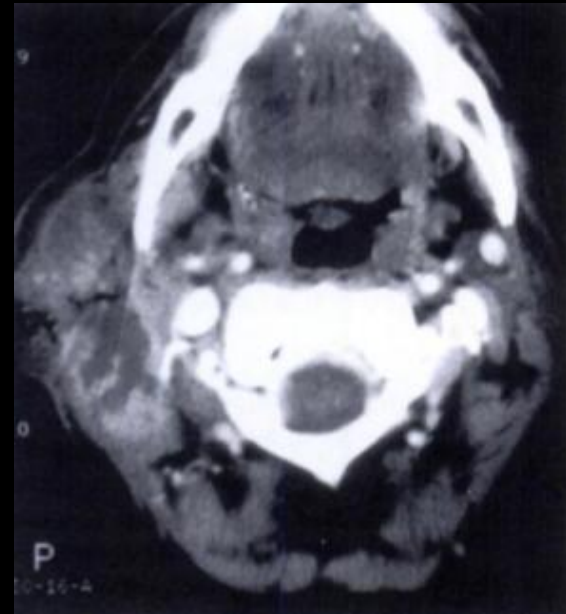
Erosion of cortex with epidural abscess on soft tissue windows

Middle Ear: Inflammatory lesions

- Coalescent otomastoiditis with abscess
 - Extratemporal (subperiosteal, epidural, subdural) abscess/empyema complicating coalescent otomastoiditis

Bezold Abscess

Cortical erosion at the mastoid tip resulting in abscess extending into the neck.



Middle Ear: Inflammatory lesions

Acquired Cholesteatomas

- “Erosive collections of keratinous debris from ingrowth of stratified squamous epithelium through a perforated tympanic membrane.”
- Patients with chronic otomastoiditis

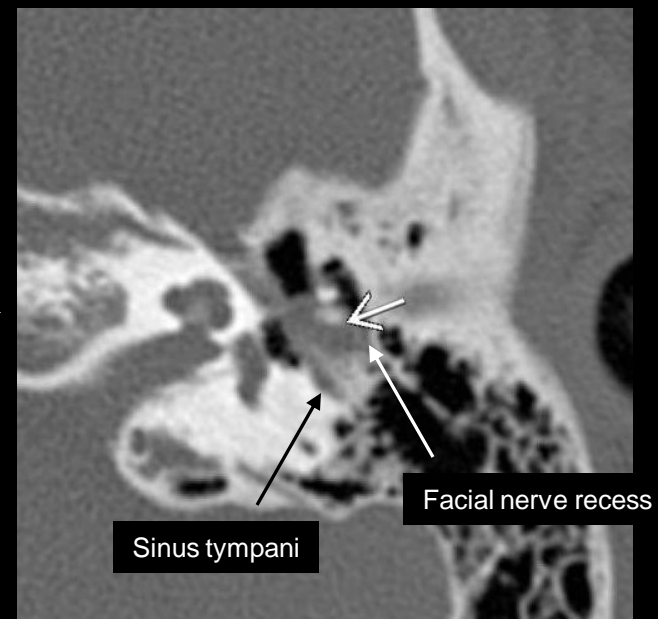
80% - pars flaccida type “attic cholesteatoma”

Most common middle ear mass lesion

- Prussak space mass
- Erosion of scutum
- Ossicle erosion (lateral to medial) in 70%

20% - pars tensa type “sinus cholestatoma”

- soft tissue mass that involves sinus tympani & facial nerve recess of posterior mesotympanum
- Ossicle erosion from medial to lateral



Middle Ear: Benign lesions

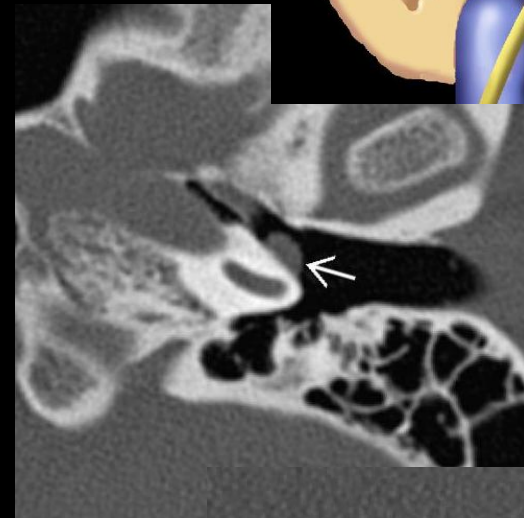
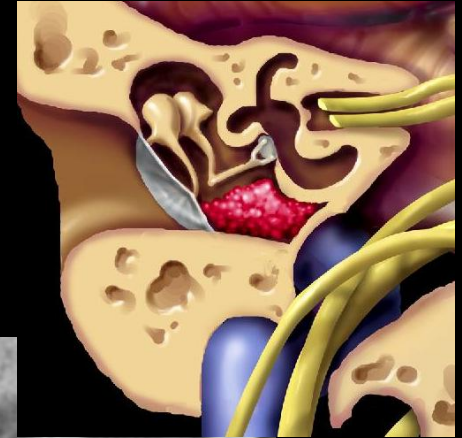
Glomus Tympanicum paraganglioma

- Arises from glomus bodies at cochlear promontory
 - Margin abutting cochlear promontory is flat

Engulfs, not erodes ossicles

DDx

aberrant course of carotid artery, pars
tensa cholesteatoma, epidermoid



Aberrant internal carotid artery

Glomus Jugulare paraganglioma

Dehiscent jugular bulb

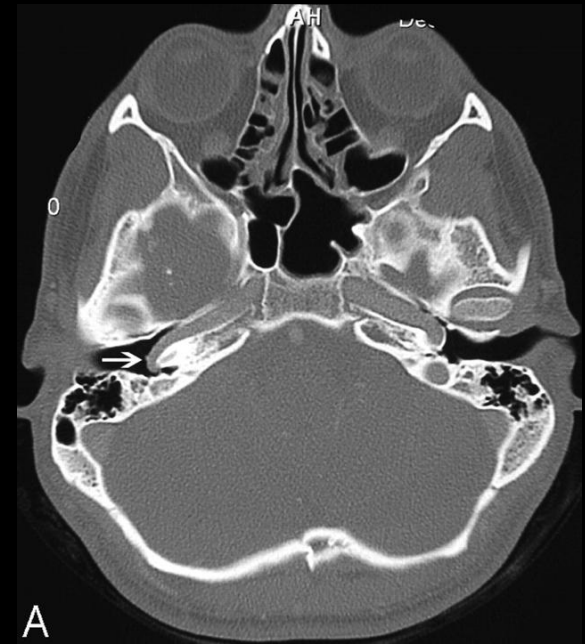


Middle Ear: Benign lesions

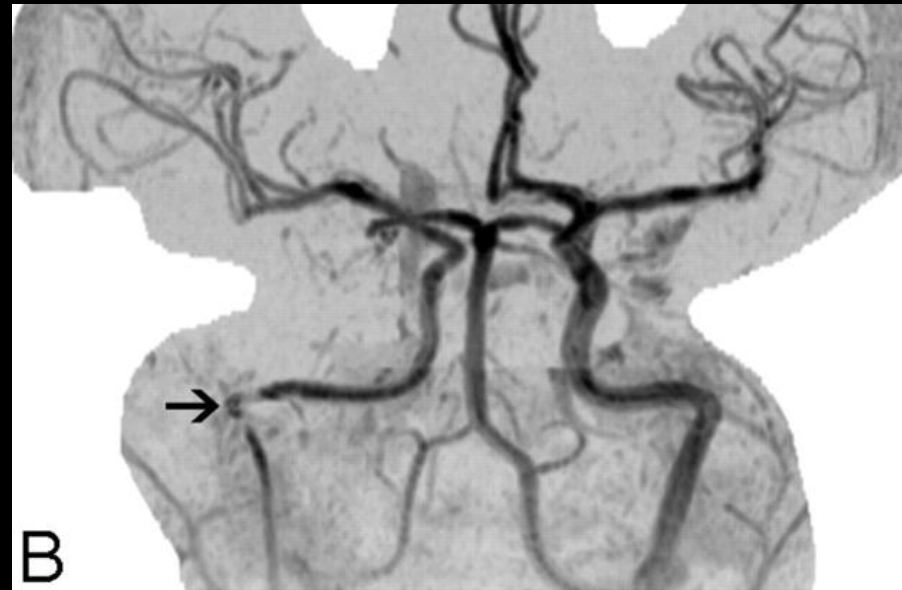
Aberrant internal carotid artery

- Pulsative tinnitus
- Can look exactly like glomus tympanicum on coronal images
 - Check for TUBULARITY on axials!
- DON'T BIOPSY!

Lateral course through middle ear with dehiscence of overlying bone



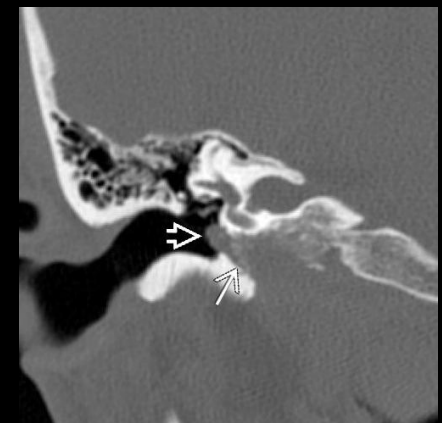
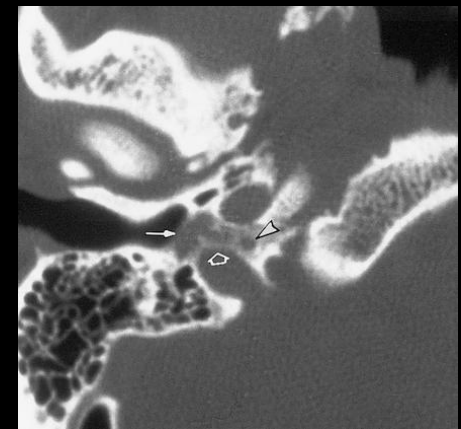
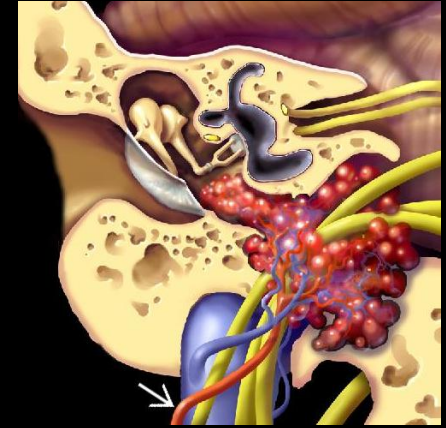
“7” sign



Middle Ear: Benign lesions

Glomus Jugulare paraganglioma

- Jugular foramen mass with permeative destruction of the adjacent bone and extension into hypo/mesotympanum

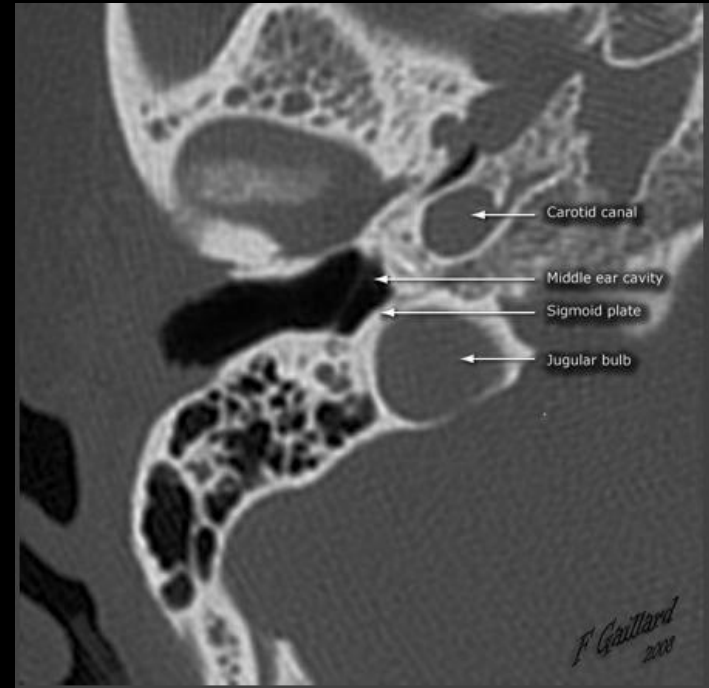


Middle Ear: Benign lesions

normal

Dehiscent jugular bulb

Enlarged jugular bulb with dehiscence of sigmoid plate and protrusion of jugular vein into the posterior aspect of the middle ear.



Middle Ear: clues to masses

- In tympanic cavity with or without osseous erosion.
- Most are similar in appearance.
- Location can give clues to the diagnosis.

Medial to ossicles

pars tensa cholesteatoma - mesotympanum mass, ossicle erosion (medial to lateral)

epidermoid - late ossicle erosion

glomus tympanicum paraganglioma(schwannoma) - no ossicle erosion

aberrant course of ICA

Lateral to ossicles

pars flaccida - scutum erosion, ossicle erosion (lateral to medial)

Middle Ear: Malignant lesions

Rare and beyond scope of this lecture

Adults

Metastases - lung and breast

EAC SCCa with secondary invasion

Perineural spread of parotid tumor along
CN7

adenoma

Endolymphatic sac tumor

Kids

Rhabdomyosarcoma

LCH

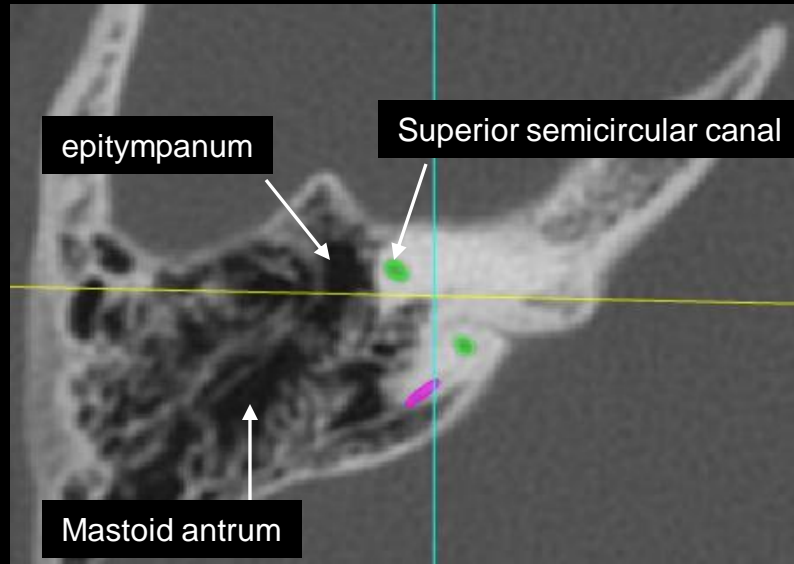


Inner Ear: Anatomy

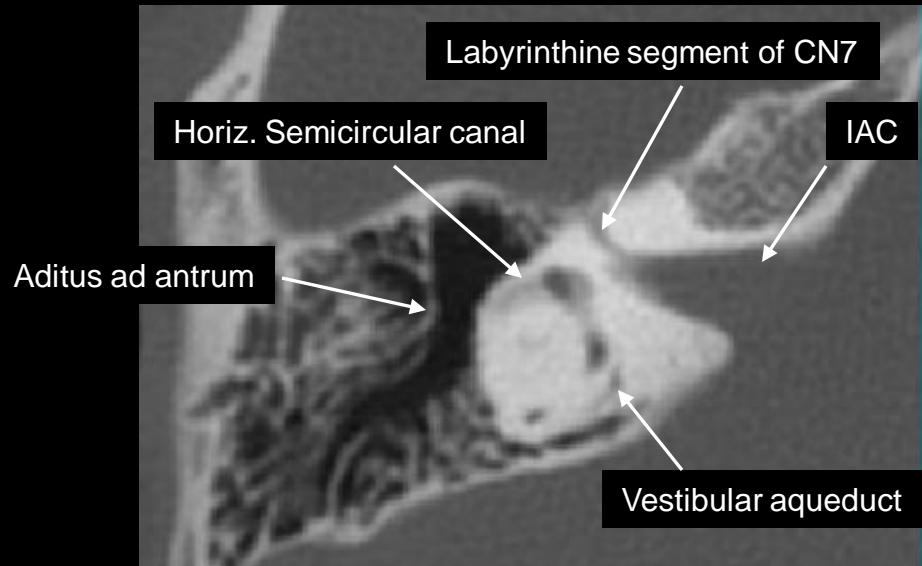
Superior to inferior

See what you remember so far...

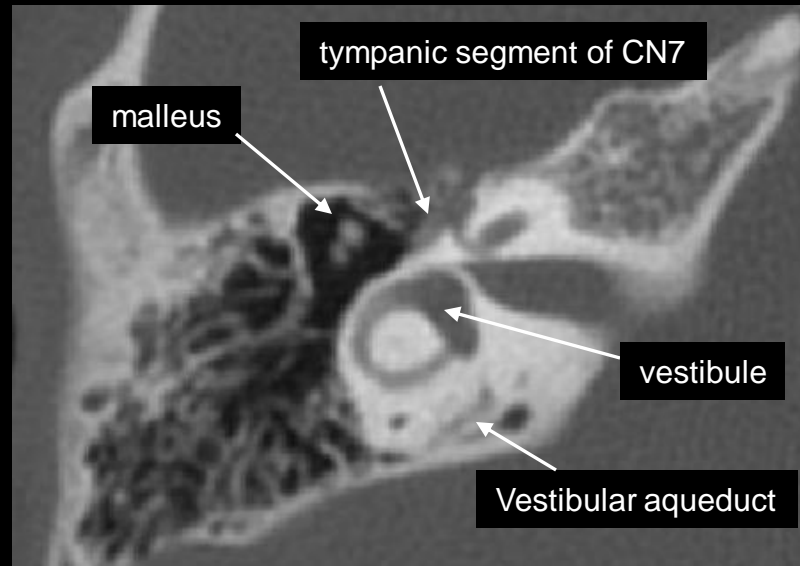
Inner Ear: Anatomy



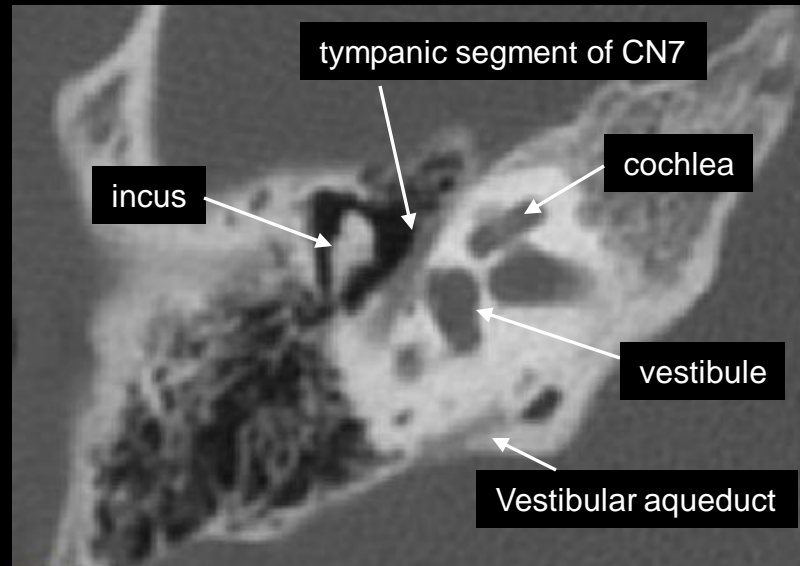
Inner Ear: Anatomy



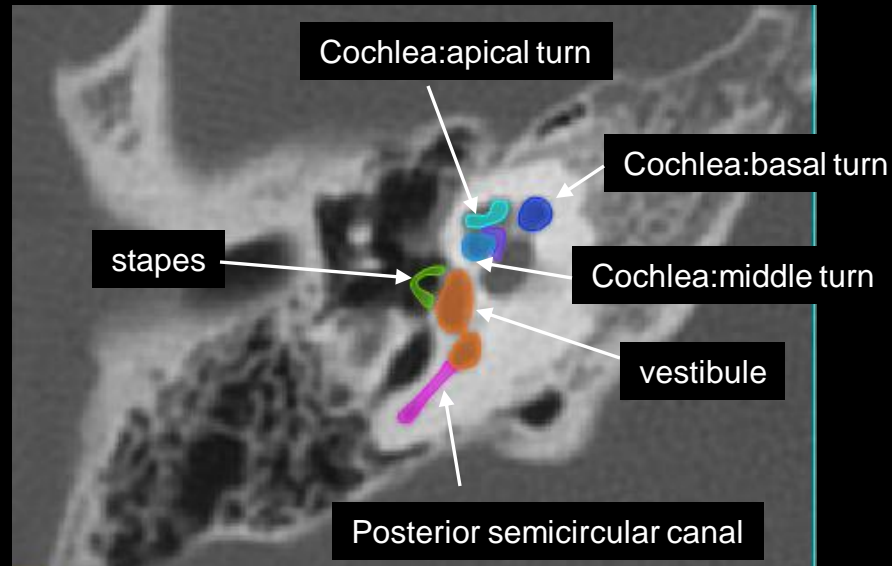
Inner Ear: Anatomy



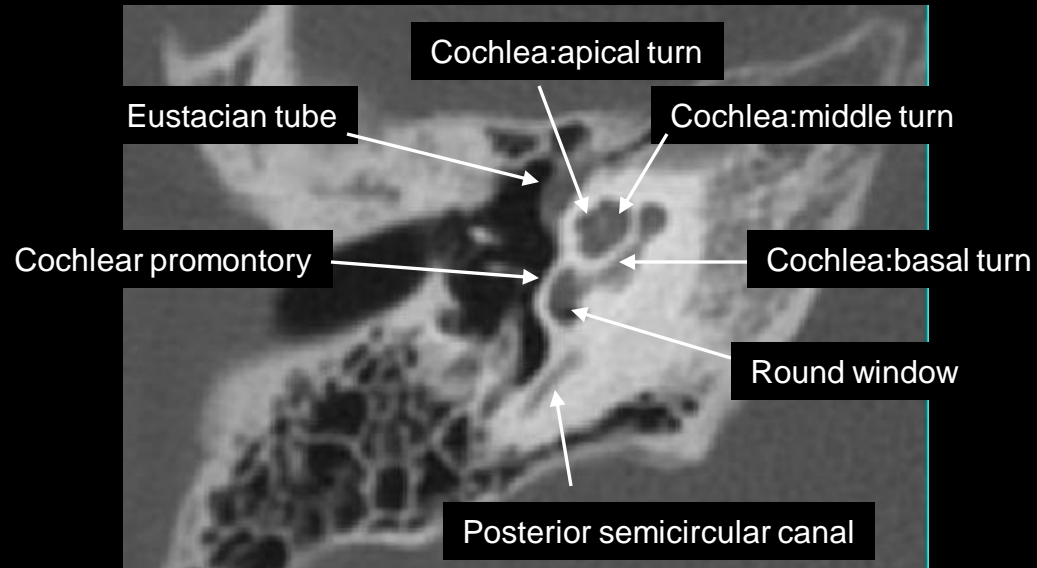
Inner Ear: Anatomy



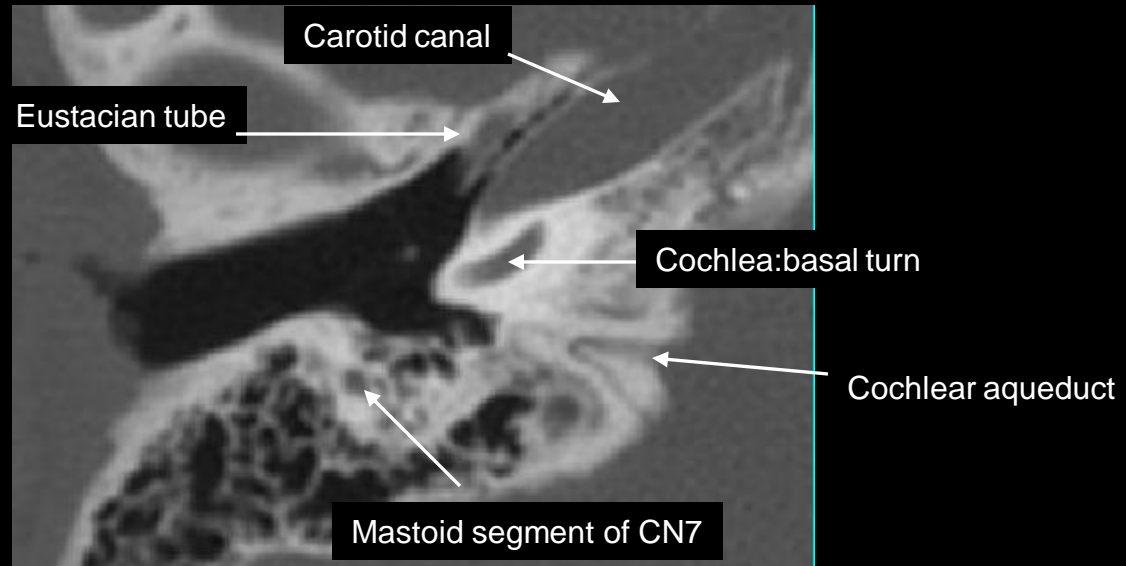
Inner Ear: Anatomy



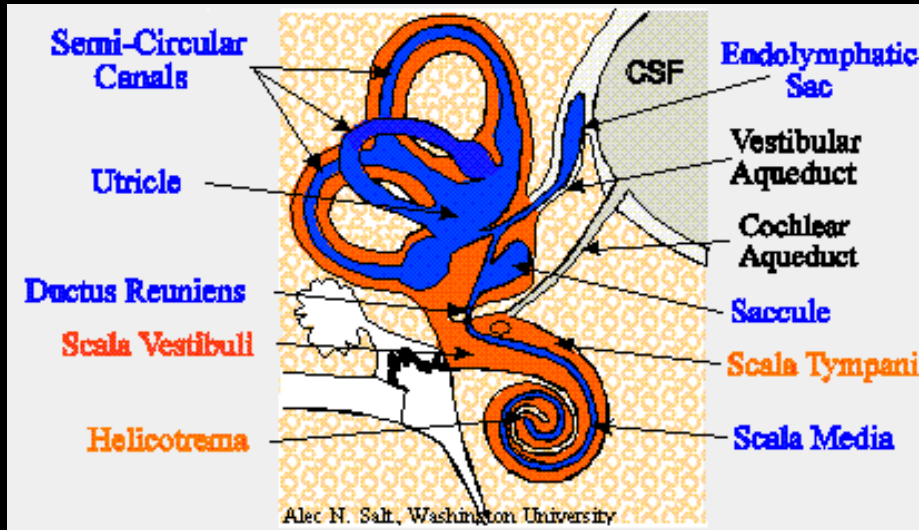
Inner Ear: Anatomy



Inner Ear: Anatomy



Inner Ear: Anatomy



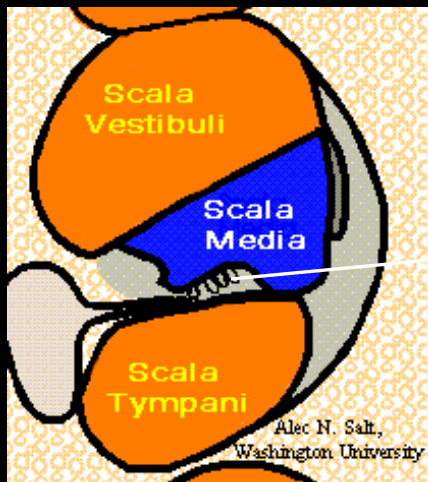
Perilymph

Csf like extracellular fluid
Between membranous and bony labyrinths
Contiguous with the subarachnoid space
No appreciable “flow”

Endolymph

Fluid that fills the membranous labyrinth.
Unique in body - high K⁺
“sealed” compartment maintained by ion exchange in endolymphatic sac

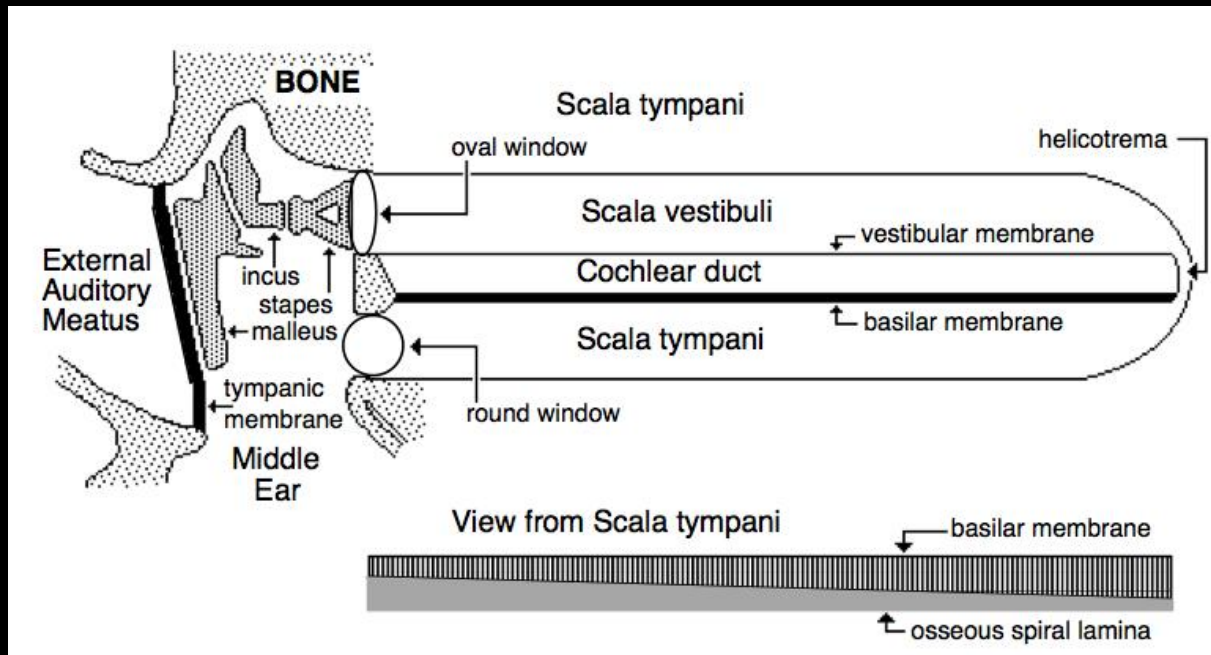
Crosssection of cochlea



Organ of Corti hair cells



Inner Ear: Anatomy



- Pressure wave transmitted by stapes to incompressible perilymph and then to cochlear duct and basilar membrane.
- Basilar membrane has variable resonant frequency and vibrates displacing hair cells and causing them to depolarize, modulating action potentials in cochlear nerve.
- Round window is membranous and allows wave to propagate.

Inner Ear: congenital anomalies

- Sensorineural hearing loss (SNHL)
- Abnormalities of bony or membranous labyrinth.
- While most abnormalities confined to membranous labyrinth , CT used in diagnosis of bony labyrinth anomalies

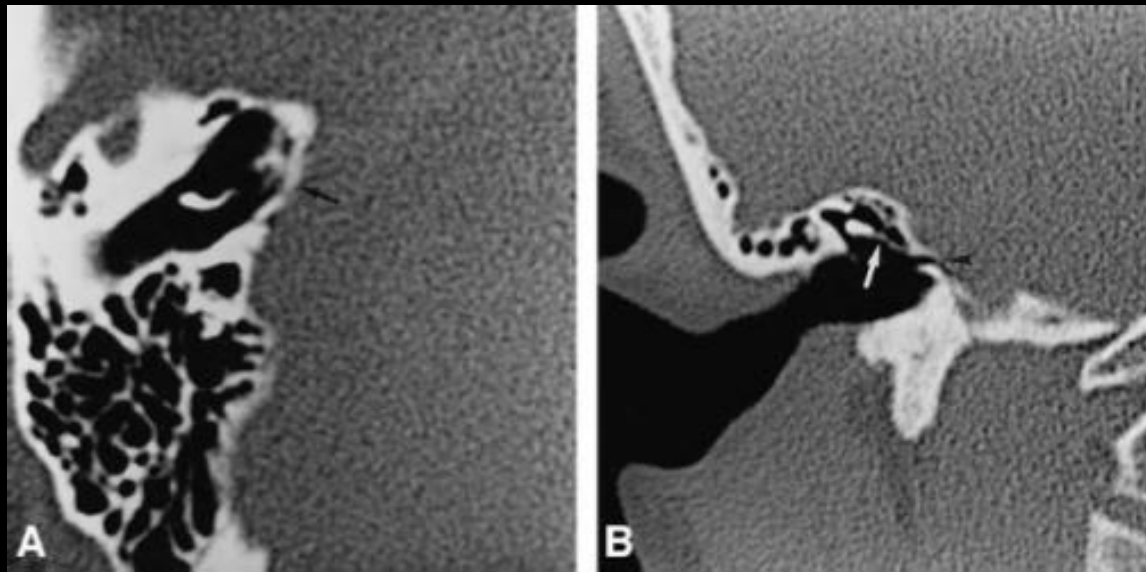
Jackler 1987 –detailed classification system based on embryological development (wks 4-8).

- Michel aplasia – complete labyrinthine aplasia
- Large vestibular aqueduct (LVA)
- Cystic cochleovestibular anomaly
- Semicircular canal dysplasia
- Common cavity deformity
- Cochlear aplasia/hypoplasia

Inner Ear: congenital anomalies

Michel aplasia – complete labyrinthine aplasia

- Bilateral absence of middle ear structures.
- Profound SNHL
- Growth arrest before fourth week of gestation
- thalidomide exposure, anencephaly, and Klippel-Feil syndrome



Note normal
EAC and middle
ear

Inner Ear: congenital anomalies

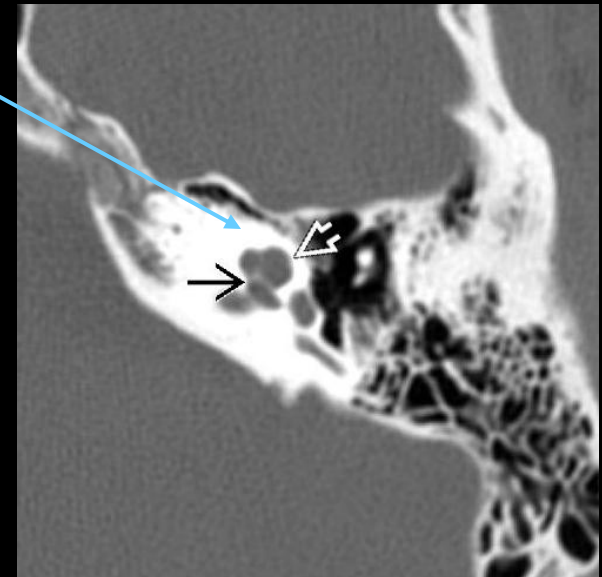
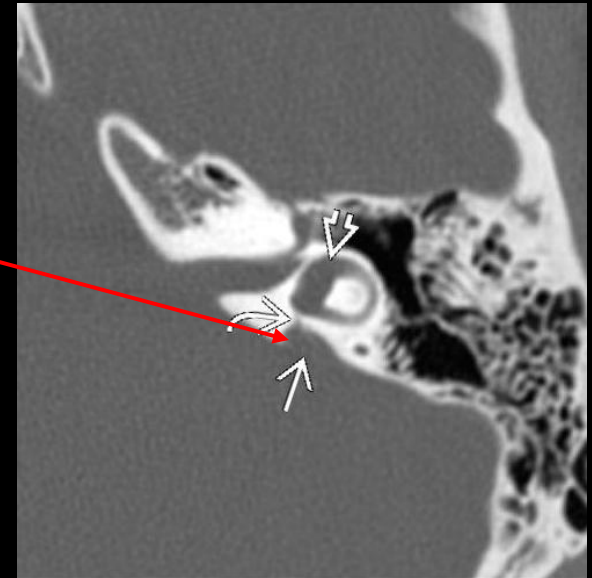
Cochlear anomalies

Large vestibular aqueduct syndrome (LVA), **Mondini**

- Most common abnormal imaging finding in SNHL

Incomplete partitioning of cochlea

- **Cochlea lacks 2.5 complete turns. Has 1.5 turns**
 - Apical turn is dysmorphic
- bilateral
 - Etiology for SNHL is proposed as trauma to fragile cochlea



Inner Ear: congenital anomalies

Cystic cochleovestibular anomaly

SNHL from birth

- **Snowman** shaped inner ear with cystic featureless cochlea and dilated cystic vestibule



Semicircular canal dysplasia

- **Lateral SCC** most often affected. Forms common cavity with dilated vestibule
- **CHARGE** syndrome
 - All SCCs absent
 - Oval window atresia



Common cavity

Cystic cavity representing rudimentary vestibule and cochlea



Cochlear aplasia/hypoplasia

No cochlea is present but vestibule, semicircular canals & internal auditory canal (IAC) are present in some form



Inner Ear: inflammatory lesions

Labyrinthine ossificans

Cochlear Otosclerosis/otospongiosis

Fenestral Otosclerosis/otospongiosis

Semicircular canal dehiscence

Inner Ear: inflammatory lesions

Labyrinthine ossificans

- Ossification of membranous labyrinth as **healing response** to infection, trauma, surgery
- Classic presentation is bilateral SNHL in child after meningitis
- **Bone deposition in fluid spaces** of vestibule, semicircular canals and cochlea

Ossification of left cochlea and vestibule



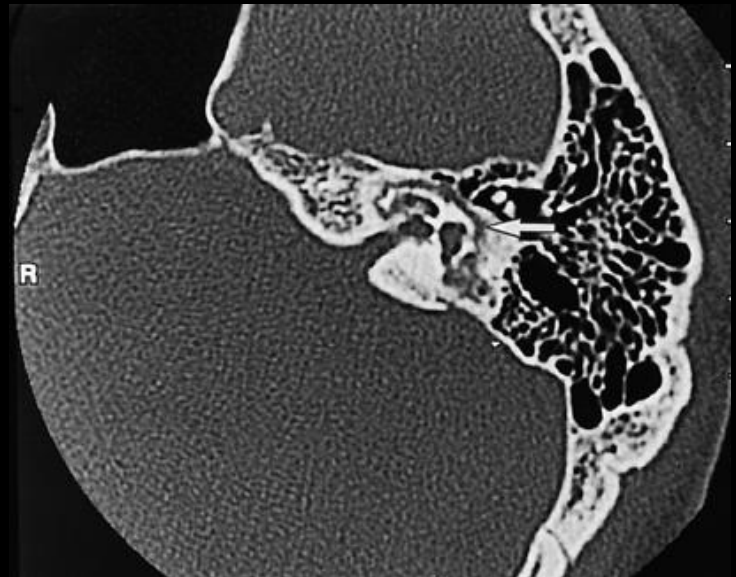
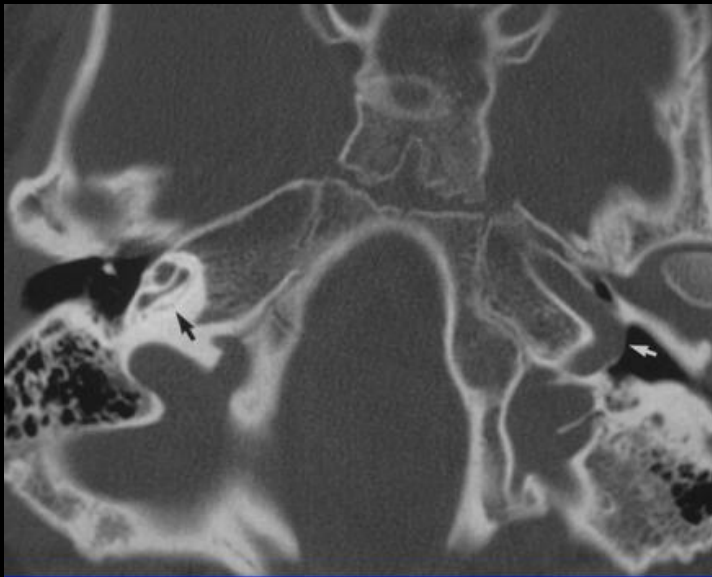
Inner Ear: inflammatory lesions

Cochlear Otosclerosis/otospongiosis

Young adult with bilateral mixed hearing loss

- **Focal lytic plaques in pericochlear bony labyrinth**
- 85% bilateral symmetric
- Unknown etiology
- Treated with flouride

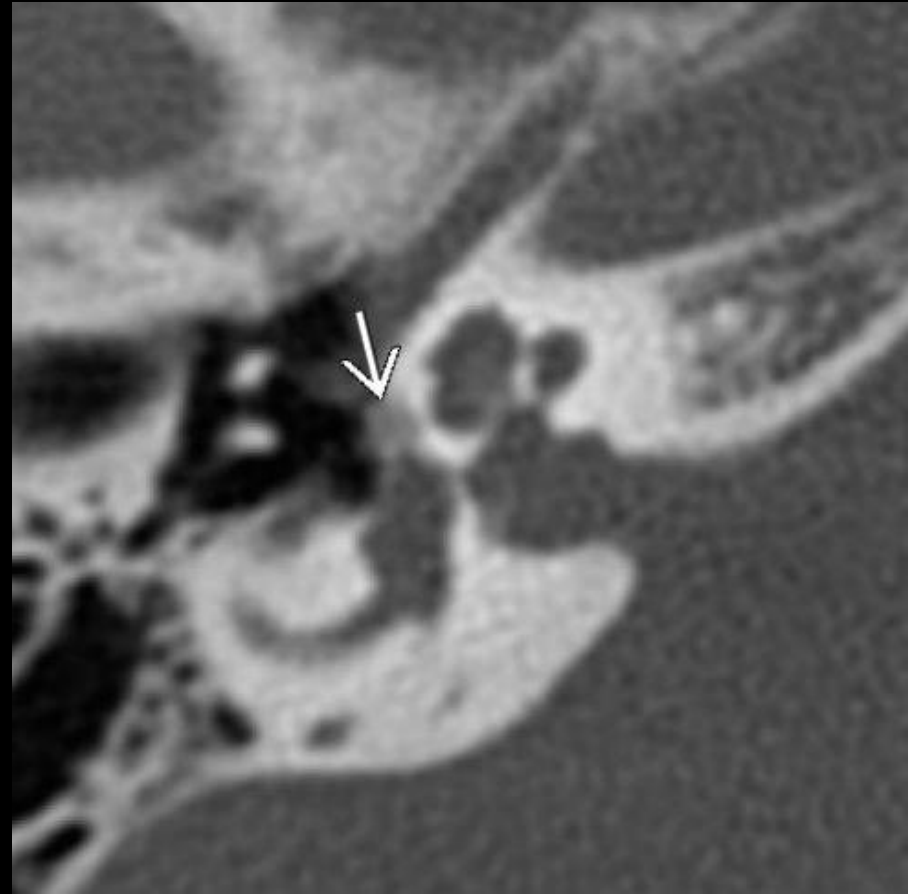
Lucent halo surrounding basal turn of cochlea



Inner Ear: inflammatory lesions

Fenestral Otosclerosis/otospongiosus

- Adults with conductive hearing loss
- **More common than cochlear otosclerosis**
- Similar process involving the oval and round window region
- Unknown etiology
- Fluoride treatment slows hearing loss.

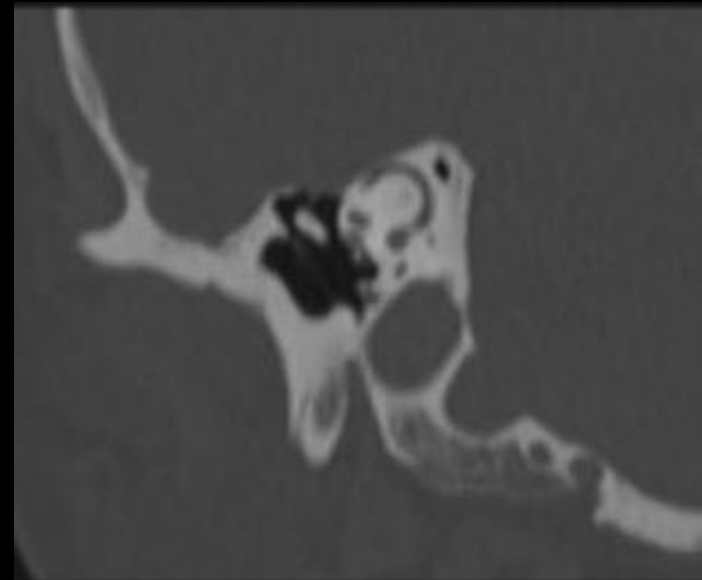
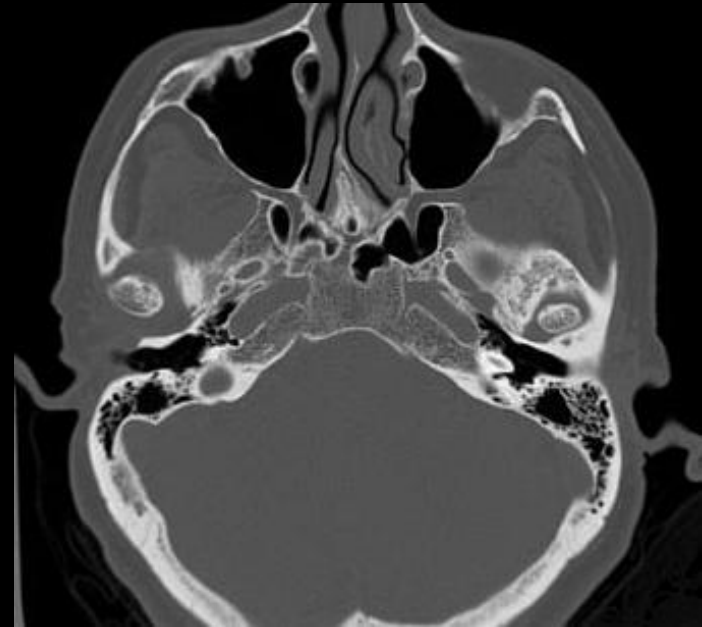


Plaque near oval window

Inner Ear: inflammatory lesions

Semicircular canal dehiscence

- thinning or absence of bony roof over **superior or posterior semicircular canal**
- Noise induced vestibular symptoms
- Unknown etiology
- Affects adults



Inner Ear: benign and malignant lesions

Benign

- CN VIII schwannomas

- Petrous apex

 - Chordoma

 - Meningioma

 - Cholesterol granuloma

- Pagets

- LCH

Malignant

- Metastases

- Endolymphatic sac tumor

- Perineural spread of malignancy

 - Skin

 - Parotid

 - Pharynx

- Rhabdomyosarcoma

- lymphoma



Chinese palace

Temporal bone fractures

Complications of temporal bone fractures

- facial nerve paresis or paralysis, cerebrospinal fluid (CSF) leakage, conductive hearing loss (CHL), sensorineural hearing loss (SNHL), and dizziness or balance dysfunction

Classic teaching discusses two main fracture orientations

1. Longitudinal - parallel to petrous ridge

Conductive hearing loss

- 4-5x more common than transverse
- More commonly associated with **ossicle dislocation**
 - Incudostapedial is the weakest
 - Challenging to see on CT
 - EAC and glenoid fossa extension
- 20% have facial nerve injury (at geniculate ganglion)

2. Transverse

Sensorineural hearing loss

- **CN7 injury** at transverse portion

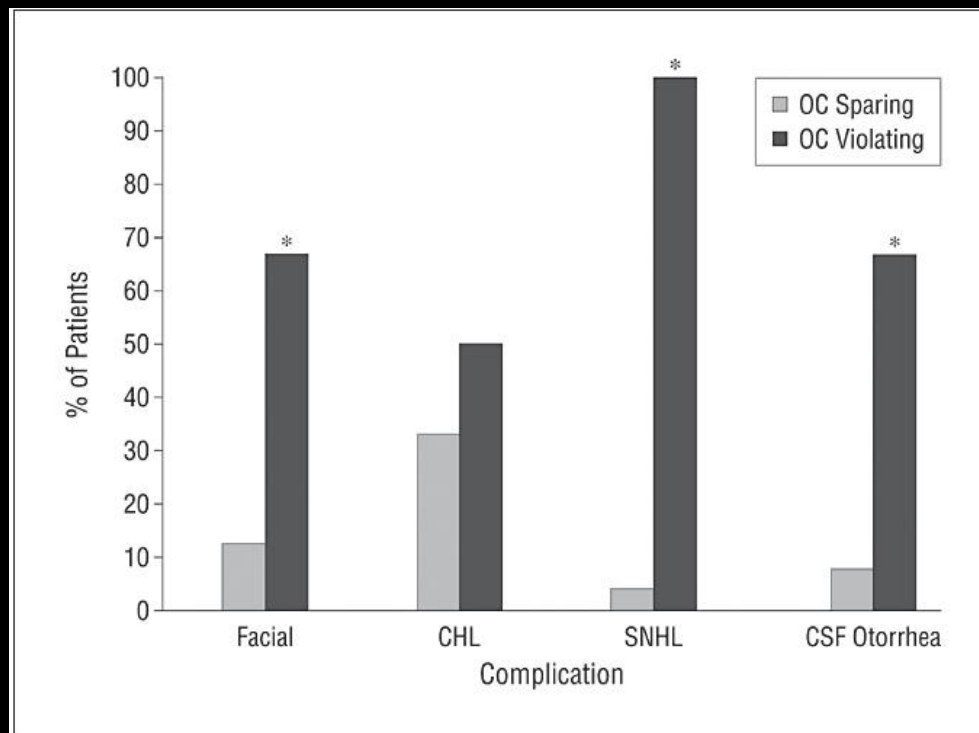
Temporal bone fractures

Most fractures are combined longitudinal and transverse

- Traditional classification poor at predicting complications

New classification

- fracture does, or does not violate otic capsule (bony labyrinth of inner ear)
- Better prediction of complications





References

- Khanna, G. et al. Causes of Facial Swelling in Pediatric Patients: Correlation of Clinical and Radiologic Findings. January 2006 RadioGraphics, 26, 157-171.
- Anatomy of external auditory canal Webpage by Dr, T. Balasubramanian M.S. D.L.O.
- Statdx
- eMedicine
- Radiopaedia
- Radiologyassistant
- Wikipedia
- Grossman. Neuroradiology Requisites.
- Mayer T E et al. High-Resolution CT of the Temporal Bone in Dysplasia of the Auricle and External Auditory Canal. AJNR Am J Neuroradiol 18:53–65, January 1997
- J. Linn, T. Pfefferkorn, K. Ivanicova, S. Müller-Schunk, S. Hartz, M. Wiesmann, M. Dichgans, and H. Brückmann. *Noncontrast CT in Deep Cerebral Venous Thrombosis and Sinus Thrombosis: Comparison of its Diagnostic Value for Both Entities.* AJNR Am. J. Neuroradiol., Apr 2009; 30: 728 - 735.
- Johannes J. Manni, Lysandra C. M., Berenos-Riley. *Ossification of the external ear: a case report and review of the literature.* Eur Arch Otorhinolaryngol (2005) 262: 961-964

References

- Herman. Physics of the Human Body. Springer 2007.
- [Vazquez E](#), [Castellote A](#), [Piqueras J](#), [Mauleon S](#), [Creixell S](#), [Pumarola F](#), [Figueras C](#), [Carre JC](#), [Lucaya J](#). Imaging of complications of acute mastoiditis in children. [Radiographics](#). 2003 Mar-Apr;23(2):359-72.
- M Castillo, VS Albernaz, SK Mukherji, MM Smith, and JL Weissman Imaging of Bezold's abscess Am. J. Roentgenol., Dec 1998; 171: 1491 - 1495.
- [Weissman JL](#), [Hirsch BE](#). Imaging of tinnitus: a review. [Radiology](#). 2000 Aug;216(2):342-9.
- Cochlear fluids lab. [Department of Otolaryngology](#) Washington University School of Medicine
- Kimsey Rodriguez, MDa, Rahul K. Shah, MDb, Margaret Kenna, MD, MPHc,d. Anomalies of the Middle and Inner Ear. Otolaryngol Clin N Am 40 (2007) 81-96
- Kathlyn Marsot-Dupuch,a, Alessandro Dominguez-Britoa, Karim Ghaslia and Claude-Henri Chouard. CT and MR Findings of Michel Anomaly: Inner Ear Aplasia. *American Journal of Neuroradiology* 20:281-284 (2 1999)
- Robert K Jackler MD, William M. Luxfor MD, William F. House MD. **Congenital malformations of the inner ear: A classification based on embryogenesis. The Laryngoscope. [Volume 97, Issue Supplement S40](#), pages 2-14, March 1987**
- [Stewart C. Little, MD](#); [Bradley W. Kesser, MD](#) . **Radiographic Classification of Temporal Bone Fractures: Clinical Predictability Using a New System.** *Arch Otolaryngol Head Neck Surg*. 2006;132:1300-1304.