Cochlear Implantation

Deepa Galaiya, MD

Presented by: Deepa Galaiya, MD

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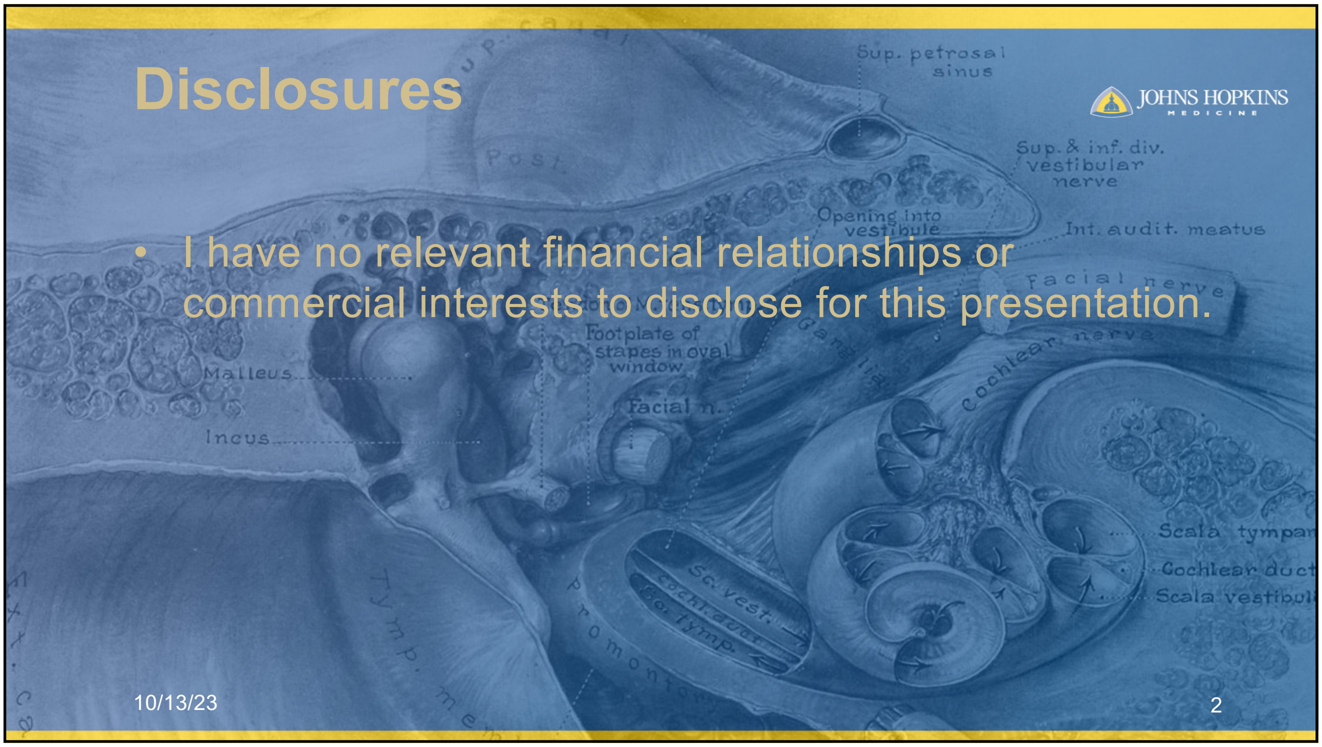
Disclosures

- I have no relevant financial relationships or commercial interests to disclose for this presentation.



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Who am I?

JOHNS HOPKINS MEDICINE

- Otolaryngologist
  - Head and neck surgery
  - Endoscopes & Microscopes
  - Minimally Invasive Techniques
- Neurotologist
  - Skull Base Surgery
  - Ear Diseases and Hearing
  - Interface of Brain and Sensory Organs

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Outline

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1. History of Surgical Innovation
2. Anatomy and Physiology of the Ear
3. History of Cochlear Implantation
4. Indications for Cochlear Implantation
5. Cochlear Implant Surgical Technique and Goals
6. Types of Cochlear Implants
7. Cochlear Implants as the Foundation for Brain-Machine Interfaces

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Surgery: Both Ancient and Innovative

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- For much of the history of mankind, surgery remained one of the only effective treatments for disease.
- Surgery was not considered safe until about 100-150 years ago.
  - Germ theory of disease, sterilization, sanitation
  - Anesthesia
- Surgery: both rudimentary and advanced
  - Global Health & Access to Care Implications

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- 3000 BC - ancient Egyptians
  - Learned human anatomy from mummification
  - Treated wounds with clamps, sutures, cauterization, using tools like saws, forceps, scalpels and scissors
  - Honey as an antiseptic
- 500 BC – Sushutra – ancient India – reconstructive rhinoplasty
- Ancient Greece – set broken bones, perform amputations
  - Wine as an antiseptic

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- Middle Ages: Barber-surgeon
  - cut hair, pulled teeth, performed amputations, bloodlet and set broken bones
  - Alcohol and opium for pain
  - Cauterization for infection control
- 1500s – formal study of human anatomy
- 1818 - First blood transfusion
- 1843 - First hysterectomy
- 1843 – Ether
- 1867 – Joseph Lister's Antiseptic Principle in the Practice of Surgery

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- 1928 – Penicillin
- 1940 – First metal hip replacement
- 1950 – First kidney transplant
- 1953 – Heart-lung bypass
- 1967 – First heart transplant
- 1975 – First use of laparoscopic surgery
- 1985 – First use of robots in surgery
- 1990s/2000s – Wide use of endoscopes in surgery
- 2000 – da Vinci system gains FDA approval

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Surgical history has been defined by innovation.

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- Foundation of modern surgery:
  - discovery of general anesthesia
  - development of aseptic technique in the nineteenth century.
- Major “open” surgical procedures for benign and malignant diseases.
- Further innovations in vascular anastomosis, electrosurgery, positive pressure ventilation, cardiopulmonary bypass circuits, transplant immunology, and parenteral nutrition widened the aperture of surgical opportunity.
- At the end of the twentieth century, innovations in **minimally invasive**, **image-guided surgery** (from laparoscopy to endovascular surgery) forever changed the practice of surgery and the training of surgeons.
- New technologies can expand indications and reduce morbidity, but access to care might be cost-limited.

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Cochlear Implants

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- Restoration of a human sense with a neuroprosthetic
- Foundation for brain-machine interfaces
  - Retinal prosthetics
  - Auditory brainstem implants
  - Deep brain stimulation
  - Prosthetic limbs

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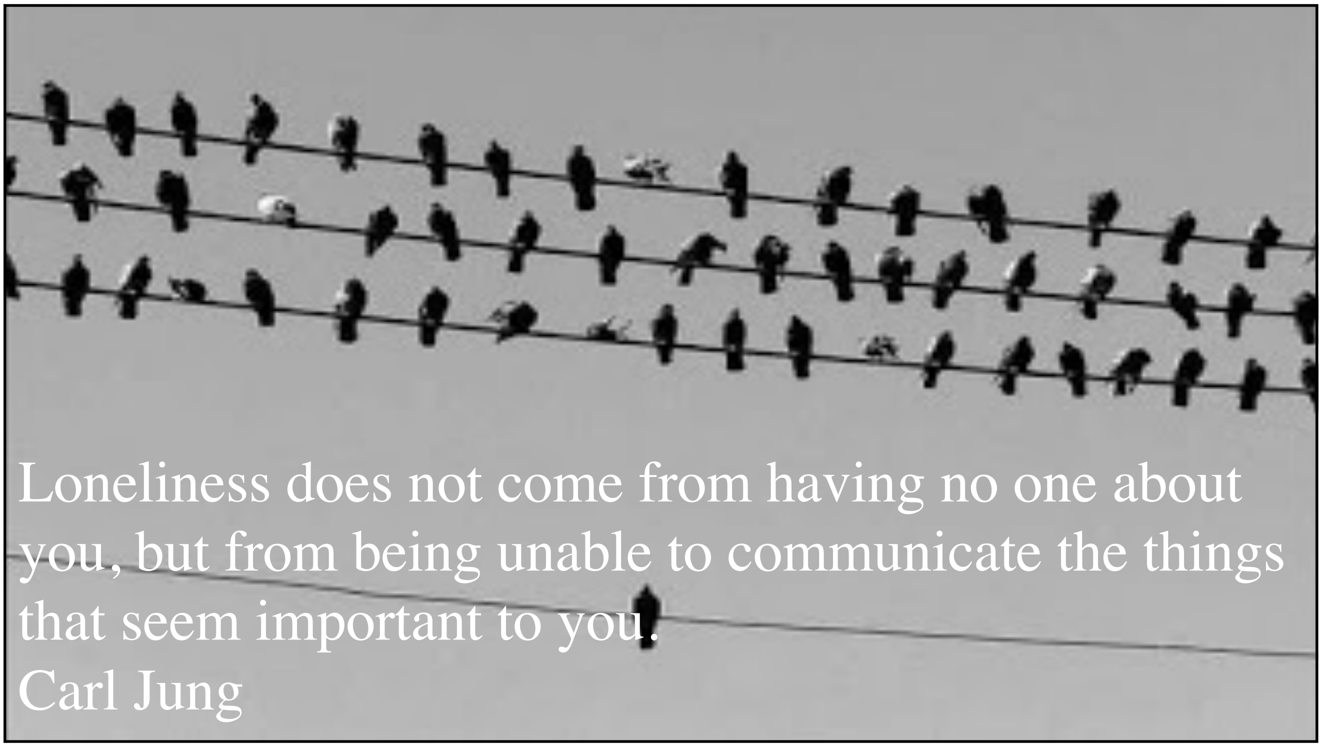

Loneliness does not come from having no one about you, but from being unable to communicate the things that seem important to you.
Carl Jung

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Ear Anatomy

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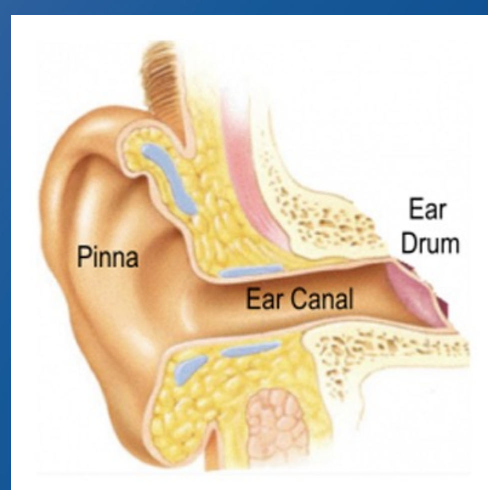
- External Ear
  - Pinna
  - External Auditory Canal



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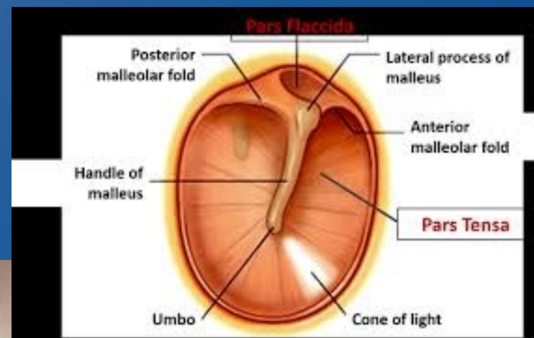
Ear Anatomy

- Middle Ear
  - Tympanic Membrane
  - Ossicles
    - Malleus ("Hammer")
    - Incus ("Anvil")
    - Stapes ("Stirrup")



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Ear Anatomy

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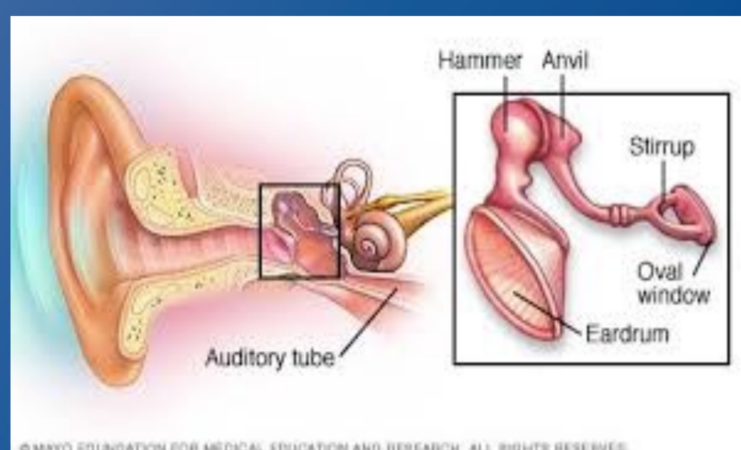

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Ear Anatomy

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- Middle Ear
  - Tympanic Membrane
  - Ossicles
    - Malleus (“Hammer”)
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Ear Anatomy

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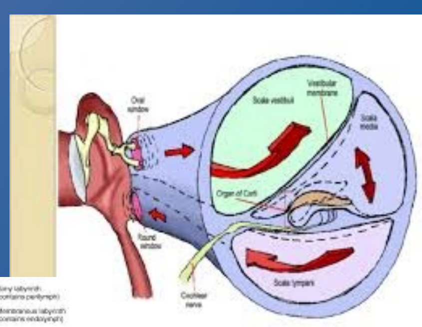
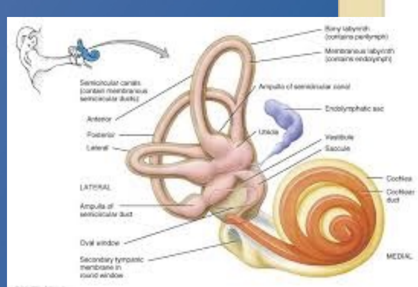
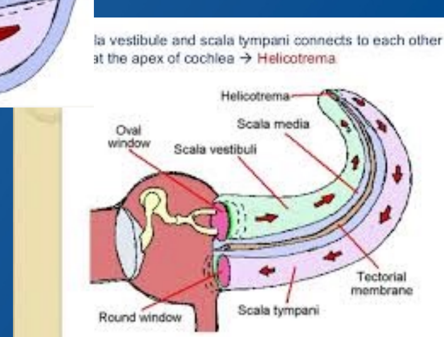
- Inner Ear
  - Cochlea
  - Labyrinth







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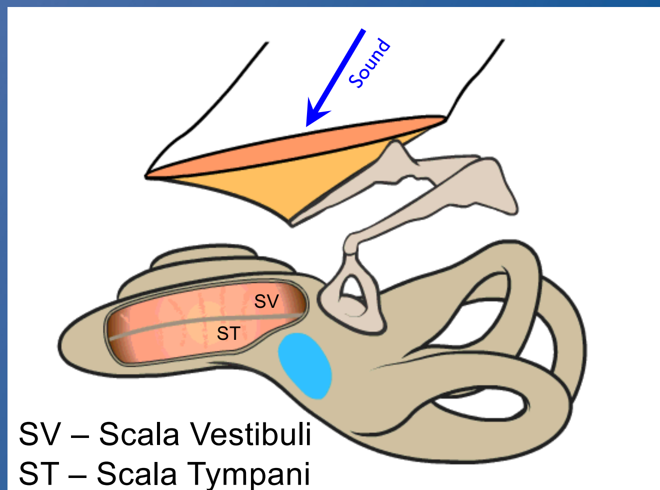
Sound Transduction



$P_{SV} - P_{ST} = \Delta P$ = Cochlear Input Drive

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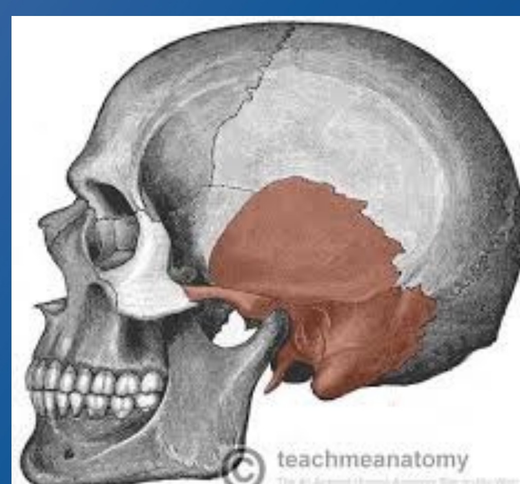
Temporal Bone/Mastoid

- Important Structures
  - Tegmen (”Brain”)
  - Sigmoid (“Vein”)
  - Facial Nerve (CNVII)
  - Semicircular Canals (Balance Canals)



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Temporal Bone/Mastoid

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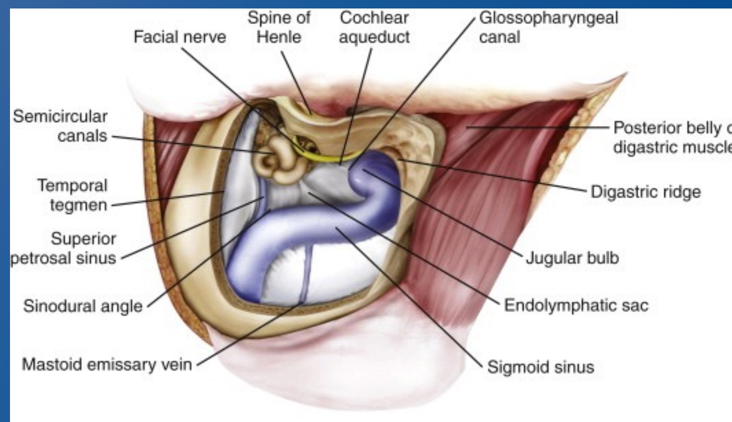

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How Hearing Works

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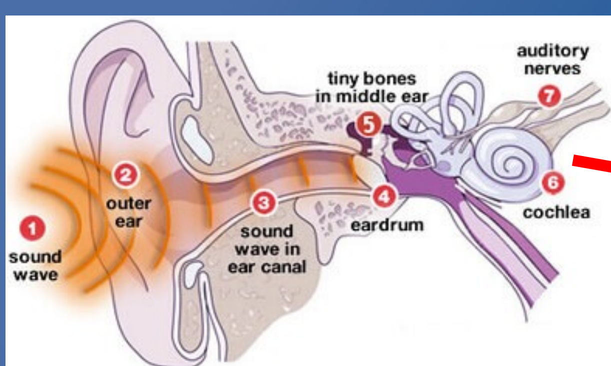

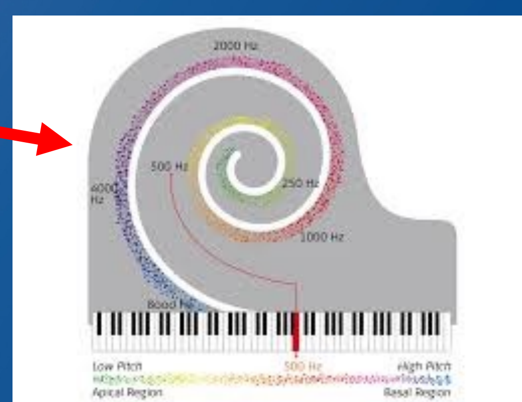

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How Hearing Works

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Types of Hearing Loss

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- Conductive Hearing Loss

  “Sound Can’t Get into the Inner Ear”

  1. Ear Canal Problem
     - WAX
  2. Ear Drum Problem
     - Tympanic Membrane Perforation
  3. Hearing Bones Problem
     - Otosclerosis/Temporal Bone Fracture/Cholesteatoma

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Types of Hearing Loss

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- Sensorineural Hearing Loss

  “Sound Can’t Get from Inner Ear to Brain”

  1. Congenital → “baby b
  2. Acquired → “meningi
  3. Age-Related →

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Treatments for Sensorineural Hearing Loss

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- Hearing Aids

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Treatments for Sensorineural Hearing Loss

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- Bone Anchored Hearing Aids ("BAHA")

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Treatments for Sensorineural Hearing Loss

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- Cochlear Implants

Hearing aids amplify sounds so they may be detected by damaged ears.

Cochlear implants bypass damaged portions of the ear and directly stimulate the auditory nerve.

Signals generated by the **implant** are sent by way of the auditory nerve to the brain, which recognizes the signals as sound.

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Cochlear Implants: A Case Study in Surgical Innovation

- 1800 - Alessandro Volta:
  - "The disagreable sensation, which I apprehended being dangerous, of shock in the brain, prevented me from repeating the experiment."
- 1957 – French surgeons placed an electrode in the ear during surgery
- 1961 – Bill House and John Doyle – single wire electrode into the cochlea of two deaf patients resulted in sound stimulation

Cochlear Implants: A Case Study in Surgical Innovation

- 1960s - cardiac pacemakers
  - Biocompatible materials
  - Electrode insulation
  - Effect of electrical stimulation of the nerves
  - Smaller circuit design/electronics
- 1970s – Jack Urban and Bill House implanted the first patient with a single electrode device that could be worn continuously

Cochlear Implants: A Case Study in Surgical Innovation

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- 1970s – first series of cochlear implants with multiple channels
  - 200 patients implanted by 1981
- 1980s/90s
  - FDA approval for expanding indications
  - Threat to the Deaf community
- 2000s – Cochlear implants become widely available.
  - Electrode and surgical improvements to preserve residual hearing.

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Indications for a Cochlear Implant

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- Implants are EXPENSIVE!!!!
  ~$20-25,000
- Implants can **damage** what residual hearing is left
- Only want to implant people who are going to get benefit from it

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Indications for a Cochlear Implant

Criteria	1985	1990	1998	2000	2014
AGE of implantation	Adults 18 yrs +	Adults & Children 2 yrs +	Adults & Children 18 mos +	Adults & Children 12 mos +	Adults only for Hybrid
ONSET of hearing loss	Post linguistic	Post linguistic adults/ Pre & Post Linguistic Children	Adults & Children Pre & Post Linguistic	Adults & Children Pre & Post Linguistic	Adults & Children Pre- and Post- Linguistic
DEGREE of hearing loss	Profound	Profound	S/P Adults Profound Children	S/P Patients 2 yrs+ Prof Child<2 yrs	Nucleus Hybrid: Normal to Moderate in low freq; S/P mid to high frequencies
SPEECH SCORES	0%	0%	40% or less	Sentences score 50% or less in ear to be implanted, ≤ 60% in best aided condition	CNC word score >10% but less than 60% in ear to be implanted; <80% CNC words in contralateral ear

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Understand < 40% of words in the ear to be implanted, and the contralateral ear has to understand < 60% of words

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Importance of Timing of Hearing Loss

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- Pre-Lingually Deafened
  - Need to implant early in order to allow neural pathways for auditory input to develop
- Post-Lingually Deafened

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Importance of Rehabilitation

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- Implants are activated ~4 weeks after surgery
- Requires multiple programming sessions and intensive training to get the best results out of the CI
  - Role for Telemedicine to Increase Access?

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Cochlear Implant Activation

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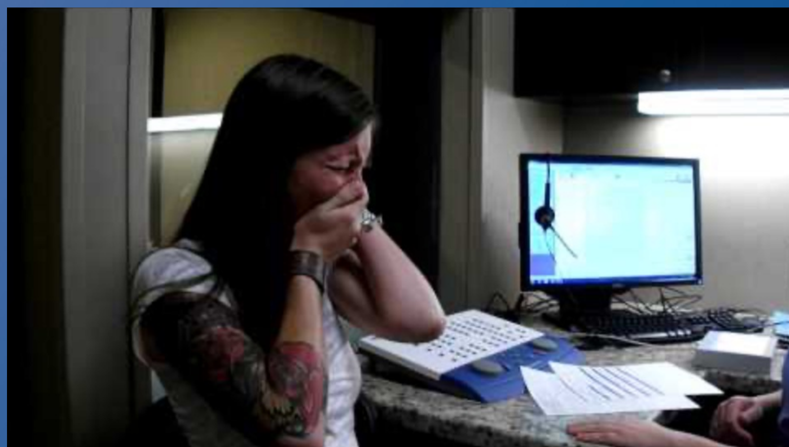

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How Cochlear Implants Work

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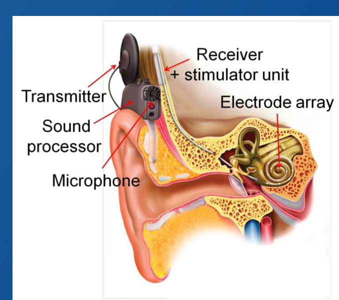

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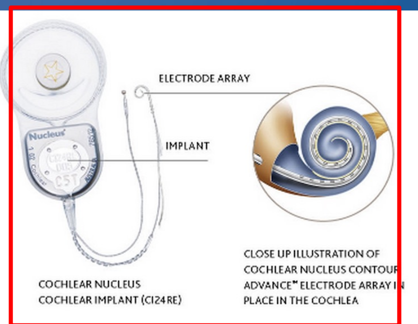
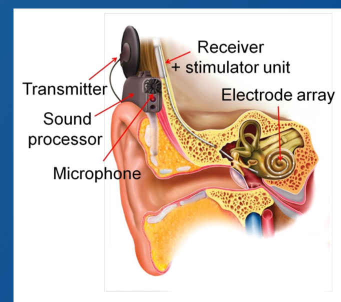
How Cochlear Implants Work





External

Internal

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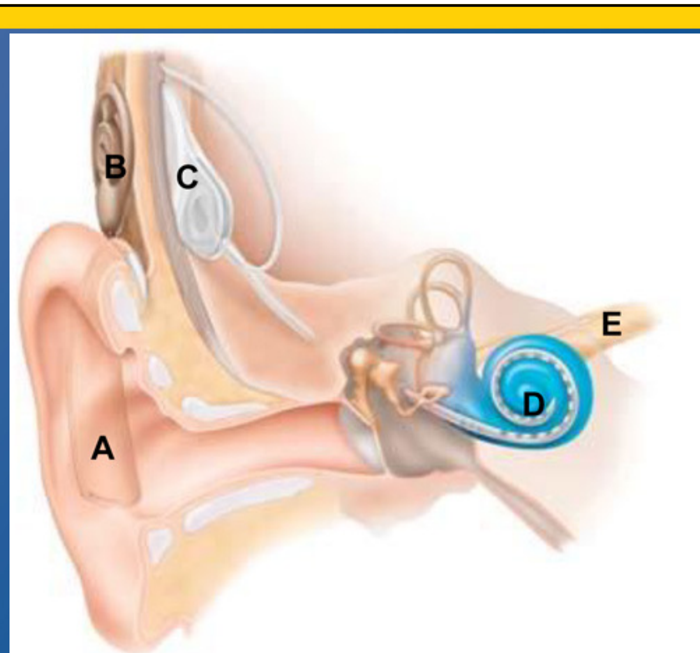
The **sound processor (A)** captures sound and turns it into digital code. The sound processor has a battery that powers the entire system.

The sound processor transmits the digitally-coded sound through the **coil (B**) to the **implant (C)** just under the skin.



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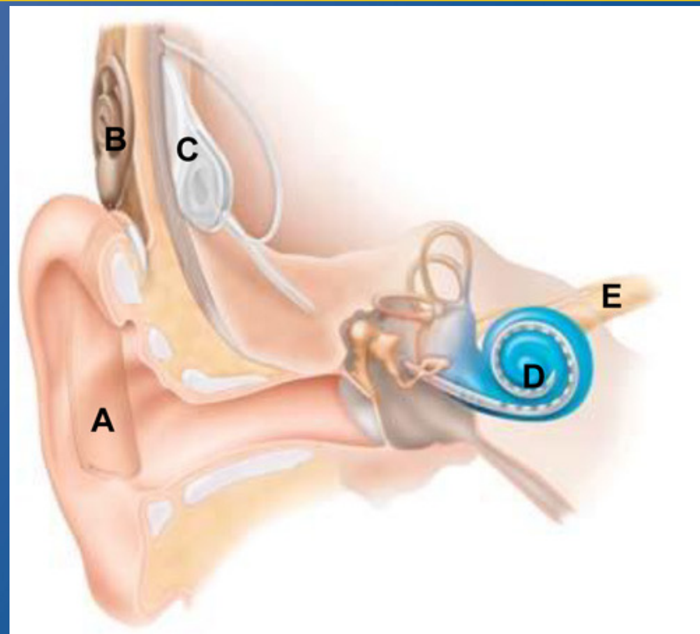
The **implant (D**) converts the digitally-coded sound into electrical signals and sends them along the electrode array which is positioned in the cochlea (the inner ear) (D).

The implant's **electrodes** stimulate the cochlea's hearing nerve fibres **(E)**, which relay the sound signals to the brain to produce hearing sensations.



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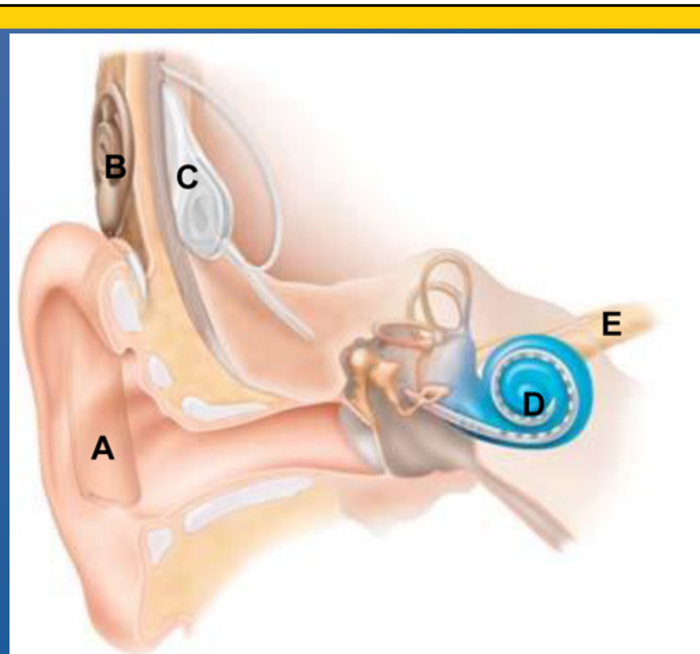
All cochlear implant systems have the same broad characteristics and design principles and are all well engineered.

Variations arise in styling, accessories and battery type.

Particular differences exist in electrode design, MRI compatibility and speech processing strategies which encode the external sound frequency details into digital signals.



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Different Types of Cochlear Implants

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3 Companies are FDA Approved

1. Cochlear Corporation
2. Advanced Bionics
3. Med-El

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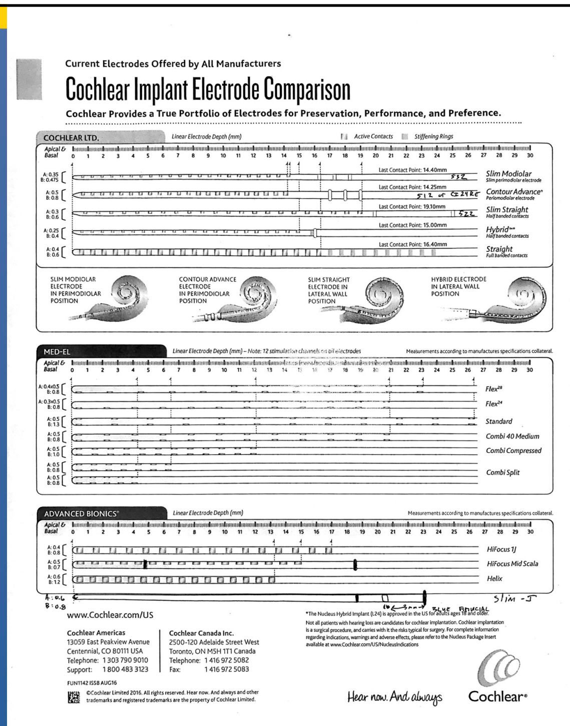

Surgical Technique

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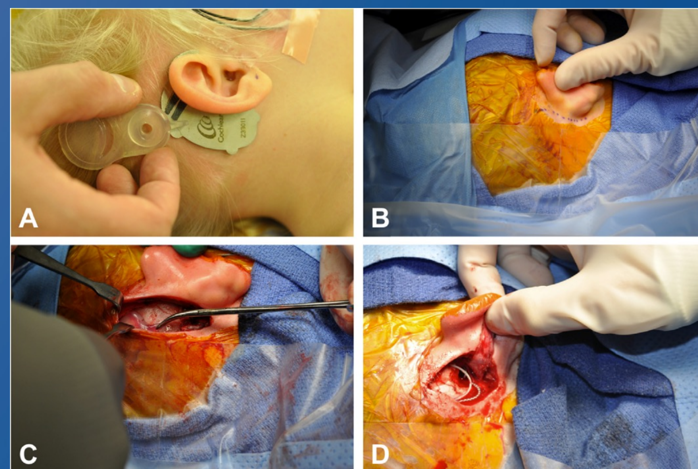
1. Incision
2. Make Pocket to Hold the Receiver Processor



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Surgical Technique

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3. Drill Mastoidectomy
   - 6 / 4 cutting burr
   - Want LARGEST SUCTION
   - Want HIGH IRRIGATION

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Surgical Technique

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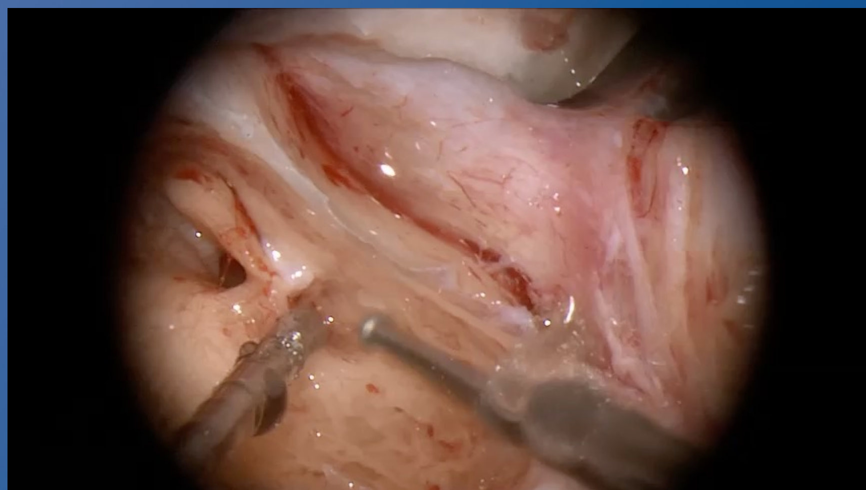
4. Open Facial Recess



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Surgical Technique

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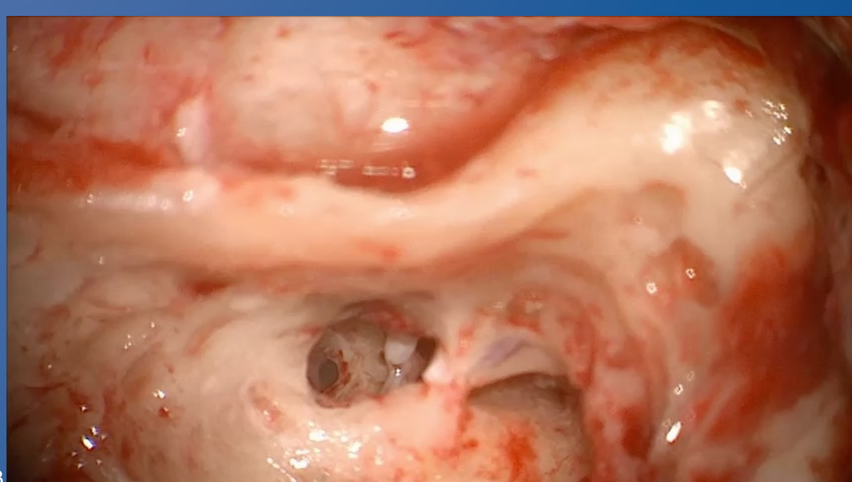
5. Open Round Window Niche



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Surgical Technique

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6. Insert Cochlear Implant
   – Advance off Stylet (Advanced Bionics)
     • **Want Cochlear Forceps, Claw, Regular Forceps**
   – Cochlear Insertion Tool (Cochlear Corp)
     • Cochlear 632 model, precurved
     • https://www.youtube.com/watch?v=YxTSdMrBSjw
     • Want Cochlear Forceps, Regular Forceps
   – Freehand (Med-El)
     • Want Regular Forceps x 2

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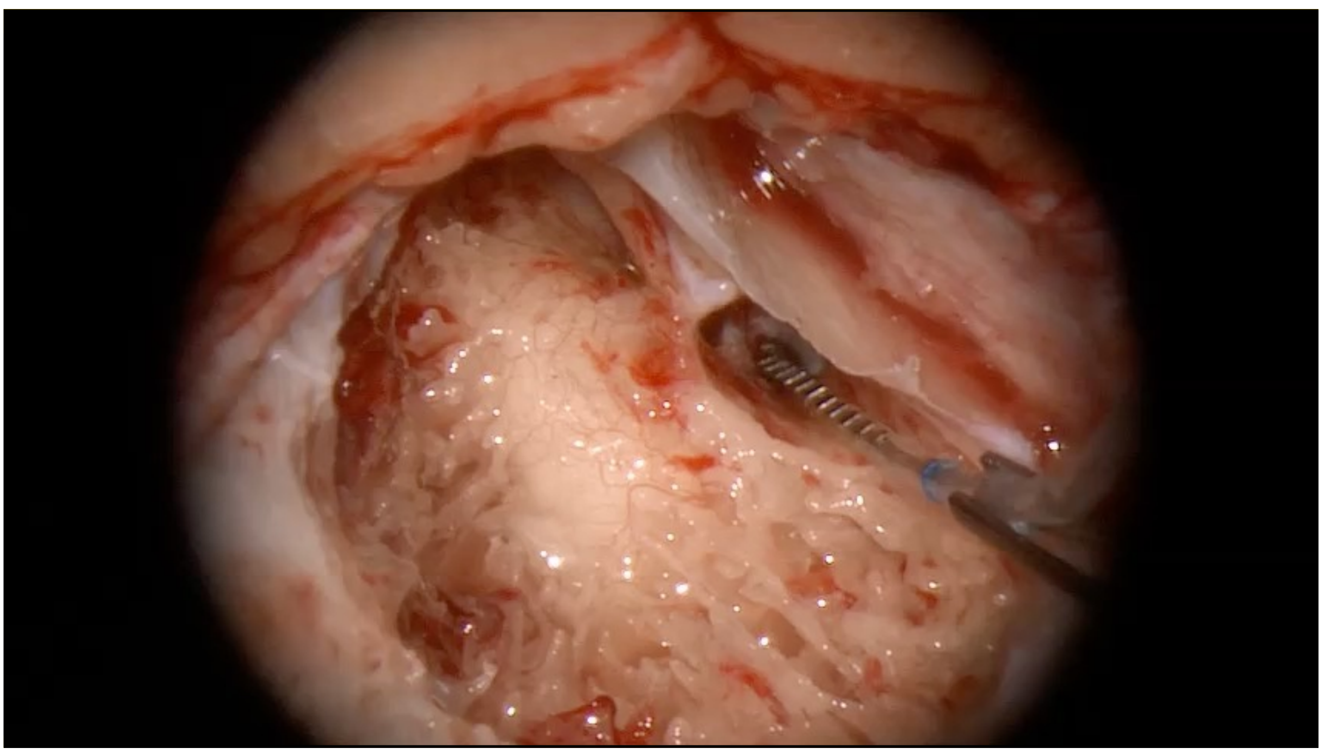

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Surgical Technique

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6. Insert Cochlear Implant
   - Advance of Stylet (Advanced Bionics)
     - Want Cochlear Forceps, Claw, Regular Forceps
   - Cochlear Insertion Tool (Cochlear Corp)
     - Cochlear 532 model, precurved
     - https://www.youtube.com/watch?v=YxTSdMrBSjw
     - ***Want Cochlear Forceps, Regular Forceps***
   - Freehand (Med-El)
     - Want Regular Forceps x 2

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Surgical Technique

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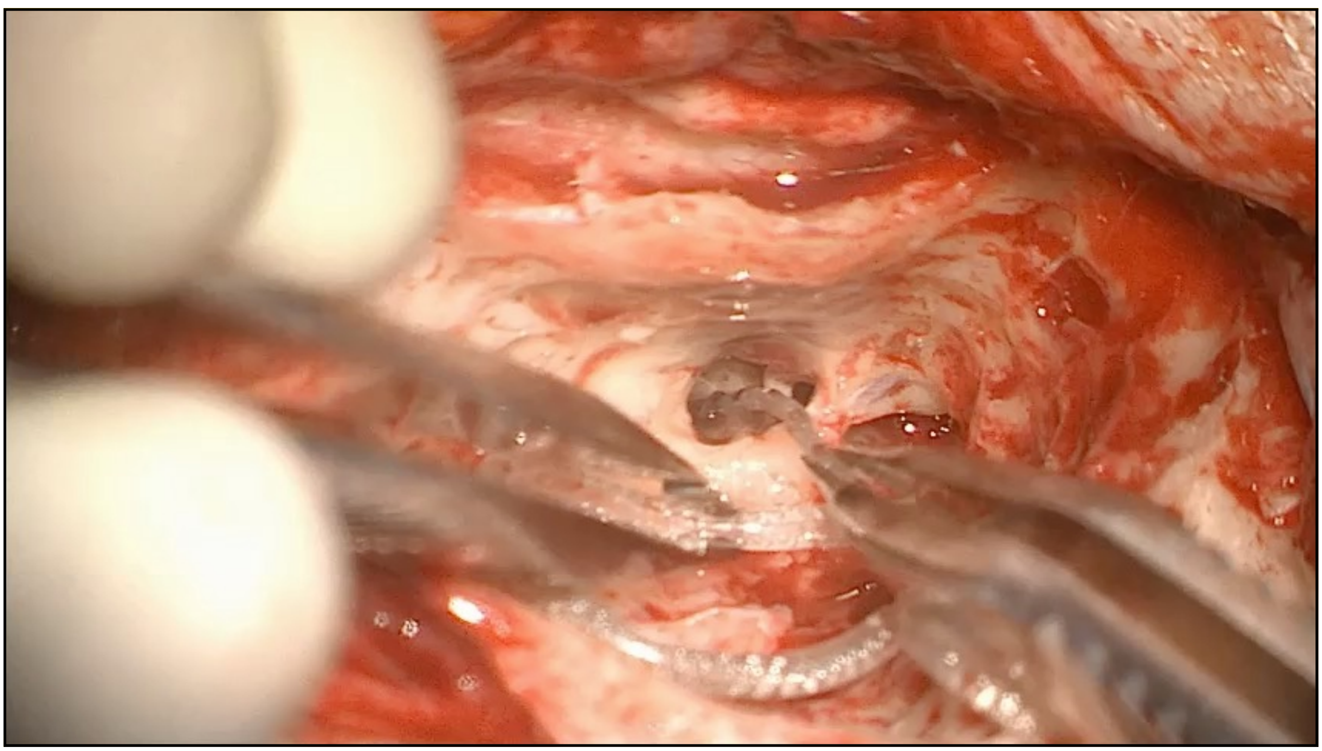

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Electrode Position Matters

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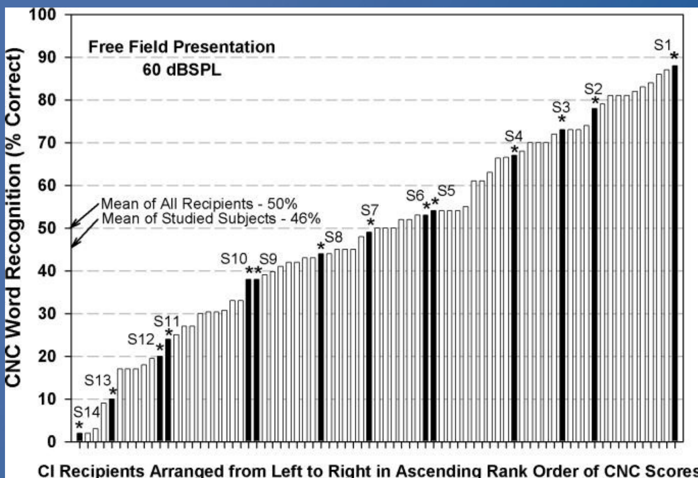

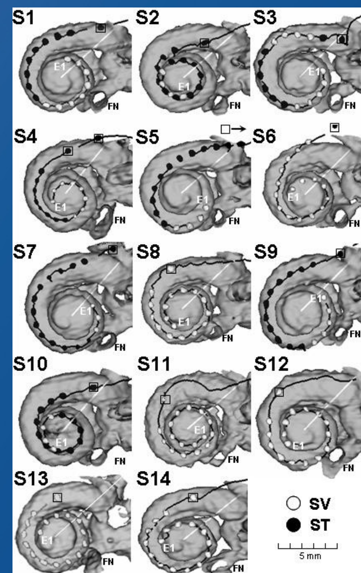

Finley CC, Holden TA, Holden LK, et al. Role of electrode placement as a contributor to variability in cochlear implant outcomes. *Otol Neurotol*. 2008;29(7):920-928. doi:10.1097/MAO.0b013e318184f492

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Electrode Position Matters

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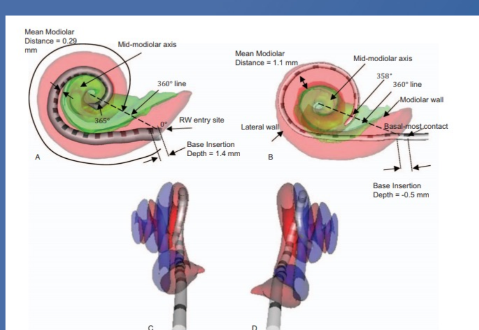

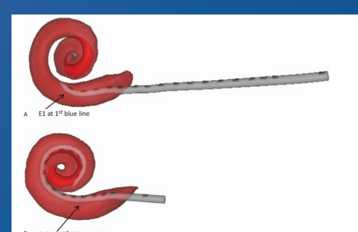

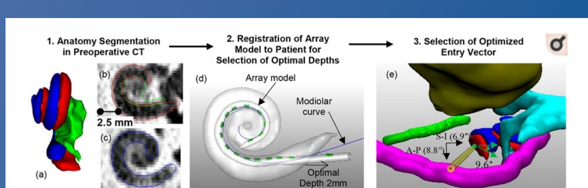

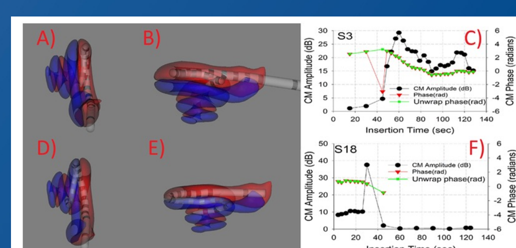

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Electrode Force Matters

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- Force of insertion is measured to be 20-40 mN in cadaveric models
- Force of trauma to the basilar membrane is ~120 mN
- This is beyond the resolution that a surgeon can detect

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iotaMotion

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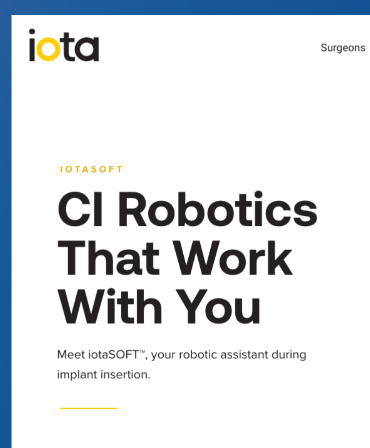
https://vimeo.com/736672184



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How Can Computers Help?

- Improve insertion vectors
- Improve insertion forces
- Improve electrode mapping
- Improve surgical efficiency
- Reduce cost of high-cost equipment
- Increase access to high-cost surgery
  - Easy to learn, easy to maintain, easy to fix, interchangeable components
- Simulations to train surgeons
- Make hearing rehabilitation more accessible by improving remote learning and programming

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Questions?

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