Factors Impacting Cochlear Implant (CI) Outcomes

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Cochlear Implant Indications: 1997-2022

1997

Conventional CI
Adults
≤ 40% sentence rec

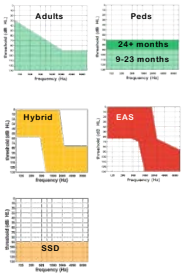
Children
18+ months
≤ 20% word rec

2022

Conventional CI
Adults
≤ 60% sentence rec
Medicare
≤ 60% sentence rec
Children
9+ months
≤ 30% word rec

EAS/Hybrid
18+ years
≤ 60% CNC

SSD
5+ years
≤ 5% CNC



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State of Knowledge: Adults & Children

1997

1995: NIH consensus conference: cochlear implants in adults & children
JAMA. 1995. 274(24):1955-1961.

- **Significant communication benefit for postlingual, but not prelingual adults**
  - But, improved environmental sound awareness
- **Highly variable outcomes:**
  - Short duration of deafness
  - Postlingual
  - If prelingual, implanted before 6 years.
- **Percutaneous CIs still have value**
- **Needs: MRI compatibility & telemetry**

2022

2020: Cochlear implant systematic review and consensus statements (adults)
Buchman et al. JAMA-OTO, 46(10):942-953.

- **Significant communication benefit & QOL *for all recipients***
  - All implant types
  - Preserve hearing when possible
- **Highly variable outcomes:**
  - Shorter duration of deafness
  - Younger age
    - But, all ages will benefit
    - Increased risk of dementia with untreated (or undertreated) hearing loss
- **Needs: CI awareness!**

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CI Utilization in adults and children

NIDCD (2021): As of late 2019 → 118,100 CIs in adults, 65,000 CIs in children

- **Adults**: ~2.3 to 12.7% utilization
  - *Sorkin (2013). Cochlear Implant Intl, 14: S4-S12; Sorkin & Buchman (2016). Otol Neurotol, 37(2):e161–e4; Perkins et al. (2021). Otol Neurotol, 42(6):815-823; Nassiri et al. (2022). Otol Neurotol*
- **Children**: ~50 to 59% utilization
  - *Sorkin & Buchman (2016). Otol Neurotol, 37(2):e161-164.*

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CI outcomes

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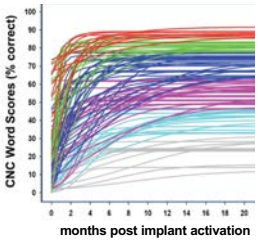

n = 113

Holden et al. (2013). Ear Hear, 34:342-360.

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Monosyllabic word recognition: Adults

- Helms et al. (1997). ORL Otorhinolaryngol Relat Spec, 59(1): 23-35:
  - n = 55; 55%
- Balkany et al. (2007). Otolaryngology–Head and Neck Surgery, 136: 757-762
  - n = 71; 57%
- Gifford et al. (2008). Audiol Neurotol, 13(3): 193-205:
  - n = 157; 57%
- Holden et al. (2013). Ear Hear, 34(3): 342-360:
  - n = 114; 62%
- Buchman et al. (2020). JAMA Otolaryngol, 146(10):916-924.
  - n = 96; 61%
- Goudy et al. (2021). Trends Hear, 25:1-17.
  - n = 2735; 49% (246 prelingual → 15- to 28-percentage points lower word recognition scores)

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Monosyllabic word recognition: Children

- Davidson et al (2010). Otol Neurotol, 31:1310-1314
  - n = 109 (15-18 years) → 60% LNT @ 70 dB SPL
    47% LNT @ 50 dB SPL
- Breneman et al. (2012). J Am Acad Audiol 23:5–17
  - n = 70 (7-16 years)→ ~80% LNT/CNC, 60 dB SPL
- Geers et al. (2013). Ear Hear, 34: 562-74
  - n = 60 (9-12 years) → 77% LNT, 70 dB SPL
- Dettman et al. (2016). Otol Neurotol, 37:e82–e95.
  - n = 125 (5-9 years) → 56% CNC, 65 dB SPL
- Davidson et al. (2019). JSLHR, 22: 1–14
  - n = 117 (5-9 years) → 82% LNT, 60 dB SPL

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Clinical factors

- Listening configuration
- Age at implantation
- Etiology
- Duration of deafness
- Hours of daily CI use
- Pre-/post-lingual onset of deafness
- Age at onset of hearing loss
- Scalar electrode location (ST, SV, ST-SV)
- Preop audiogram
- Preop aided speech recognition
- Preop duration of HA use
- Cognitive function
- Neural health

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Listening configuration

Two ears are better than one.

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2 > 1

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2 > 1

BIMODAL or

CI  HA

Adults
Dunn et al. (2005).
Gifford et al. (2007, 2014, 2019)

Children
Davidson et al. (2015, 2019)
Choi et al. (2016).

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2 > 1

BILATERAL CI

CI  CI

Adults
Schleich et al. (2004).
Litovsky et al. (2006).
Buss et al. (2007)

Children
Boons et al. (2012)
Gordon et al. (2011, 2021)
Polonenko et al. (2018)

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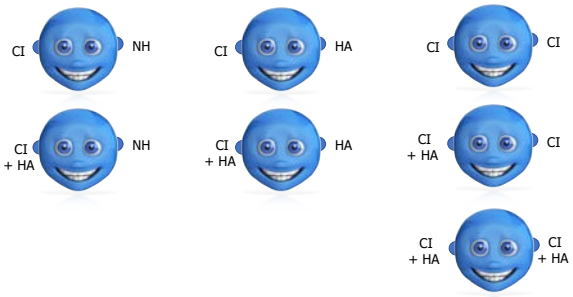
Various "2-eared" hearing configurations



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Clinical factors

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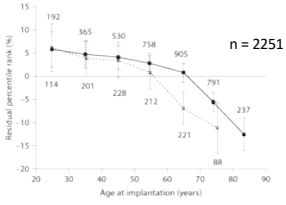
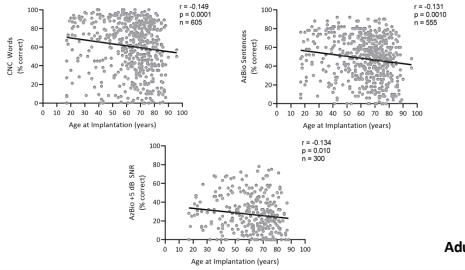
Blamey et al. (2013). *Audiol Neurotol*, 18:36-47.



Adults

17

DeFreese et al. (submitted); DeFreese et al. (2022). ACIA.



Adults

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Influence of patient age on adult CI outcomes

- **Yea:** Blamey et al. 2013 (n = 2251); Roberts et al., 2013 (n = 113); Sladen & Zappler, 2015 (n = 40); Crowson et al., 2020 (n = 1604)
- **Nay:** Carlson et al., 2010 (n = 232); Budenz et al. 2011 (n = 108); Lenarz et al., 2012 (n = 1005); Chen et al., 2013 (n = 445); Bergman et al., 2020 (n = 40)

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Dettman et al. (2016). Otol Neurotol, 37:e82–e95.

n = 95
PLS-5 at school entry

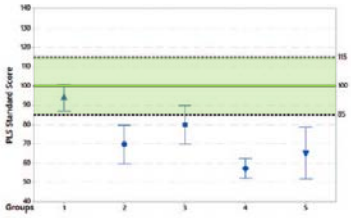

FIG. 3. PLS 4 and 5 standard scores for n = 95 at school entry, Groups 1–5.

Children

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Dettman et al. (2016). Otol Neurotol, 37:e82–e95.

n = 207
PPVT at school entry

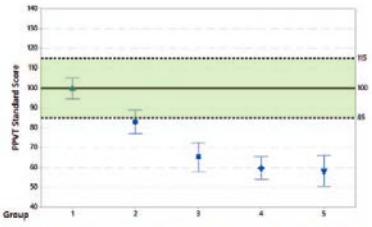

FIG. 4. PPVT standard scores for n = 207 at school entry, Groups 1–5.

Children

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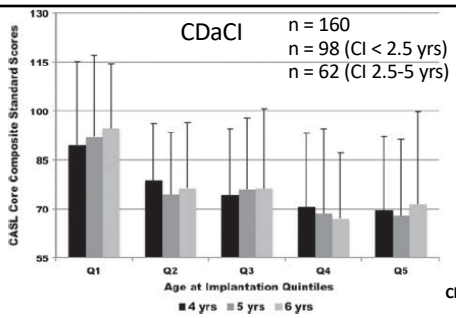
CDaCI

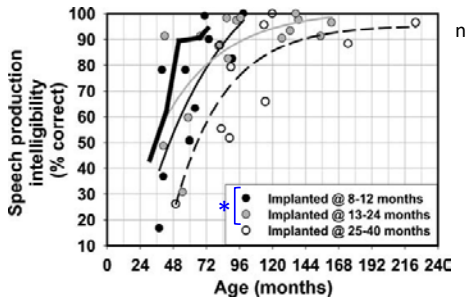
n = 160
n = 98 (CI < 2.5 yrs)
n = 62 (CI 2.5-5 yrs)



Children

Tobey et al. (2013). Intl J Audiol, 52: 219–229.

22



n = 40

Children

Habib et al. (2010). *Int J Ped Otorhinolaryngol*, 74: 855-59.

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Dettman et al. (2016). Otol Neurotol, 37:e82–e95.

School entry

Group N = 125	Number completed OSW	Mean age at testing (yrs)	Mean device exp (yrs)	Mean OSW % words (SD)	Mean OSW % phon (SD)	Mean OSS % correct (SD)
1. < 12 mo	17	5.1	4.3	58.0 (18.7)	83.8 (8.2)	80.8 (18.5)
2. 13 to 18 mo	23	5.5	4.3	59.3 (15.5)	82.8 (7.9)	78.0 (29.2)
3. 19 to 24 mo	32	5.7	3.9	44.7 (25.2)	72 (19.2)	71.0 (23.3)
4. 25 to 42 mo	30	5.7	3.1	35.8 (23.6)	69.6 (16.2)	53.2 (24.8)
5. 43 to 72 mo	23	6.3	1.9	37.7 (23.7)	68.9 (16.9)	57.3 (29.8)

n = 125

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Dettman et al. (2016). Otol Neurotol, 37:e82–e95.

Late primary/early secondary school

Group N = 81	Number completed OSW	Mean age at testing (yrs)	Mean device exp (yrs)	Mean OSW % words (SD)	Mean OSW % phon (SD)	Mean OSS % correct (SD)
1. < 12 mo	10	9.1	8.3	83.7 (7.5)	93.7 (3.3)	96.4 (5.3)
2. 13 to 18 mo	16	9.4	8.1	74.8 (8.7)	90.1 (4.2)	93.9 (6.3)
3. 19 to 24 mo	13	9.3	7.6	75.5 (17.6)	90.1 (8.3)	90.2 (9.5)
4. 25 to 42 mo	27	9.6	6.9	53.9 (19.7)	77.8 (11.2)	75.3 (21.4)
5. 43 to 72 mo	15	9.6	5.0	48.2 (23.4)	74.1 (15.4)	79.9 (19.9)

n = 81

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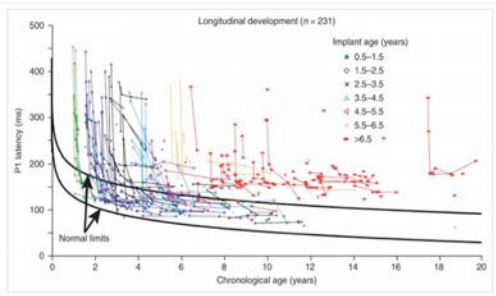
Sharma et al. (2007). Int J Audiol, 46: 494-499.



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Clinical factors

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- Cognitive function
- Neural health

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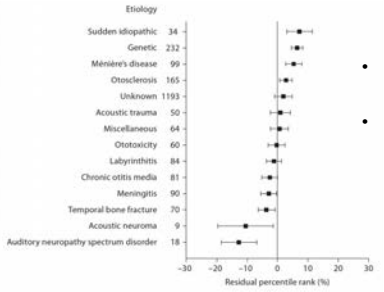
Etiology: Adults



- Better outcomes:
  - sudden, genetic, Meniere's disease, otosclerosis
- Poorer outcomes:
  - meningitis, temporal bone fracture, ANSD

Blamey et al., 2013. Audiol Neurotol, 18:36-47

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Etiology: Children

- Better outcomes:
  - Genetic factors not affecting spiral ganglion
    - GJB2
      - Reading (Bauer et al., 2003)
      - Auditory development (Abdurehim et al., 2017; Wu et al., 2011)
      - Speech recognition (Cullen et al., 2004; Abdurehim et al., 2017)
  - Non-syndromic
    - Auditory development (Lee et al., 2022)
- Poorer outcomes:
  - Cochlear Nerve Deficiency (CND) (Wu et al., 2015; Lee et al., 2022)
  - Syndromic (Lee et al., 2022)
  - cCMV (Malik et al., 2011; Corazzi et al., 2022)

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Clinical factors

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- **Age at implantation**
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- Rubinstein et al., 1999. Am J Otol, 20(4):445-52.
- Leung et al. (2005). Arch Otolaryngol Head Neck Surg, 131(12):1049-54.
- Friedland et al. (2004). Otol Neurotol, 24(4):582-9.
- Roditi et al. (2009). Otol Neurotol, 30(4):449-54.

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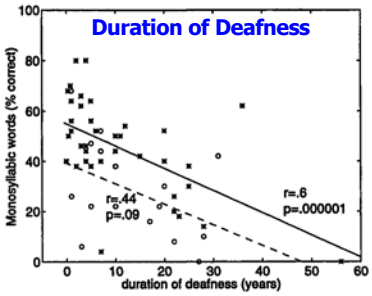

Rubinstein et al. (1999). *Am J Otol*, 20(4):445-52

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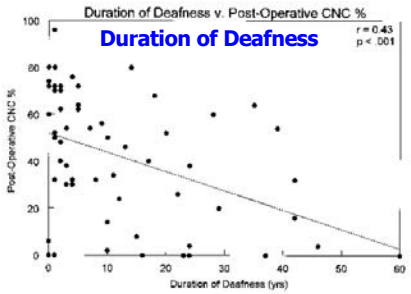

Friedland et al. (2003). *Otol Neurotol*, 24(4):582-9

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What is the relationship between

Duration of Deafness

Age at Implantation

Daily Processor Use

and adult CI outcomes?

DeFreese et al. (submitted); DeFreese et al. (2022). ACIA, Washington, DC

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DeFreese et al. (submitted); DeFreese et al. (2022). ACIA.

617 postlingually deafened adults

Duration of Deafness: 0.1-74 years (median = 3 years)

Age at Implantation: 17-96 years (mean = 63 years)

Daily Processor Use: 0-23 hours (mean = 10 hours)

Speech recognition: CNC, AzBio, AzBio +5 dB
2-76 months' CI use
Mean = 9 months

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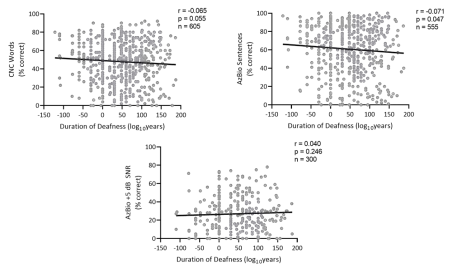
DeFreese et al. (submitted); DeFreese et al. (2022). ACIA.



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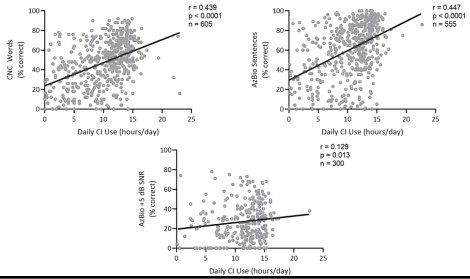
DeFreese et al. (submitted); DeFreese et al. (2022). ACIA.



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DeFreese et al. (submitted); DeFreese et al. (2022). ACIA.

Variance in Post-Operative Speech Recognition Outcomes Explained Jointly and Uniquely by Daily Processor Use, Age at Implantation and Duration of Deafness

	Unique Variance Explained			Total Variance Explained
	Daily Processor Use	Age	Duration of Deafness	
CNC Words Quiet	19.4%*	1.2%	0.7%	21.3%*
AzBio Sentences Quiet	19.8%*	0.8%	0.6%	21.2%*
AzBio Sentences Noise	2.6%	0%	0%	2.6%

Note. * $p < .001$

n = 614
postlingually deafened, adult CI recipients

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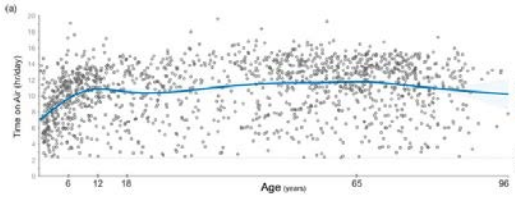
Busch et al. (2017). JSLHR, 60: 1362-1377.



n = 1501
0-96 years

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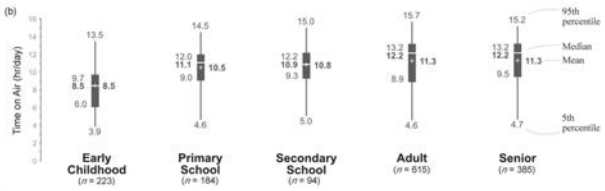
Busch et al. (2017). JSLHR, 60: 1362-1377.



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Easwar et al. (2016). JAAA, 27(10): 824-838.

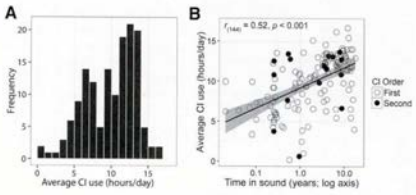

Figure 2. (A) Distribution of CI use per day. (B) Variation in CI use per day with time in sound. Gray-shaded region represents standard error.

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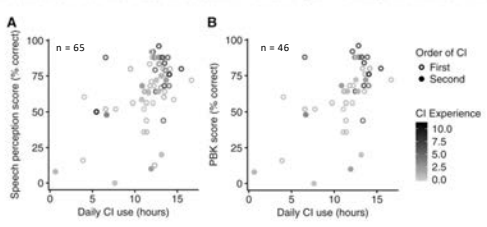
Easwar et al. (2018). JAAA, 29: 835-846.



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Clinical factors

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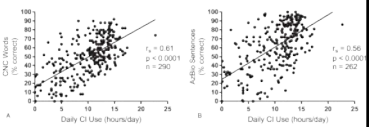
Hours of daily CI use

Schvartz-Leyzac et al. (2019): 16-19% (n=177)
Holder et al. (2020): 31-37% (n=300)



Holder et al. 2020. Otol Neurotol, 41(2):e227-e231.

Causality?

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Holder & Gifford (2021). *J Speech Lang Hear Res*, 64(10):4044-4055

Purpose: Investigate causal relationship between CI wear time and speech recognition

- 20 adult CI recipients
  - mean age = 55.1 years (18-79 yrs)
  - 12 female
- 12+ months CI experience
  - 9 AB, 11 Cochlear
- Daily CI wear time < 10 hrs/day
  - Mean = 5.9 hrs (0-10 hrs/day)
- Willingness to increase daily wear time

Jourdan Holder, AuD, PhD
Assistant Professor

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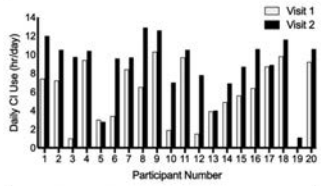
Holder & Gifford (2021). *J Speech Lang Hear Res*, 64(10):4044-4055



Visit 1: 5.9 hrs
- Range: 0-10 hrs

Visit 2: 8.9 hrs
- Range: 1-13 hrs

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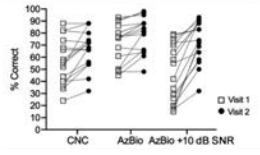
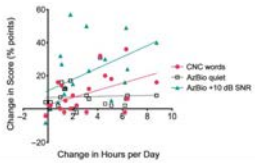
Holder & Gifford (2021). *J Speech Lang Hear Res*, 64(10):4044-4055





For every 1 hour increase:
- **CNC**: 3-percentage points
- **AzBio quiet**: 2.4-percentage points
- **AzBio +10 dB**: 7.0-percentage points

AzBio +10 dB: 25%
5 hours/day
Increase to 10 hours/day
AzBio +10 dB → 60%

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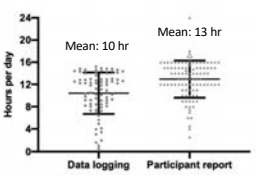
Holder et al. (2022). Otol Neurotol, 43:e23–e29.

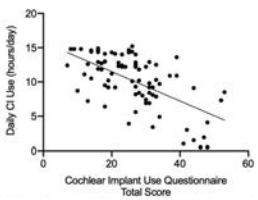
Development and validation of the Cochlear Implant Use Questionnaire (CIUQ)
- Based on Information-Motivation-Behavioral skills (IMB) model for identifying factors that contribute to successful medication adherence
  - Amico et al. (2005). AIDS Behav, 13:66–75.
  - Mayberry et al. (2014). Diabetes Care, 37:1246–53.
- n = 100
- Purpose: identify daily CI use habits and barriers to daily CI use using the IMB model



46

Holder et al. (2022). Otol Neurotol, 43:e23–e29.

Development and validation of the Cochlear Implant Use Questionnaire (CIUQ)
- Based on Information-Motivation-Behavioral skills (IMB) model for identifying factors that contribute to successful medication adherence
  - Amico et al. (2005). AIDS Behav, 13:66–75.
  - Mayberry et al. (2014). Diabetes Care, 37:1246–53.
- n = 100
- Purpose: identify daily CI use habits and barriers to daily CI use using the IMB model



CIUQ free download: https://www.vumc.org/cochlear-implant-lab/whats-new

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Clinical factors

- **Listening configuration**
- **Age at implantation**
- **Etiology**
- **Duration of deafness**
- **Hours of daily CI use**
- Pre-/post-lingual onset of deafness
- Age at onset of hearing loss
- Scalar electrode location (ST, SV, ST-SV)
- Preop audiogram
- Preop aided speech recognition
- Preop duration of HA use
- Cognitive function
- Neural health

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Clinical factors

- **Listening configuration**
- **Age at implantation**
- **Etiology**
- **Duration of deafness**
- **Hours of daily CI use**
- **Pre-/post-lingual onset of deafness**
- **Age at onset of hearing loss**
- Scalar electrode location (ST, SV, ST-SV)
- Preop audiogram
- Preop aided speech recognition
- Preop duration of HA use
- Cognitive function
- Neural health

Pre- vs. Post-lingual onset

Chakravorti et al. (2019). Otol Neurotol: n = 220

Goudey et al. (2021). Trends Hear: n = 2735

- Prelingual onset → 15 to 30 points lower

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Clinical factors

- **Listening configuration**
- **Age at implantation**
- **Etiology**
- **Duration of deafness**
- **Hours of daily CI use**
- **Pre-/post-lingual onset of deafness**
- **Age at onset of hearing loss**
- Scalar electrode location (ST, SV, ST-SV)
- Preop audiogram
- Preop aided speech recognition
- Preop duration of HA use
- Cognitive function
- Neural health

50

Scalar electrode location

- Percentage of electrodes in scala tympani → better outcomes
  - Finley et al. (2008). Otol Neurotol, 29(7):920-8.
  - Holden et al. (2013). Ear Hear, 34(3):342-60.
  - Wanna et al. (2014). Laryngoscope, 124(Suppl 6):S1-7.
  - O'Connell et al. (2016). Laryngoscope, 37(8):1032-5
  - Schaul et al. (2018). J Laryngol Otol, 132(11):1000-1006.
  - Chakravorti et al. (2019). Otol Neurotol, 40:617-624.

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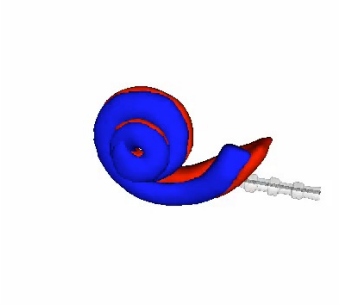

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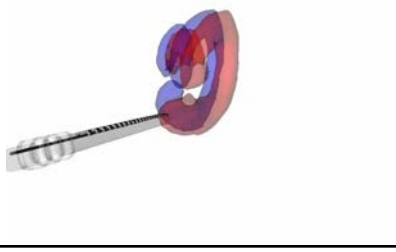

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Clinical factors

- **Listening configuration**
- **Age at implantation**
- **Etiology**
- **Duration of deafness**
- **Hours of daily CI use**
- **Pre-/post-lingual onset of deafness**
- **Age at onset of hearing loss**
- **Scalar electrode location (ST, SV, ST-SV)**
- Preop audiogram
- Preop aided speech recognition
- Preop duration of HA use
- Cognitive function
- Neural health

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Clinical factors: Adult outcomes

- Listening configuration
- Age at implantation
- Etiology
- Duration of deafness
- Hours of daily CI use
- Age at onset of hearing loss
- Pre-/post-lingual onset of deafness
- Scalar electrode location (ST, SV, ST-SV)
- Preop audiogram
- Preop aided speech recognition
- Preop duration of HA use
- Cognitive function
- Neural health

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Clinical factors: Adult outcomes

- Listening configuration
- Age at implantation
- Etiology
- Duration of deafness
- Hours of daily CI use
- Age at onset of hearing loss
- Pre-/post-lingual onset of deafness
- Scalar electrode location (ST, SV, ST-SV)
- Preop audiogram
- Preop aided speech recognition
- Preop duration of HA use
- Cognitive function
- Neural health

11-20% of the variance in CI outcomes

Blamey et al. (1996): n = 808
Lazard et al. (2012): n = 2251
Blamey et al. (2013): n = 2251
Goudey et al. (2021): n = 2735

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Clinical factors: Adult outcomes

- Listening configuration
- Age at implantation
- Etiology
- Duration of deafness
- **Hours of daily CI use**
- Age at onset of hearing loss
- Pre-/post-lingual onset of deafness
- **Scalar electrode location (ST, SV, ST-SV)**
- Preop audiogram
- Preop aided speech recognition
- Preop duration of HA use
- **Cognitive function**
- **Neural health**

Cognitive function
Zhan et al. (2020): 23-36% (n=19)

Neural health
Fitzpatrick et al. (2014): 47% (n=84)
Fontenot et al. (2019): 15% children; 46% adults (n=284)

Combined cognition + neural health
Walia et al. (2022): 60% (n=35)

Transcalar displacement
Holden et al. (2013): 11-12% (n=113)
Chakravorti et al. (2019): 9-16% (n=224)

Hours of daily CI use
Schvartz-Leyzac et al. (2019): 16-19% (n=177)
Holder et al. (2020): 31-37% (n=300)

~10-60% of the variance in CI outcomes

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Other factors for consideration

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Niparko et al (2010). JAMA. 303(15):1498-506

- CDaCI study
  - Childhood Development after Cochlear Implantation Study
- Multi-center, longitudinal study (6 CI centers)
- n = 188
- Compares children who have CI(s) to similarly aged peers with NH across multiple domains
  - oral language development
  - auditory performance
  - psychosocial and behavioral functioning
  - quality of life.

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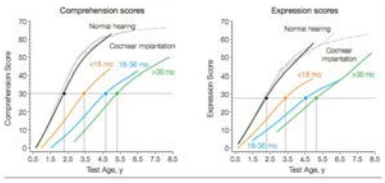
Niparko et al (2010). JAMA. 303(15):1498-506

Age at implantation



Hearing age
Family income > $50,000
Maternal education
Parent-child interactions

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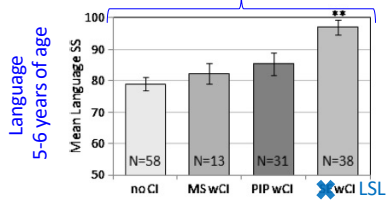
No difference in nonverbal IQ



Intervention at 2 years of age

FIG. 3. Mean standard score across a battery of language tests at ages 5 to 6 years is plotted for 4 different interventions at age 2 years: no CI (no CI or intervention), MSwCI (MS class with CI), PIPwCI (PIP with a CI), and LSLwCI (LSL class with a CI).

Moog and Geers (2010). Otol Neurotol, 31(8):1315-9

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Pediatric CI outcomes: additional factors

- Preschool educational environment (Moog & Geers, 2010)
- Mode of communication (Tobey et al., 2004)
- Prolonged use of sign language "by non-proficient signers" (Geers et al., 2017; Langereis & Vermeulen, 2015)
- Comorbidities (Ching et al., 2013)
- Anatomy

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CI manufacturer

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Davis et al. (2016). Otol Neurotol, 37(1):31-7.

n = 157

	Brand	Array Type	Electrode	Fully ST	CNC	AZ Bio Q	AZ Bio +5	AZ Bio +10	SMD 0.5	SMD 1.0	APHAB	Distance	Max Angle
Brand													
Array Type	-0.668												
Electrode	0.965	-0.450											
Fully ST	-0.368	0.418	-0.295										
CNC	-0.066	0.097	-0.045	-0.023									
AZ Bio Q	-0.052	0.054	-0.043	-0.131	0.850								
AZ Bio +5	0.032	-0.010	0.035	-0.182	0.724	0.865							
AZ Bio +10	-0.054	0.139	-0.017	-0.218	0.566	0.684	0.877						
SMD 0.5	-0.014	0.048	0.000	-0.139	0.481	0.515	0.434	0.444					
SMD 1.0	-0.126	0.119	-0.109	-0.067	0.428	0.443	0.439	0.469	0.734				
APHAB	0.181	-0.180	0.154	-0.035	-0.468	-0.473	-0.512	-0.544	-0.239	-0.305			
Distance	0.608	-0.776	0.457	-0.376	-0.188	-0.111	-0.089	-0.218	-0.145	-0.178	0.216		
Max Angle	0.651	-0.436	0.628	-0.246	0.097	0.039	0.123	0.056	0.075	-0.048	0.064	0.223	

CNC Performance

MED-EL: 46%, Advanced Bionics: 47%, Cochlear: 50%

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DeFreese et al. (submitted); DeFreese et al. (2022)

	Advanced Bionics	Cochlear Americas	MED-EL
Biological Sex (% female)	40%	47%	41%
Age at Implantation (mean years)	64.4	62.0	65.0
Duration of Deafness (mean years)	7.0	6.4	7.1
Duration of Daily Processor Use (mean hours/day)	9.9	10.9	9.8
CI-Only Speech Recognition (mean % correct)	CNC: 48% AzBio Quiet: 57% AzBio Noise: 24%	CNC: 49% AzBio Quiet: 64% AzBio Noise: 28%	CNC: 44% AzBio Quiet: 59% AzBio Noise: 31%

n = 614
postlingually deafened, adult CI recipients

66

Precurved > straight (maybe)

Chakvorti et al. (2019). Otol Neurotol, 40:617-624.
n = 220 (postop imaging)

Holder et al. (2019). Otol Neurotol, 40: 1160-66.
n = 58 (no postop imaging)

Heutink et al. (2021). Ear Hear, 42;949–960.
n = 129 (postop imaging

Sturm et al. (2021). Otol Neurotol, 42(4):532-539.
n = 119 (no postop imaging)

Caswell-Midwinter et al. (2022). Trends Hear, 26: 23312165211060983.
n = 425 (no postop imaging)

67

Holder et al. (2019). *Otol Neurotol*, 40: 1160-66.

- n = 58
- 29 CI422/CI522, 29 CI532
- Matched cohort comparison—6 months post activation
  - Age
  - Preoperative audiometric thresholds
    - No significant difference between groups for preop CNC word rec or postop daily CI use

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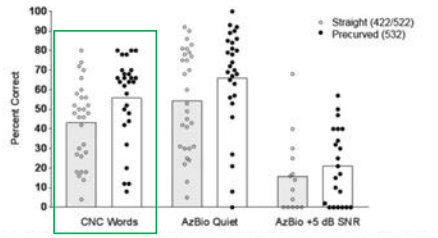
Holder et al. (2019). *Otol Neurotol*, 40: 1160-66.



p = 0.016

69

But, some studies show straight = pre-curved

MacPhail et al. (2022). Otolaryngol Head Neck Surg, 166(5):943-950.
n = 89 (no postop imaging)

Moran et al. (2019). Otol Neurotol, 40(5): 608-616.
n = 133 (no postop imaging)

Fabie et al. (2018). Otol Neurotol, 39(9):1122-1128.
n = 328 (no postop imaging)

70

And, some studies show straight > pre-curved

O'Connell et al. (2016). Otol Neurotol, 37(8):1032-5.
n = 56 (postop imaging)

Wanna et al. (2014). Laryngoscope, 124 Suppl 6:S1-7
n = 100 (postop imaging)

71

Scalar electrode location and electrode type

72

Chakravorti et al. (2019). Otol Neurotol, 40(5):617-624

- Dataset: 220 CI implanted ears from an IRB-approved database of CI users who underwent post-operative CT scanning
- Test scores used: CNC Monosyllabic Words, BKB-SIN Final CI position determined by segmenting cochlear anatomy and automatically localizing the electrodes on postoperative CTs

Manufacturer	Straight Arrays	Precurved Arrays
Advanced Bionics (AB)	Hifocus 1J (29)	Mid-Scala (21)
Cochlear (CO)	422/522 (20), 24RE(ST) (11)	Contour Advance (89)
Med-El (ME)	Flex24 (3), Flex28 (22), Medium (1), Standard (24)	--

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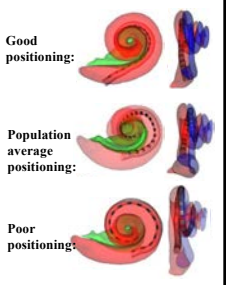
Case study:
- Male, CI at 35 y/o
- Postlingual
- 5 years CI experience

Using **Precurved** array

	ST insertion	Mean Modiolar Distance (MMD) (mm)	Base Insertion Depth (BID)(mm)	CNC score
Good Positioning	1	0.18	0	82% [66.30%, 97.83%]
Average Positioning	0.51	0.48	2.32	56%
Poor Positioning	0	0.78	4.64	30% [14.71%,



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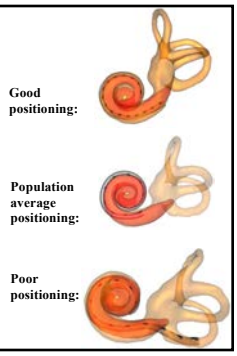
Case study:
- Male, CI at 35 y/o
- Postlingual
- 5 years CI experience

Using **Straight** array

	Base Insertion Depth (BID) (mm)	CNC score
Good Positioning	6.24	68% [56.30%, 80.20%]
Average Positioning	1.42	52% [45.50%, 58.67%]
Poor Positioning	-3.4	36% [24.50%, 47.33%]



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Case study:
- Male, CI at 35 y/o
- Postlingual
- 5 years CI experience

	Precurved Array	Straight Array
Good Positioning	82% [66.30%, 97.83%]	68% [56.30%, 80.20%]
Poor Positioning	30% [14.71%, 44.51%]	36% [24.50%, 47.33%]

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Stimulation Rate

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Stimulation Rate

- **Channel stimulation rate**: # of biphasic pulses delivered to a *single electrode* over a 1-sec period
  - earliest CIs ~100-250 pps
  - current CIs ~900-2000 pps (250 up to ~4000 pps)
- **Overall stim rate** = channel stim rate * # active channels (per frame)
  - AB: 83k; Cochlear: 32k; MED-EL: 51k
- Higher stim rates *should* provide greater temporal representation
  - greater sampling of input acoustic signal
- Electric stimulation → highly synchronous ANF firing patterns
  - higher stim rates → greater ANF stochasticity
  - higher stim rates → wider dynamic range
    - Lower thresholds (T/THR), no change to C/M/MCL

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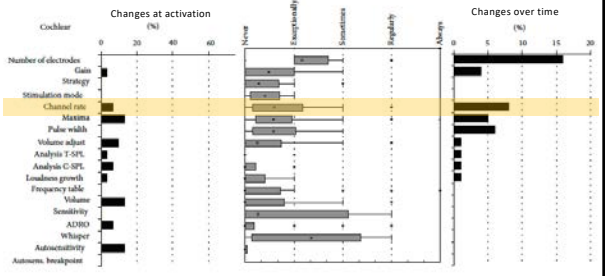
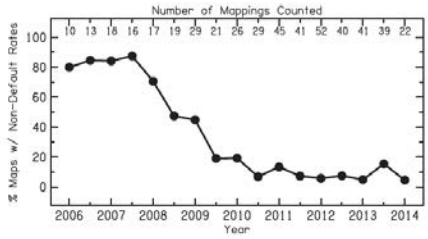
Channel Stimulation Rate



Vaerenberg et al. (2014). Sci World J. 2014:646590.

79

Channel Stimulation Rate



Shader et al. (2020). Ear Hear. 41:640–651.

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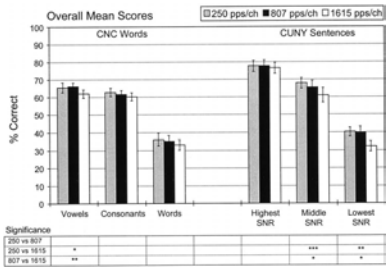
Vandali et al. (2000). Ear Hear, 21:608–624.



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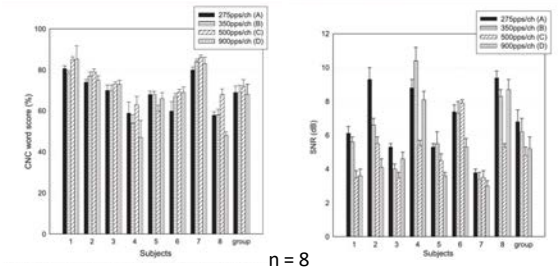
Arora et al. (2009). Intl J Audiol, 48:8, 561-567.



n = 8

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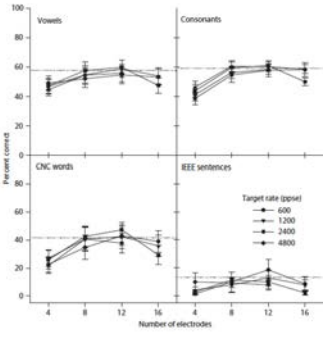

Shannon et al. (2011). Audiol Neurotol, 16:113–123.

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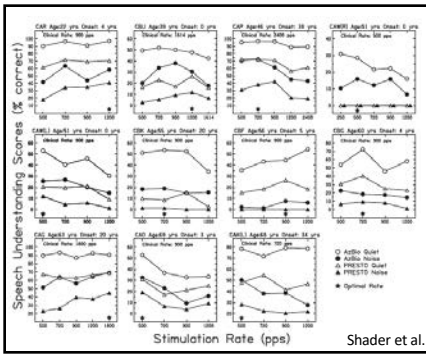

- 37 adult CI users
- > 1 year CI use
- 22-87 years
- Effect of rate
  - 500, 720, 900, 1200 Hz

Shown here:
- 11 adult CI users who showed an effect of stim rate

Shader et al. (2020). Ear Hear. 41:640–651.

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Summary

- 2 ears are better than 1
- Age at implantation
  - Critical for children, may be less important for adults
    - confounding factors in adulthood such as cognition and communication experiences
- Electrode position
  - ST > SV or ST-SV
    - Precuved > straight
      - But only when precurved is in ST; translocation → poorer outcomes
      - There are studies showing the opposite or equivocal outcomes
- Etiology
- Preschool educational environment, communication mode, comorbidities, anatomical anomalies, SES, sign language, etc.
- **Daily CI wear time**

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Questions? Comments?

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