Cochlear Implants Today: Current Practice and Emerging Technology

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Learning Objectives:

- Describe the fundamental components and function of a cochlear implant system, including candidacy criteria and expected outcomes.
- Identify current gaps or limitations in cochlear implant technology and practice.
- Discuss emerging technologies and innovations in the cochlear implant field and their potential impact on future patient care.

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Disclosures

- None

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- ~1/3 of patients have substantial reservations about proceeding with CI
- 20-36% of patients for whom CIs are recommended do not proceed with CI

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CI barriers to care

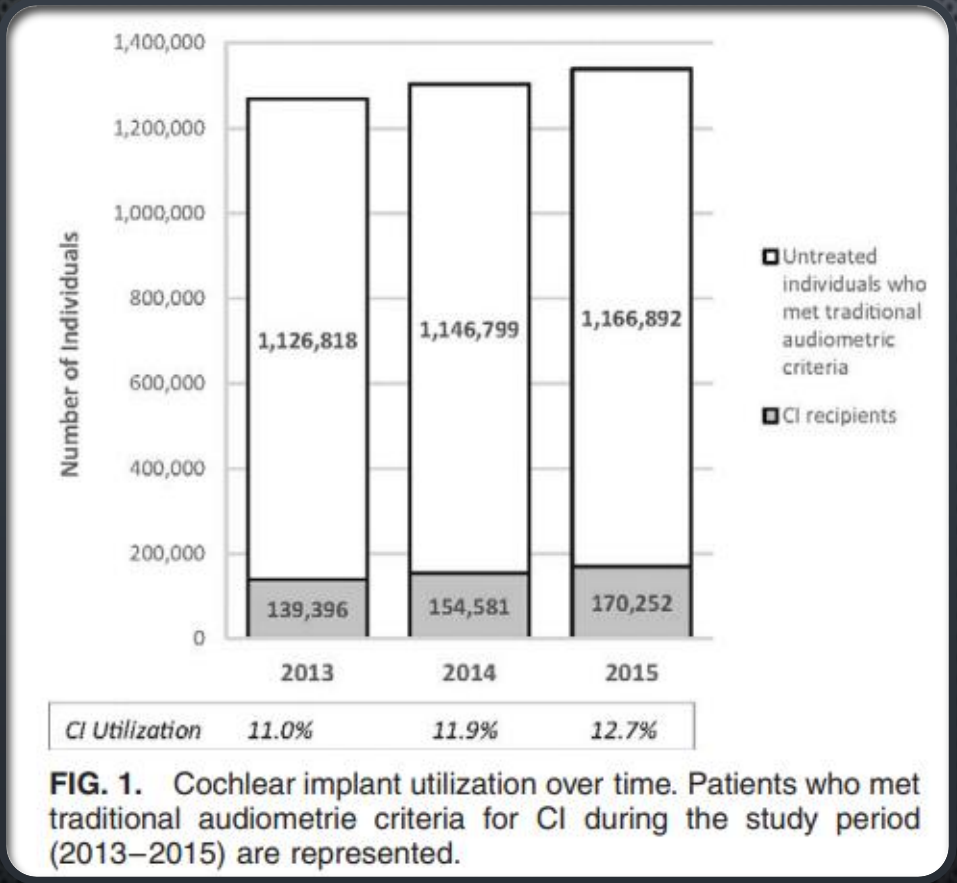

FIG. 1. Cochlear implant utilization over time. Patients who met traditional audiometrie criteria for CI during the study period (2013–2015) are represented.

- Current CI utilization ranges from 2.1% to 12.7% (Nassiri et el., 2022)
- Indications for cochlear implantation are expanding
- Why??
  - Misconceptions about CI
  - Patient education on options for hearing loss
  - Socioeconomic and geographic inequities
  - Medical mistrust
  - Racial and ethnic disparities and outreach

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Candidacy

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Candidacy Initially…

- Initially very strict but straightforward
- Bilateral profound deafness and **failure to receive benefit from hearing aids**
- FDA controls criteria for candidacy, but insurance companies dictate the details

FDA Labeling for CI

- Differs per company (Advanced Bionics, Cochlear, and Med-El)
- Over the past 25 years, essentially considers **children** who:
  - Have bilateral severe-to-profound sensorineural hearing loss
  - Over 12 months old
  - Have no greater than 20-30% word recognition score
- Over the past 25 years, essentially considers **adults** who:
  - Have bilateral moderate-to-profound sensorineural hearing loss
  - Have no greater than 60% sentence recognition score in the best-aided condition
- **Outdated!** Patients are implanted outside of these criteria who benefit from cochlear implantation

Recent Advancements…

July 2019: Med-El received FDA approval for use of their cochlear implant for single-sided deafness and asymmetric hearing loss down to 5 years old. Cochlear followed suit in January 2022.

March 2020: Cochlear announced that they received FDA approval for use of their cochlear implant in children as young as 9 months old with bilateral profound sensorineural hearing loss. In November 2025, Med-El was FDA approved for use as young as 7 months.

October 2022: Medicare expanded their candidacy criteria to include all individuals who perform less than or equal to 60% in the best-aided condition

- All of these advancements help pave the way to expanded criteria for all potential cochlear implant recipients
- Insurance companies often have different criteria!

When to refer?

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Referral guidelines: Adults

- Using a 60/60 screening tool (Zwolan, Schvartz-Leyzac, & Pleasant, 2020)
- Used for hearing loss in BOTH ears

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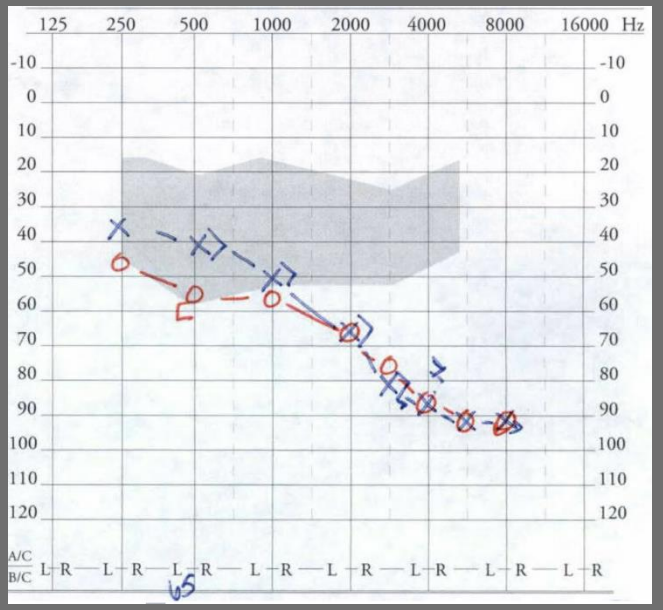
Case 1

- 86-year-old male
- Longstanding moderate to profound SNHL with consistent hearing aid use
- Poor quality of life
  - Struggles to communicate in most environments with hearing aids
  - Withdrawing from social situations
- Cochlear implant evaluation raised concerns for significant cognitive decline
  - Poor aided word recognition
- AuD and ENT recommended neuropsychology evaluation prior to cochlear implantation

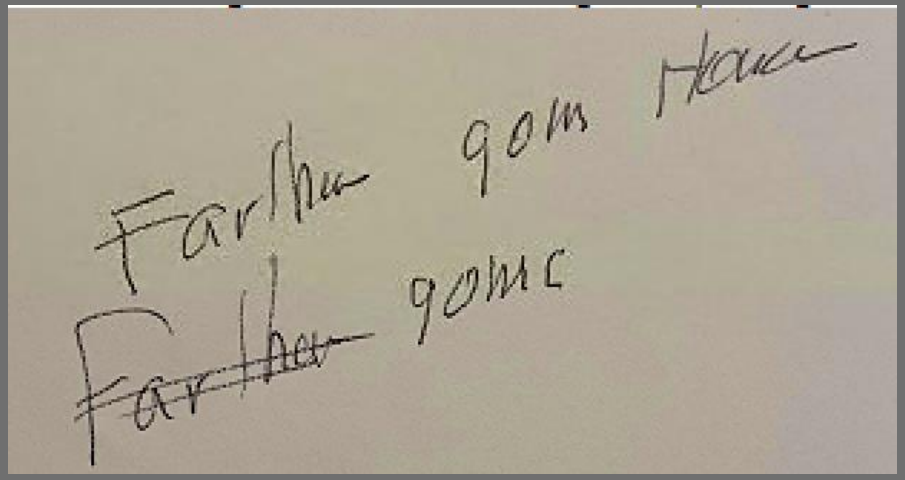


Test	List #	Right Aided	List #	Left Aided (FIRST PRESENTATION)	List #	Left Aided (REPEATED)
CNC- Words	6	54%	7	22%	9	44%
CNC- Phonemes	6	60%	7	24%	9	53%
AzBio Sentences- Quiet	7	61%	10	32%	11	45%
AzBio Sentences- +10 SNR	19	10%	DNT	DNT	6	6%

- Neuropsych evaluation
  - 16/30 on Hearing Impaired MoCA
  - Met criteria for **major neurocognitive disorder**
  - Possible aphasia

- **Team decision to proceed with cochlear implantation with guarded expectations**

"Father came home"

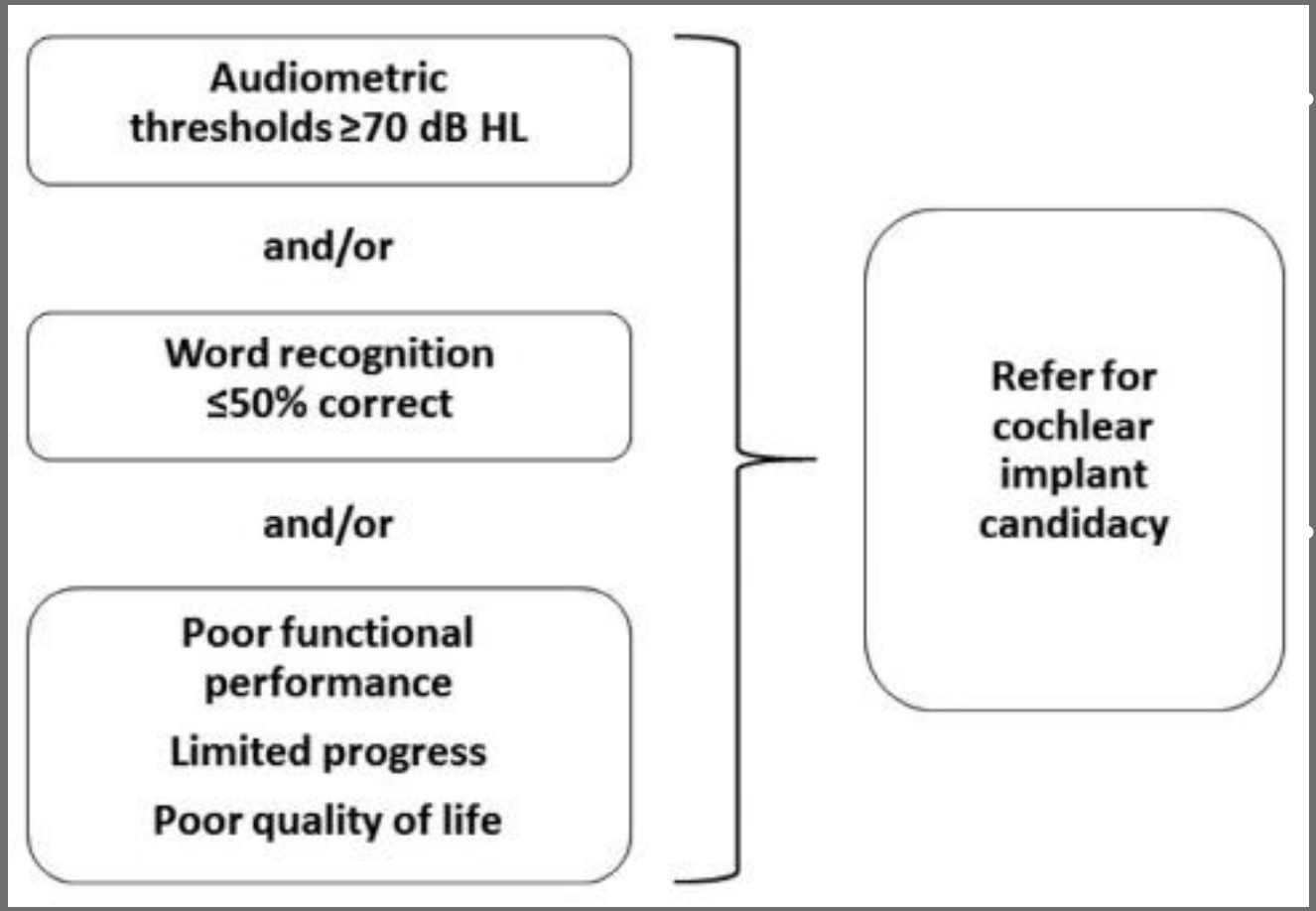


Case 1

- Currently 3 months post activation
- Quality of life improved significantly
  - Communicates with less effort
  - Becoming more social and active
  - Enjoys television
- "It gave me my life back"

Test	List #	CI Score	List #	CI + HA
CNC- Words	2	68%		
CNC- Phonemes	2	82%		
AzBio Sentences- Quiet	16	60%	18	77%
AzBio Sentences- +10 SNR	17	29%	20	68%

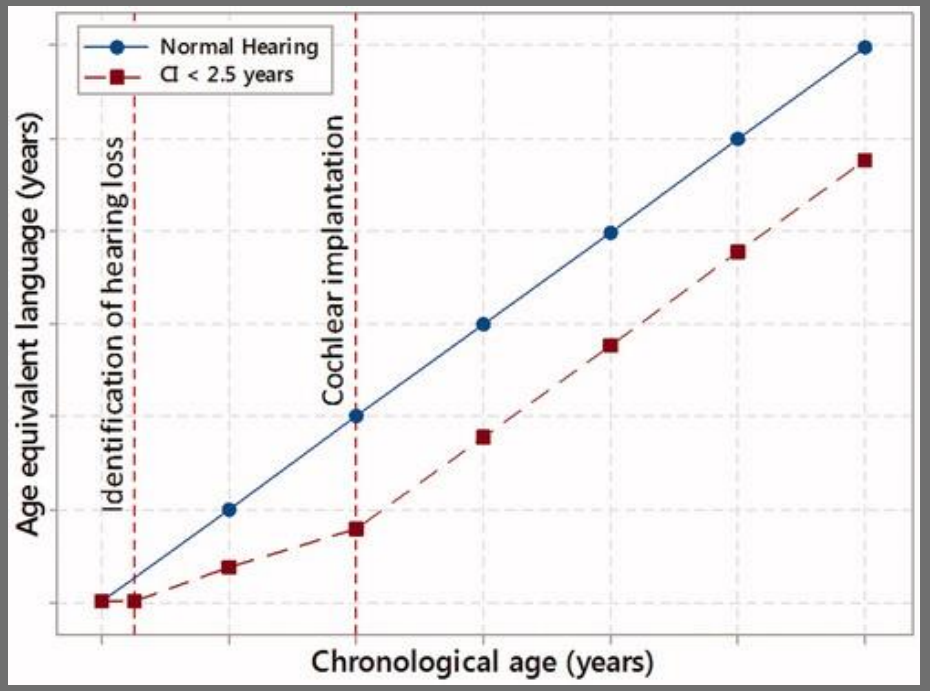
Referral guidelines: Pediatrics



- 50/70 referral criteria for children
  - (Warner-Czyz, et al., 2022)
- Used for hearing loss in BOTH ears

Pediatric Referral

- "Children implanted under 2.5 years with no significant cognitive deficits made normal language progress but maintained a delay approximately equal to their age at implantation"



Leigh, Dettman, & Dowll, 2016

Long-term communication outcomes for children receiving cochlear Implants younger than 12 months: A multicenter study

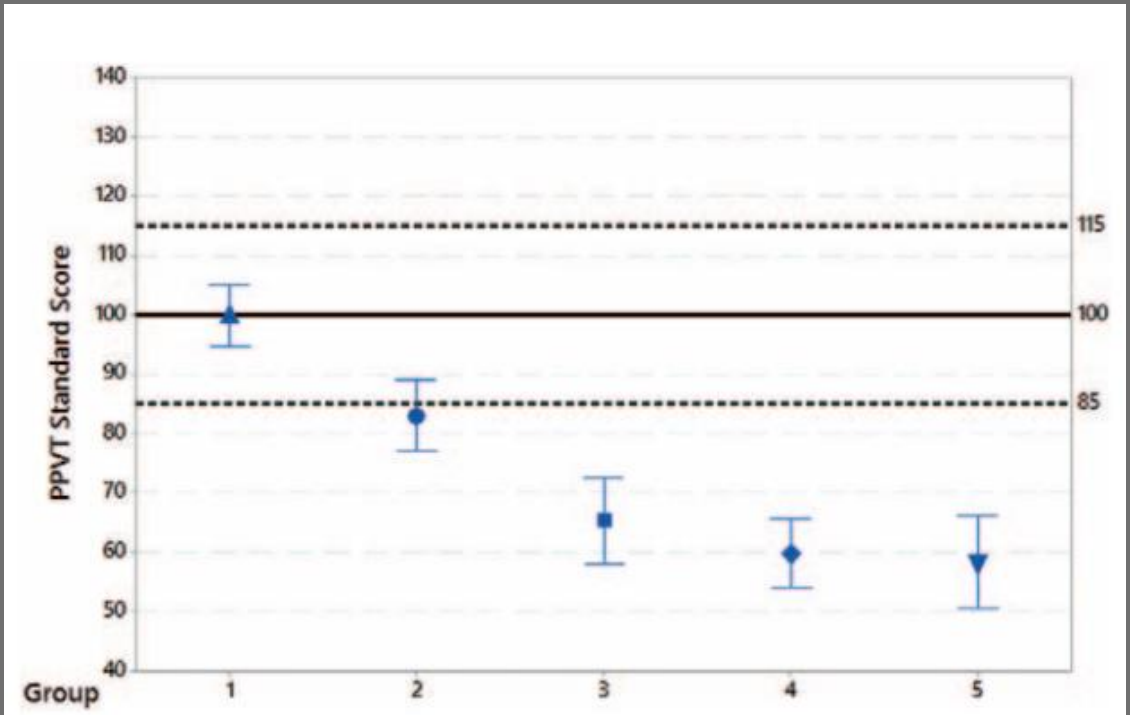


FIG. 4. PPVT standard scores for n = 207 at school entry, Groups 1–5.

Dettman et al., 2016

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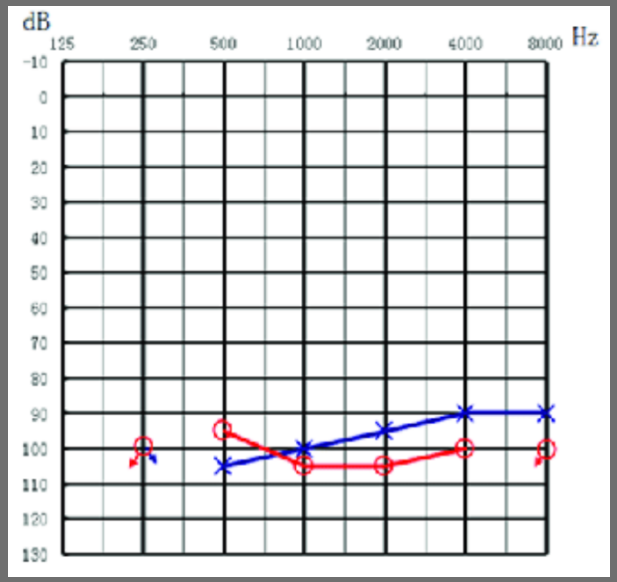
Case 2

- Born at 25 weeks
- Global developmental delay
- Diagnosed with bilateral profound loss as an infant
- Consistent hearing aid use
- Cochlear implants ~11 years old
- Realistic expectations:
  - Other factors contributing to language development
  - Family wanted better sound awareness
- Now 17 years old, full-time use of devices
- Uses an ASL interpreter and communication board
- Family reports he is more engaged and interactive



What about asymmetric (AHL) and Single Sided Deafness (SSD)?

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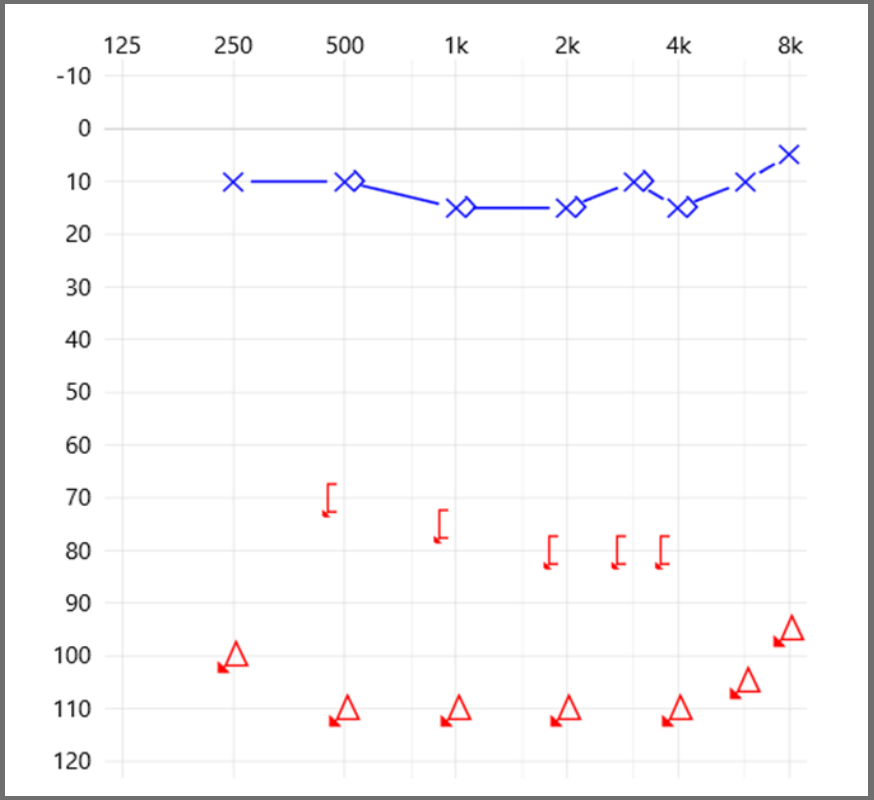
Single Sided Deafness

- Ear to be implanted: Severe to profound
- Contralateral: Normal to mild hearing loss



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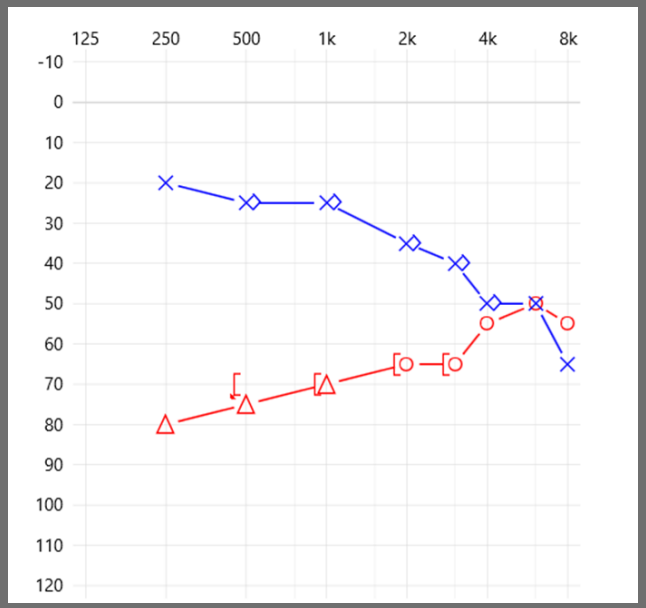
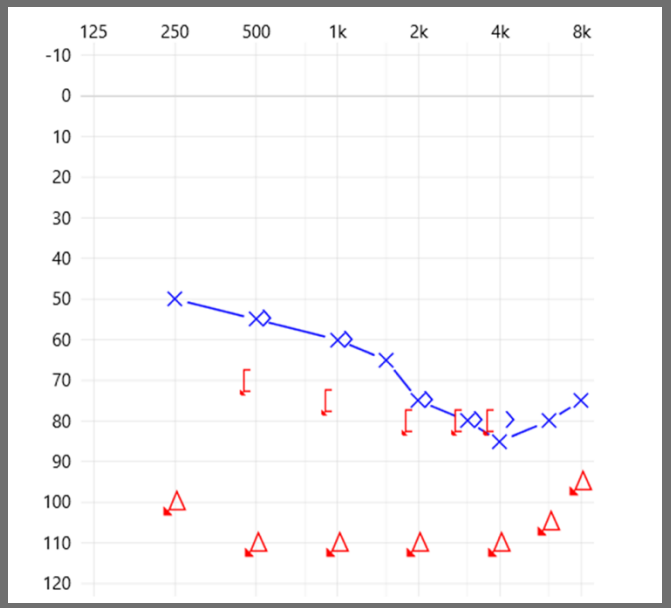
Asymmetric Sensorineural Hearing Loss

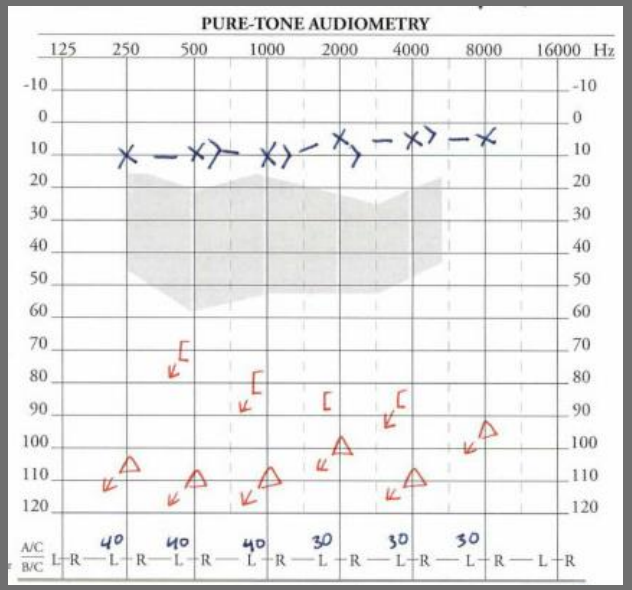
- Wide spectrum of hearing loss between SSD and profound bilateral loss





SSD: Sudden Loss

- 7-year-old male
- Etiology: skull fracture after golf cart accident
- Tinnitus present, vertigo resolved at time of CIE



Test	List #	Left Unaided	List #	Right Aided*
LNT hard	1	84%	2	0%
CNC- Words	1	84%	2	0%
CNC- Phonemes	1	92%	2	0%
Pediatric AzBio Sentences- Quiet	4	99%		DNT

*with 50 dB HL of masking presented to the left ear via insert

- Parents report he cannot localize without it
- Patient reports "it just feels right"
- Uses remote microphone in school

1 month – 9.8 h/d

Test	List #	Score
LNT Easy	1	20%

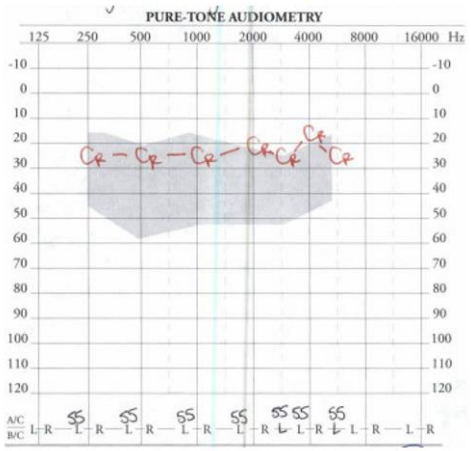
2 months – 6.7 h/d

Test	List #	Score
LNT Easy	2	68%

6 months – 6.7 h/d

Test	List #	Score
CNC Words	1	35%
CNC Phonemes	1	64%
AzBio Peds Sentences- Quiet	4	73%*

1 year – 6.8 h/d



Test	List #	Score
CNC Words	4	62%
CNC Phonemes	4	82%
AzBio Peds Sentences- Quiet	2	81%
AzBio Peds Sentences- +10 SNR	7	51%*

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AHL and SSD Take Home

- We can't necessarily look at an audiogram and determine candidacy, we look at their functional benefit with a HA, quality of life, and the person as whole to decide if they would benefit from a cochlear implant.
- Sudden losses generally do quite well
  - Ideally need to evaluate benefit better using spatial testing
  - Improved localization and attention is the most common reported benefit by parents
- Longer periods of auditory depravation (6-11 years in these cases) limit speech understanding
  - Less report of benefit by individuals
  - Feel sound as pressure rather than hearing it

"There are no inappropriate referrals for a CI. If a patient does not meet candidacy criteria, the evaluation will provide an opportunity for counseling and a baseline for monitoring progression." (Warner-Czyz, et al., 2022)

Current Technology

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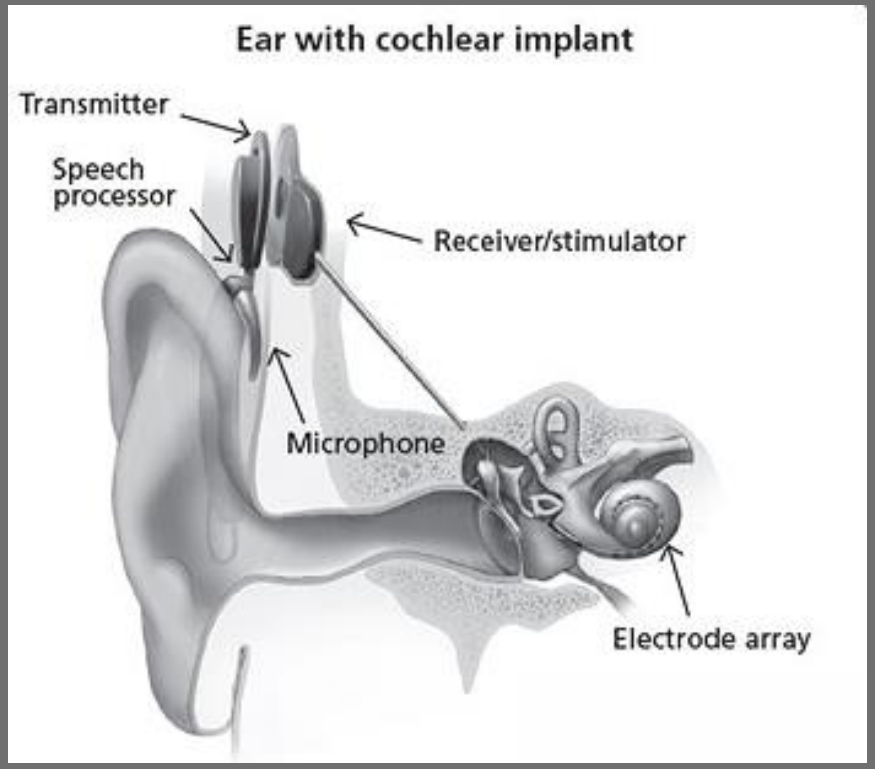
Cochlear Implant



Internal Device

1. Receiver Stimulator
2. Electrode Array +/- Grounding Electrode

External Component

1. Sound Processor with microphone

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Cochlear Implant Evaluation

Audiologist

- Unaided hearing testing
- Aided hearing testing
- ?Vestibular screening
- Questionnaires (MoCA)
- Discussion

Neurotologist/Otologist

- Medical evaluation
- Imaging (CT or MRI)
- Surgery discussion
- Other referrals (developmental peds, neuropsych, SLP)

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Cochlear Implant Surgery

- Outpatient (home same day)
- Lasts ~ 2 hours
- Small post-auricular incision with little to no hair trimming
- One ear at a time (unless pediatrics)
- Device activation in 2-4 weeks (changing!)

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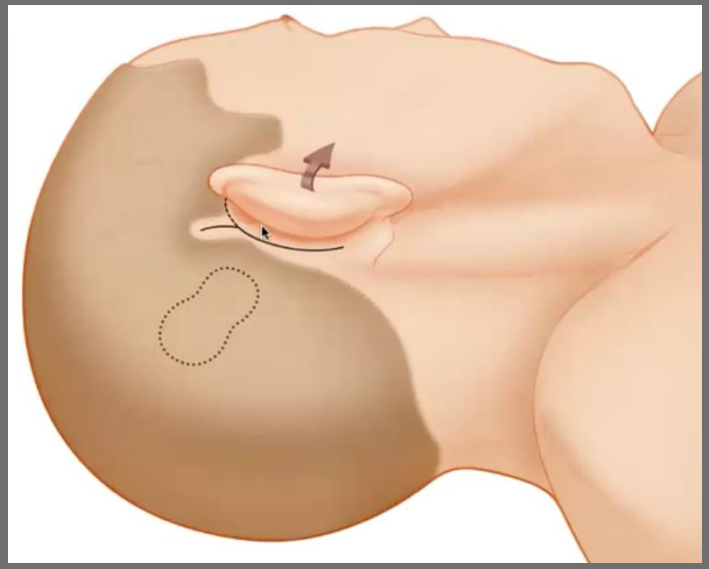
Surgery

- GA
- Otologic position
- Small skin incision (prior wound healing problems)
- Mastoid → facial recess → RW niche → Scala tympani insertion
- Subperiosteal pocket



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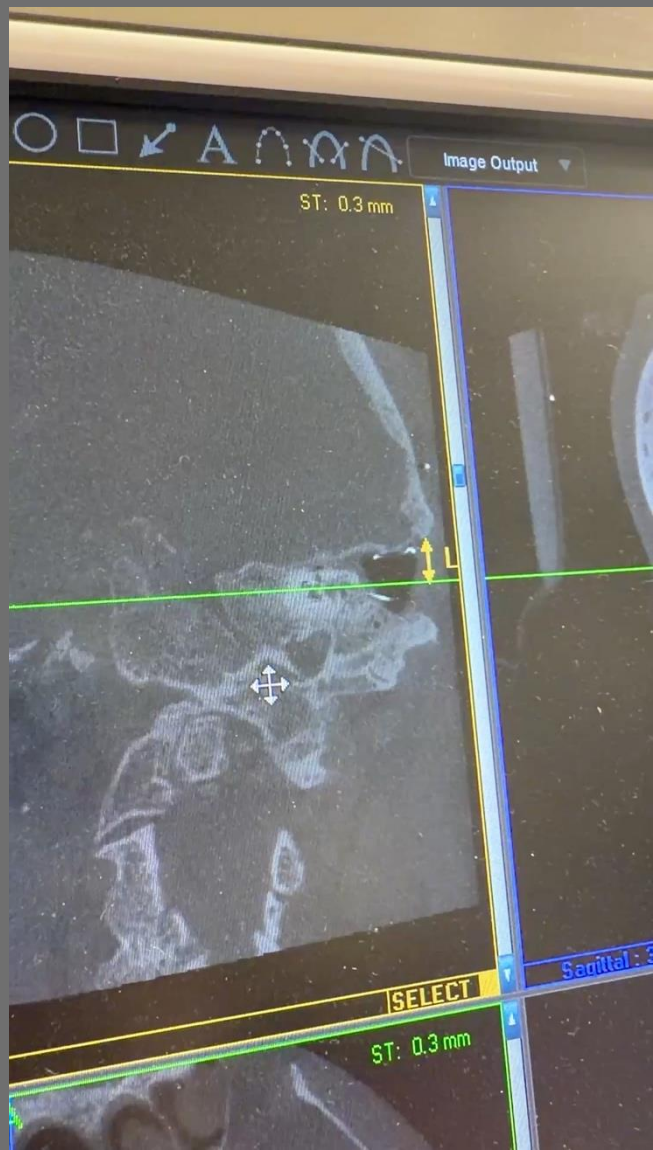
Testing in the OR?

- **Impedances**
  - Function of the array itself and resistive characteristics of the fluid or tissue surrounding each electrode
  - Provides information about individual electrode integrity and electrode tissue interface
  - **Is it in water?**
- **Electrically evoked compound action potentials (ECAP)**
  - NRT, ART based on company
  - Electrically stimulates the auditory nerve and neighboring electrode and records response. *
    - *You will get response if stimulating facial nerve as well
  - **Does the electrode work?**
  - Can be used to estimate safe and comfortable hearing levels, especially in pediatric population

Testing in the OR?

- Imaging
  - X ray or CT scan for device placement
  - Reassurance for families and surgeon
  - Done prior to wake up, after incision closure unless concerns



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Surgical Complications

- Facial nerve injury (<0.1%)
- CSF leak
- Wound dehiscence, wound infection
- Balance problem (2.2%)
- Meningitis (<0.1%)
- Device Exposure, pain, late device failure (1.9-6%),
- Facial nerve twitching after activation (~7%)
  - More common in bony abnormalities of the cochlea
  - Turn off offending electrode, do not remove the implant

Surgery for Cochlear Implants

- Team approach
- Adjustment of internal device placement for patient comfort and processor placement

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Setting Expectations

Time

- 3-12 months (up to 3 years?)
- Generally, 'mechanical sound' will improve in that 3–6 month window
- Slower gains if >80 years old
- Slower and unpredictable in cochlear nerve deficiency

Practice

- Listing exercises

Dedication

- Must wear as often as possible

Patience

- Must adjust to new hearing normal
- Won't sound like "normal" hearing

How do we measure outcomes?

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Audiometric Outcomes

- Acoustic and electric thresholds do not reliably correlate with post-op speech
- Speech testing (8-54% improvement)
  - CNC word (+33.7%)
  - CNC phoneme
  - AzBio sentence testing
    - Quiet (+45.6%)
    - Noise, 10 dB (+33.6%)

Who succeeds here?

- Shorter duration of deafness
- Higher preoperative speech scores
- Who has poor outcomes?
  - Minority, up to ~16% of adults score <30% at12 months

Quality of Life Outcomes (PROMS)

- **There are many….**
  - **CIQOL-35 Profile and CIQOL-10 Global —** CI-specific, psychometrically validated across six domains (communication, emotional, entertainment, environment, listening effort, social); recommended by current living guidelines and more robust than legacy instruments.
  - **Nijmegen Cochlear Implant Questionnaire (NCIQ)** — legacy CI-specific QoL instrument.
  - **Speech, Spatial and Qualities of Hearing Scale (SSQ/SSQ12)** — especially for spatial hearing self-report. [
  - **APHAB, Glasgow Health Status/Hearing Participation Scale, Health Utilities Index 3 (HUI-3), and VAS satisfaction** — general and hearing-specific benefit/QoL measures (HUI-3 shows weak reliability and is not recommended).
  - **Satisfaction and decisional regret —** associated with CIQOL gains more than with speech scores.
  - **LivCI —** a newer PROM targeting personal factors of living with a CI.

CIQOL Toolkit

1. CIQOL-35 Profile — measures *actual* QOL across 6 domains (communication, emotional, entertainment, environment, listening effort, social); 0–100 scale

2. CIQOL-Expectations — same items in future tense; captures what a candidate *anticipates*

3. c
vi

Stage III (Moderate Limitation)	**46 – 65**	*"I handle routine one-on-one talks easily and can follow familiar voices without looking at them. Small, quiet family gatherings are manageable, though noisy restaurants or multi-talker rooms remain exhausting or difficult."*	Common 3-to-6-month post-activation milestone for average performers.

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Measure → Compare → Correct

	Never	Rarely	Sometimes	Often	Always
1. I will be able to have a conversation in a quiet place without asking the other person to repeat themselves					
2. Other people's voices will sound clear and natural to me					
3. I will be able to have a conversation with a group of three or more people					
4. I will be able to have a conversation without asking the other person to repeat themselves					
5. I will be able to hear and understand without looking at the person speaking					
6. I will have to ask a lot of questions about what is being said in a conversation					
7. I will understand a conversation in a crowded environment (restaurant, party, etc.)					
8. I will be able to have a conversation with someone in a noisy place without asking them to repeat themselves					
9. I will understand strangers without lip-reading in a noisy place					
10. I will follow the conversation in a group of five people in a crowded restaurant when I cannot see everyone					
11. I will feel comfortable being myself					
12. My hearing loss will make me feel inadequate					
13. My hearing loss will make me irritable					
14. I will keep quiet in a conversation to avoid saying the wrong thing					
15. I will become frustrated when I cannot follow a conversation					
16. My hearing loss will prevent me from listening to TV or radio					

Communication

Emotional

	Never	Rarely	Sometimes	Often	Always
17. I will be able to enjoy listening to the radio and TV					
18. I will be able to enjoy music					
19. I will recognize certain melodies in music					
20. Music will sound clear and natural to me					
21. Everyday sounds (birds chirping, rain, car horns, etc.) will be are clear to me					
22. Everyday sounds (microwave, birds chirping, rain, car horn) will sound natural to me					
23. I will be able to distinguish sounds in nature					
24. I will be able to hear cars approaching in traffic					
25. I will be able to hear someone approaching from behind					
26. I will be able to follow a conversation with minimal effort					
27. I will be able to ignore competing sounds and focus on the person who is speaking					
28. I will easily have a conversation in a noisy place (restaurant, party, store)					
29. I will have to concentrate when having a conversation					
30. I will have to concentrate when having a conversation with strangers when in a noisy place					
31. If I am interested, I will join family or friends for a social event					
32. I will have the confidence to socialize					
33. I will avoid socializing with friends, relatives, or neighbors due to my hearing loss					
34. I will avoid social situations due to my hearing loss					
35. I will feel left out when I am with a group of people due to my hearing loss					

Entertainment

Environment

Listening Effort

Social

McRackan TR, Hand BN, Chidarala S, Dubno JR. Understanding Patient Expectations Before Implantation Using the Cochlear Implant Quality of Life-Expectations Instrument. JAMA Otolaryngol Head Neck Surg. 2022;148(9):870-8. PMID: 35951334; PMCID: PMC9372907.

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Studying Expectations

- **Expectations are identifiable modifiable**
- Expectations most often exceed reality in **communication** and **listening effort** (<1 in 5 experienced users reach expected level)
- **Emotional domain** aligns best (~60%)
- At 12 months: expectations **unmet in 42%**, **met in 49%**, **exceeded in only 10%**
- Can be modified from high expectation to moderate after counseling

Emerging Technologies

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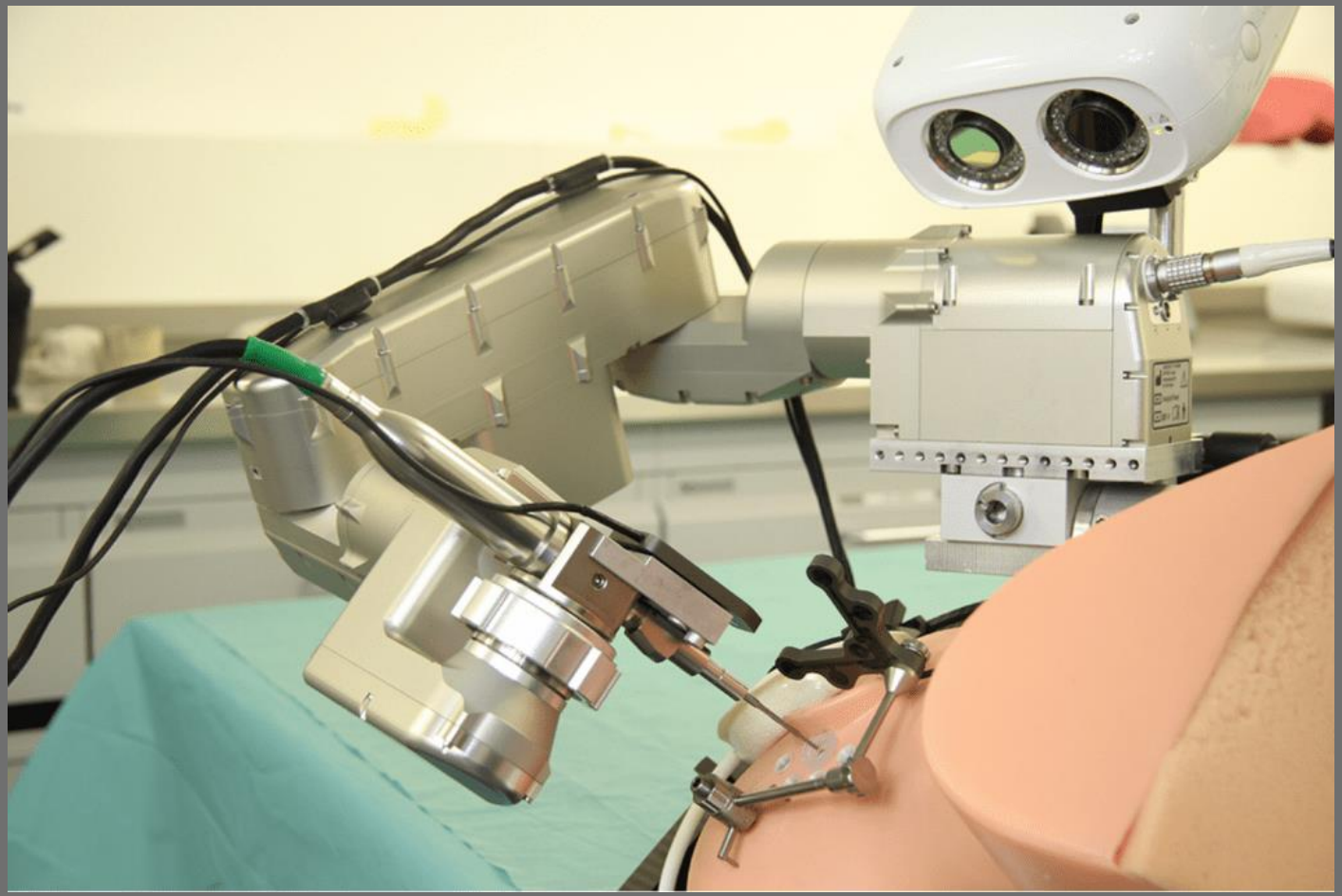
…So much to discuss!

- Tinnitus
  - Improvement of tinnitus with CI is a convenient side effect
  - Etiology is complex and not understood completely
- SSD
  - Localization and better SR in noise, reduced tinnitus
- Implantation with retrocochlear lesions and after tumor surgery
- All FDA approved magnets are currently MRI-conditional up to 3 Tesla

Flexible Arrays

- Hearing preservation (low frequency) with thinner, flexible electrodes
- Insertion techniques & drug eluding electrodes (ie dexamethasone) to decrease insertion trauma, reduce foreign body response and preserve low frequency hearing
  - Trials are ongoing

Robotic Insertion



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Upgradable Software

- Traditionally, upgrades require hardware adjustments (processor)
- New devices have onboard memory and upgradeable firmware
- Automatic syncing can reduce the need for in person mapping appointments

Telehealth

- 88% of adult CI patients prefer at least some remote follow up (Altuna et al. (2025)
- Remote platforms are being used for routine visits
- Triage based follow up to reduce low-yield visits for stable patients

Implantable Implants…

- "TICI"
- Various companies are working on this
- Full invisible under the skin
- Provides 24/7 access to hearing (swimming, sleeping, showering)
- No external hardware that requires continuous use

Will AI join in on CI care?

- It already has!
- Machine learning models help organize and optimize device programming
- Continuing to evolve

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Take Homes

1. Cochlear Implant should not be a last resort
2. Residual hearing should not be a deterrent
3. Don't exclude by age (<12 mo to >80 years old benefit)
4. If worried or interested? Refer for CIE!

UC Health™ - Cochlear Implant Team

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References

General CI Care (Candidacy, Follow-Up, Technology)

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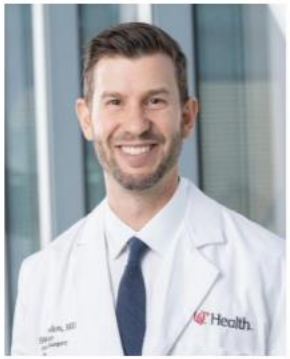
Questions?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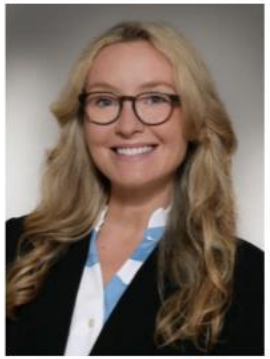
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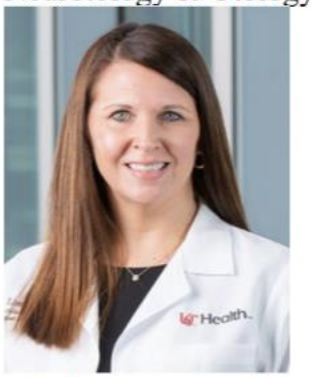
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Electrophysiologic and Reflex Measures

- **Electrically evoked stapedius reflex threshold (eSRT)** — correlates well with subjective MCL and best predicts maximum stimulation levels, but may be absent in up to ~30% of users.
- **Electrically evoked compound action potential (eCAP)** — most widely used objective measure (~85% of centers), good for predicting behavioral thresholds, but weak correlation with speech discrimination.
- **Electrically evoked auditory brainstem response (eABR)** — objective threshold estimation; correlates poorly with T/C levels.
- **Cortical auditory evoked potentials (CAEP, P1-N1-P2 complex)** — verify cortical speech detection and relate to speech perception scores.
- **Electrocochleography (ECochG)** — intraoperative/postoperative measure of residual cochlear function; predictive of speech-in-noise outcomes.