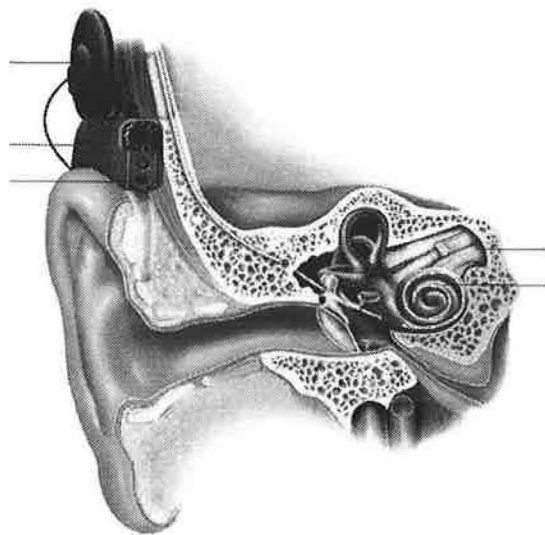


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Internal Medicine Grand Rounds
University of Texas Southwestern Medical Center at Dallas

July 7, 2005

Cochlear Implants



This is to acknowledge that Eric Steen, M.D. has not disclosed financial interests or other relationships with commercial concerns related directly or indirectly to this program. Dr. Steen will not be discussing off-label uses in this presentation.

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Cochlear Implants

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Cochlear Implants

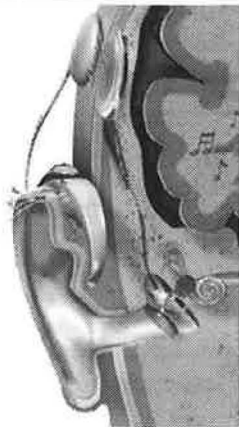
- Method of hearing/auditory rehabilitation
- Bypasses much of the ear anatomy
- Directly stimulates spiral ganglion cells

Bionic Sense Organs

- Electromechanical transducer
- Sound waves converted to electrical output
- Electrical stimulation of nerve
- Hearing aids just amplify sound using normal anatomy



Cochlear Implants



Goals for the Audience

- Estimate the demographics of hearing loss
- Summarize the anatomy and physiology of hearing
- Identify the various modalities used to improve hearing
- Describe cochlear implants

How Big a Problem is Deafness?

- U.S. - 22 million with hearing loss
- Estimated 464,000 - 738,000 with profound loss - candidates for cochlear implants

Third Most Prevalent Chronic Condition Behind Hypertension and Arthritis

- 25-40% pts over 65
- 40-60% over 75
- 80% over 85

Affects Quality of Life

- Dalton. *The Gerontologist* Vol 43; 5; 661-8
- Survey instruments
 - Mental health
 - Emotional health
 - Functional status
- Hearing loss related to poorer life quality

Only 25% of candidates get hearing help

Cost of Hearing Loss

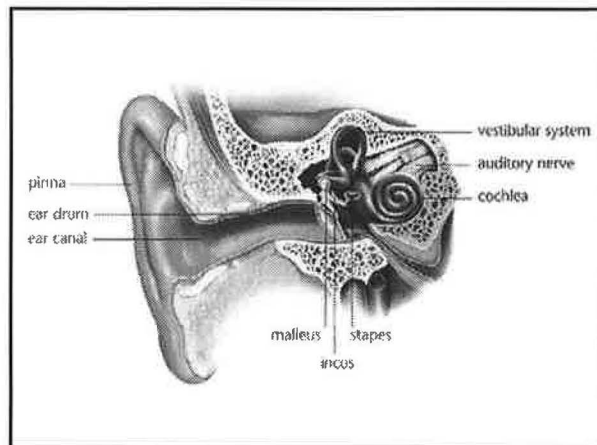
- \$2.5 billion dollars in workforce productivity losses
- \$2 billion cost of equal access for deaf
- Up to \$500,000 per child for education

Social Costs of Deafness

	Deaf	Normal
Unemployed Ages 18-44	42%	18%
High School Graduate	56%	81%
College Graduate	5%	13%

Review of Auditory Physiology

- Outer ear gathers sound waves
- Middle ear converts sound waves to mechanical energy
- Inner ear converts mechanical to electrical energy
- Brain processes electrical signals

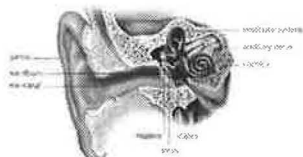


Outer Ear

- Pinna and ear canal
- Gathers sound
- Ear canal acts as resonator adds 3 dB

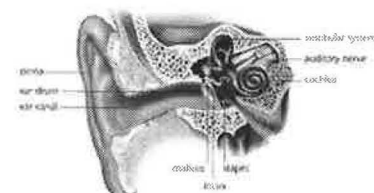
Middle Ear

- Tympanic membrane
- 3 ossicles- malleus, incus, stapes
- TM moves bones
- Convert sound to motion
- Stapes moves fluid behind the oval window
- 20-30 dB gain



Inner Ear

- Cochlea - hearing
- Labyrinth - equilibrium



Cochlea

- Snail shaped 2.5 turns
- 3 compartments of fluid
 - Scala vestibuli
 - Scala tympani
 - Scala media-cochlear duct - organ of Corti

Organ of Corti

- Organ of hearing
- 15,000 hair cells
- Cells spatially arranged by frequency
- Perilymph vibration stimulates basilar membrane
- Convert mechanical energy to electrical signal

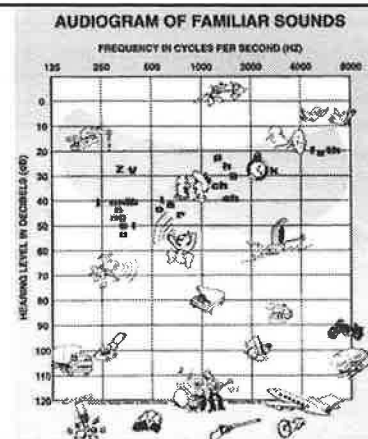
Cranial Nerve

- Axons from hair cells merge to form the acoustic branch of CN 8
- CN 8 to brain
- Brain is important for processing
- Can hear with a cochlear implant

How We Measure Hearing

Audiometry - Pure Tone

- Pure tones first at various Hz
- Test air conduction
- Test one ear at a time
- Test bone conduction
 - bypasses outer and middle ear



Hearing Loss Anatomic Characterization

- **Conductive**
 - pathology from the external to middle ear
- **Sensorineural**
 - cochlea or acoustic nerve dz
- **Mixed**
 - combination of the above
- **Central**
 - brain process that distorts processing

Conductive, Sensorineural, or Mixed?

- Do Weber and Rinne
- Audiograms can be wrong

Weber

- 512 Hz tuning fork on forehead
- Normal is not to “lateralize”
- Conductive lateralizes to bad ear
- Sensorineural lateralizes to good ear

Rinne

- Fork to mastoid
- When no longer heard on bone
- Hold 4” from ear
- Normal to hear air longer
- Conductive bone > air
- Sensorineural air > bone

Sensorineural

- 90% of hearing loss is sensorineural
- **Congenital**
 - can have delayed onset
- **Idiopathic sudden hearing loss**
- **Presbycusis**
 - most common, age related hair cell loss
- **Noise** (perhaps cause of presbycusis)
- **Ototoxic drugs**
- **Combination of factors**

Idiopathic Sudden Loss

- 1 in 5000 - relatively common
- Develops minutes to days
- Often wake up with it
- Affects young or old

Medical Emergency

- Huge outcome difference if treated in 3 days
- Definition - 30 dB loss in 3 frequencies
- Need audiogram for definitive dx
- Refer or start steroids

Exclude

- Viral
 - measles, herpes or mumps
- Perilymph fistula
 - usually after trauma
- Vascular occlusion
 - hopefully other neuro signs
- Meniere's
 - usually with vertigo
- Acoustic tumor
 - 40% can present with sudden loss but only 0.1% of idiopathics

Assumed to be "Autoimmune/Viral"

- TFT, RPR, possibly ANA, ESR
- Treat with steroids right away
- Po vs trans-tympanic route
- No data-anticoagulants, vasodilators...

Presbycusis

- Most people lose hearing as they age
- Usually above 2000 Hz
- Etiologies are controversial (all noise?)
- Reported elderly people in indigenous tribes with preserved hearing

Ototoxicity From Drugs

- Antimalarials usually temporary
- Aspirin
- Aminoglycosides (biggest litigation issue)
- Loop diuretics
- Cisplatin
- Get consent

Aminoglycosides

- Long perilymph T $\frac{1}{2}$
- Directly toxic to hair cells
- Genetic predisposition

Methods to Help Hearing Loss

- Assist devices - increase signal to noise ratio
- Amplification - hearing aids
- Implantable hearing aids - to oval window
- Cochlear implants
- Brainstem implantation
- Training

Hearing Aids

- Many sizes, shapes, prices
- Last 3 - 5 yrs
- Cheapest \$250 new, Lion's Club, Ebay
- Two ears are better
- BAHA-bone anchored to improve conductive loss
- Cost, "feeling old," difficult to use

Audiologists

- Important in all aspects of hearing
- Masters or doctorate level trained
- Selection of hearing devices
- Lip reading, body language, facial expressions
- Key to cochlear implant success

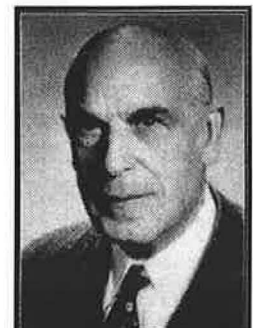
Cochlear Implants

- 60,000 done worldwide
- At UTSW youngest - 12 months
- Oldest adult - 92 yrs

History



Andre Djourno (1904-1996)



Charles Eyrles (1908-1996)

Paris 1957

- Djournno interested in nerve stimulation
- Eyries ENT chair
- Pt s/p bilateral cholesteatoma operation
- Facial nerve palsies
- Eyries looking for nerve graft material
- Met Djournno

Implantation

- Pt could tell intensity
- Frequency to some degree
- Few words
- Array broke twice
- Djournno tried a streptomycin pt
- Pt had little interest and lost to f/u

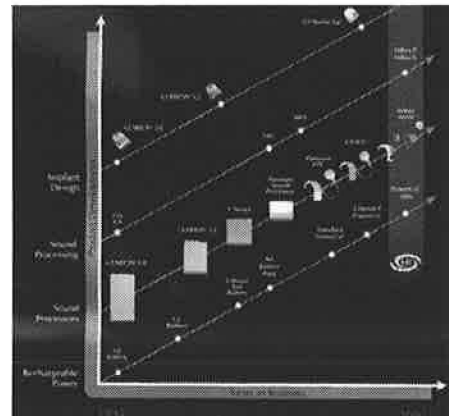


William F. House MD (Born 1923)
The "father of neurotology."

Testing in United States House / Doyle

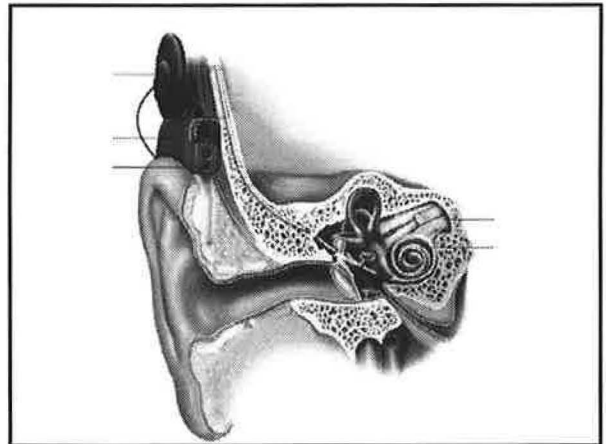
- 1960 concomitant stapes operation
- Developed frequency / duration curves
- 1961 - 3 testing
- Pt could follow voice rhythm
- Help with lip reading
- Still worked after 2 yrs

Modern Cochlear Implant



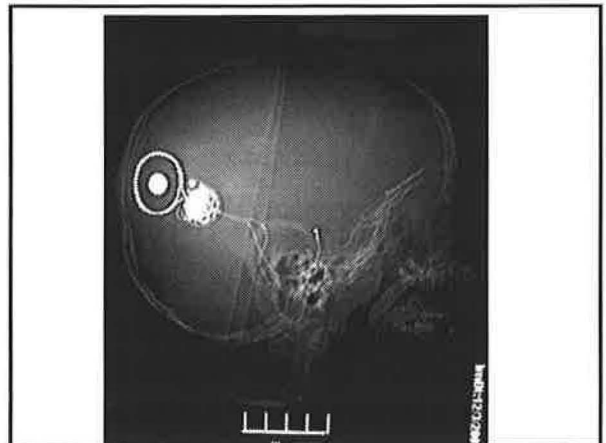
Microphone Externally Behind Ear

- Sounds taken to speech processor
- Converted to electrical impulses
- Sent to external magnet
- Magnet emits signals



Received by Coil Under the Skin

- Fed to electrode array
- Which stimulates spiral ganglion cells of the cochlear nerve
- Then signals go to CN 8 and CNS



Initial Screening for Postlingual Deafened Adults

- Pure tone loss > 70dB
- Hint testing

Special Tests

- HINT (hearing in noise test)
 - Good for sentences
 - Used in eligibility determination
 - CNC consonant nucleus consonant
 - Good for words
 - Used to follow success of CI

Psychological Evaluation

- Key (as with many procedures)
- Realistic expectations
- Will pt / family rehab?
- Especially prelingually deafened teens

Usually Implant Better Ear

Bilateral Implantation

- Pro
 - Head shadow effect
 - Allows sound localization/squelch
 - One study showed better hearing

Bilateral Implantation

- Con
 - Cost
 - Use up both ears / future technology
 - dizziness

Devices

- 3 available in United States
- No one proven superior
- Different features - like PC vs MAC

Hardware and Software Choices

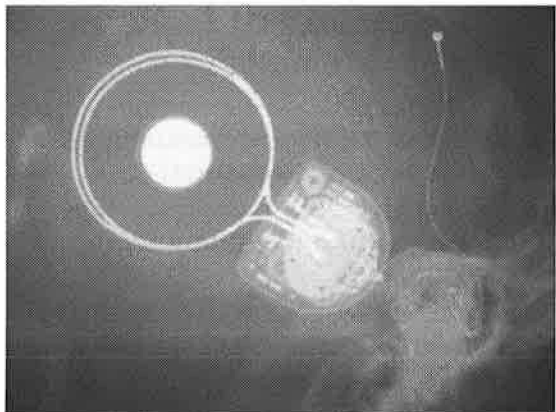
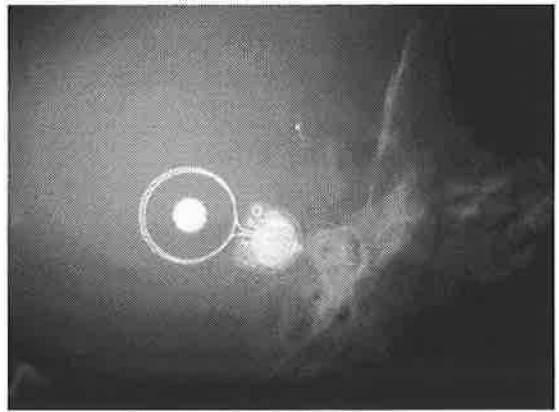
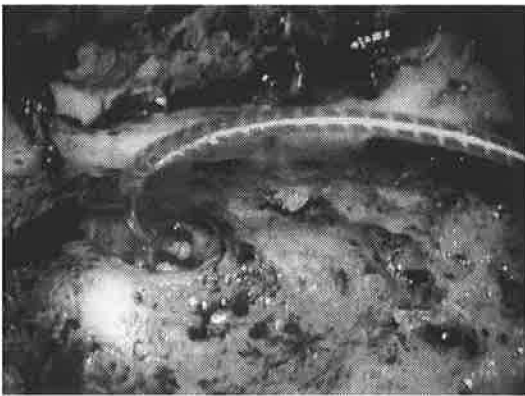
- Stimulate different frequencies at same time or sequentially
- Try to send only most useful frequencies
- How many channels?

Short Array

- Good for high freq loss
- Short lead into proximal cochlea
- Stimulates only high freq areas
- Lets pts use own low freq areas
- Allows pt to hear music

Surgical Procedure

- Skin flap
- Receiver/stimulator attached to bone well
- Mastoidectomy
- Cochleostomy
- Insert array
- Outpatient, 2 hours



Complications

- Facial nerve - rare <1%
- CSF leak / meningitis
- Transient alteration of taste
- Wound infection usually not problematic
- Flap necrosis can be serious
- May deafen implanted ear
- Dizziness / vertigo / balance

Device Problems

- Damaged arrays
- Misplaced arrays

Post Op - Hook up 4 wks

Programming by Audiologist

- Thresholds
- Comfortable loudness
- Uncomfortable loudness
- Takes several hrs to do all electrodes
- Fine tune over months
- Improve over 1 - 2 years

Rehab Training

- Critical, especially children
- Specially trained audiologists
- Allows pts to get most benefit
- "Like learning a foreign language"

**Do Cochlear Implants
Improve Hearing?**

Cohen NEJM Vol. 328; p233-7 1993

- Prospective randomized comparison of 3 CIs in 82 pts
- Multichannel clearly better than single channel
- All pts hear some
- No facial nerve injury, flap necrosis, array migration
- 60% had some open set word recognition

1993 Results

- Also environmental sounds
 - alarms, cars, birds
- Helps with lip reading
- Quality of life assessments
- Cannot perfectly predict individual results

Gstoettner Acta Otolaryngol 118; 1998

- Numbers 0 to 70 - 100%
- Monosyllables - 0 to 46%
- Sentences - 58% to 78%

2005 Results in Adults

- Personal communication with Christy Powell
- CI audiologist UTSW

**Said to Sound Robotic
Donald Duck Like at First**

- Pts not used to high frequencies
- Base of cochlea is for high freq and most exposed to problems
- 80% of speech is between 1 - 4K Hz

**Do Not Need Every
Tone to Understand**

All Gain Awareness of Sound - Safety Issue

Recently Deafened Get Best Results

- Some can close eyes and hear speech right away
- Use telephone in one month
- Max out HINT but not CNC
- CNC of 75% is great score

Deaf for > 10 yrs

- Immediate awareness of sound
- Often rely on lips for several months
- Results will vary
- Lose auditory cortex - used for vision?
- Nerve atrophy?

50 - 60% Some Telephone Use

Majority

- Max out HINT in 3 months if can use lip reading too
- Not max out CNC

Most Difficult Sounds For All

- Listen to music
- Work with background noise

Geriatric

- Can work as well
- Labadie - Otolaryngol Head Neck Surg Vol 123 Oct 2000
- 47 year old vs 72 year old no difference
- Need speech and sound exposure to learn
- Avoid in those who live alone and will not seek sound exposure

2005 Results in Children

- Personal communication with Janee Willett
 - implant audiologist Callier Center
- Implant at age 1 and wear it and train
- 90% enter normal school if not MR
- <1% no benefit
- 25% of parents do not have pt wear it
- This group does much worse

Practical Test of Results Do Patients Use It?

Archbold et al

- Am J Oto 1998; 19:328-31
- 161 kids over 3 yrs
- 95% kids all the time, 4% most of the time
- Similar with adults
- Improved use of phone
- Compare to use of Jobst stockings

Older Children or Young Adults

- Prelingually deafened
- Much worse results
- Likely too late
- Brain "plastic" age 1 - 5

Approximate Cost \$40K ("Charges")

- Medicare out of pocket \$5500
- Other insurances vary

Cost Effectiveness

- Surprising number of studies
- Done for insurance reasons
- No survival benefit
- Quality of life improvement

Surprising Uniformity of Benefit

- \$10 - 15K per Quality of Life Year
- \$20-25K a “good deal”
- Defibrillator - \$39K
- Total knee - \$59K
- 1 vessel stent – \$100K

Summary

- Expect to diagnose hearing loss
- Refer significant hearing losses
- Utilize Auditory rehab/aids
- Describe cochlear implants

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