THE INTERNATIONAL FEDERATION OF ORL SOCIETIES (IFOS)
ASEAN ORL – HNS FEDERATION
VIETNAMESE SOCIETY OF OTORHINOLARYNGOLOGY
CONFERENCE AND TRAINING

AN UPDATE ON COCHLEAR IMPLANTATION

WHERE WE WERE, WHERE WE ARE

PROF. DR. ÖZGÜR YİĞİT

I HAVE NO CONFLICT OF INTEREST

HISTORY

- **1957, Andre Djourno and Charles Eyries**
  - First electrical stimulation of the acoustic system

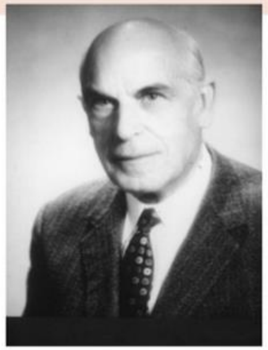
- **1961, William House and John Doyle**
  - **First single-channel** implantation

- **1970, Michelson and House**
  - Electrode placed through the scala tympani

- **1978, Graham Clark**
  - **First multichannel** CI

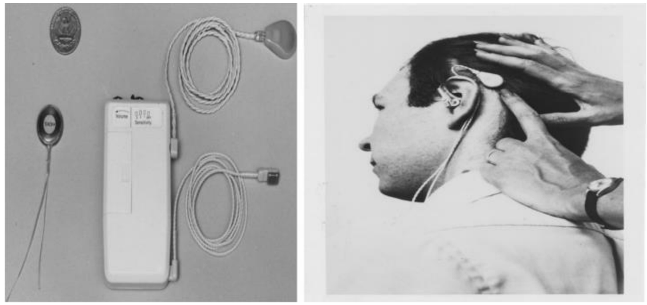
- **1987,Dr. Bekir Altay,** first cochlear implantation in Turkiye

- **1990 FDA - 2 YEARS APPROVED**
- **2000 FDA – 1 YEAR APPROVED**

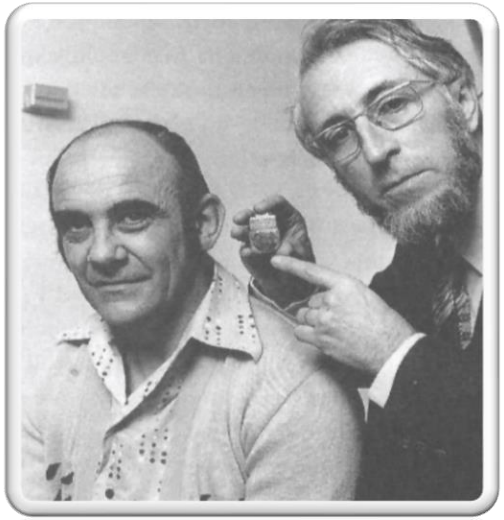


Charles Eyries, Otologist in Paris

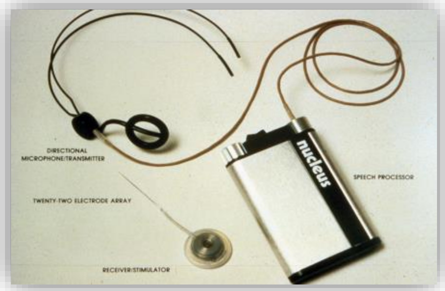
André Djurno, Engineer Co-working with Eyries



The 3M Cochlear implant system developed by House in 1973.



Rod Saunders, 1978 / first multichannel cochlear implant patient / Implanted by Graham Clark



> JASA Express Lett. 2022 Jul;2(7):077201. doi: 10.1121/10.0012825.

Celebrating the one millionth cochlear implant

Fan-Gang Zeng [1]

COCHLEAR IMPLANT INDICATIONS

Until the 2000s, cochlear implants were performed unilaterally and for those over two. Today, CI'as are **bilateral** and used **from age one**.

Advancements have expanded indications to include conditions such as **sudden hearing loss, presbycusis**, and **advanced otosclerosis**.

- ➤ Children (pre/peri/post-lingual hearing loss)
- ➤ Adults (peri/post-lingual hearing loss)
- ➤ Presbycusis
- ➤ Inner ear malformations
- ➤ Hearing loss after meningitis
- ➤ Hearing loss patients with comorbidities
- ➤ Meniere patients with severe to profound HL
- ➤ Otosclerosis patients with severe to profound HL
- ➤ Unilateral hearing loss and/or tinnitus
- ➤ Bilateral cochlear implantation

Review > Adv Otorhinolaryngol. 2018:81:74-80. doi: 10.1159/000485546. Epub 2018 Apr 6.

Extended Applications for Cochlear Implantation

John Martin Hempel, Florian Simon, Joachim Michael Müller

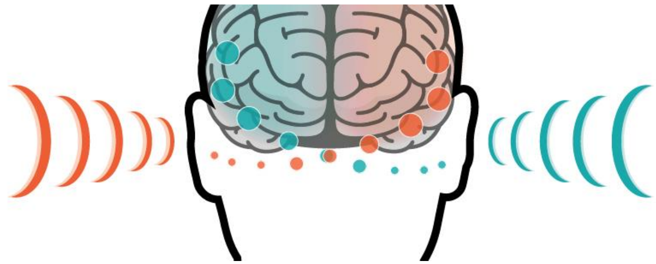
PMID: 29794417 DOI: 10.1159/000485546

Bilateral Cochlear Implantation ➔ Binaural Hearing

J Speech Lang Hear Res. 2014 Oct;57(5):1942-60. doi: 10.1044/2014_JSLHR-H-13-0144.

Head shadow, squelch, and summation effects with an energetic or informational masker in bilateral and bimodal CI users.

Pyschny V, Landwehr M, Hahn M, Lang-Roth R, Walger M, Meister H.



1. Head shadow

(7 dB / in 6 months)

2. Binaural squelch

(1-2 dB / after 1 year)

3. Binaural summation

(1-2 dB)

➤ Benefits of bilateral cochlear implantation;

* Speech understanding in noise
* Localization of sound,
* Cortical auditory responses.

Bilateral cochlear implant has the same effects as binaural hearing

Bilateral cochlear implantation has been accepted worldwide since approximately 2010.

* H. Kuhn-Inacker, W. Shehata-Dieler, J. Muller, J. Helms, Bilateral cochlear implants: a way to optimize auditory perception abilities in deaf children? Int. J. Pediatr. Otorhinolaryngol. 68 (2004) 1257–1266.
* B.R. Peters, R. Litovsky, A. Parkinson, J. Lake, Importance of age and postimplantation experience on speech perception measures in children with sequential bilateral cochlear implants, Otol. Neurotol. 28 (2007) 649–657.
* T. Steffens, A. Lesinski-Schiedat, J. Strutz, A. Aschendorff, T. Klenzner, S. Ruhl, et al., The benefits of sequential bilateral cochlear implantation for hearing-impaired children, Acta Otolaryngol. 128 (2008) 164–176.
* A.Q. Summerfield, R.E. Lovett, H. Bellenger, G. Batten, Estimates of the cost-effectiveness of pediatric bilateral cochlear implantation, Ear Hear. 31 (2010) 611–624.

Since 2016, bilateral cochlear implantation from the age of one have been covered by the Turkish Health Insurance system.

TURKISH HEALTH INSURANCE SYSTEM – 2016

Bilateral cochlear implant application are as follows,

a) Children between 12-48 months who meet the CI criteria,

b) Severe SNHL after meningitis that develops regardless of age limit,

c) Bilateral blindness accompanied by severe SNHL in patients over 48 months of age

- Bilateral CI has become standard in many countries with reimbursement by healthcare systems.
- Especially in children, bilateral CI is preferred due to the positive effect on language development observed over time.

> Acta Otolaryngol. 2021 Mar;141(sup1):1-21. doi: 10.1080/00016489.2021.1888193.

Bilateral cochlear implantation

Anandhan Dhanasingh [1], Ingeborg Hochmair [1]

Affiliations + expand

PMID: 33818259 DOI: 10.1080/00016489.2021.1888193

Abstract

Binaural hearing has certain benefits while listening in noisy environments. It provides the listeners with access to time, level and spectral differences between sound signals, perceived by the two ears. However, single sided deaf (SSD) or unilateral cochlear implant (CI) users cannot experience these binaural benefits due to the acoustic input coming from a single ear. The translational research on bilateral CIs started in the year 1998, initiated by J. Müller and J. Helms from Würzburg, Germany in association with MED-EL. Since then, several clinical studies were conducted by different research groups from across the world either independently or in collaboration with MED-EL. As a result, the bilateral CI has become the standard of care in many countries along with reimbursement by the health care systems. Recent data shows that children particularly, are given high priority for the bilateral CI implantation, most often performed simultaneously in a single surgery, as the binaural hearing has a positive effect on their language development. This article covers the milestones of translational research from the first concept to the widespread clinical use of bilateral CI.

Clinical Trial > Int J Pediatr Otorhinolaryngol. 2020 Oct:137:110237.
doi: 10.1016/j.ijporl.2020.110237. Epub 2020 Jul 10.

Bilateral cochlear implantation versus unilateral cochlear implantation in deaf children: Effects of sentence context and listening conditions on recognition of spoken words in sentences

Youngmee Lee [1], Hyunsub Sim [2]

Methods: Twenty children with bilateral CIs and 20 children with unilateral CIs participated in this study. All children were presented with semantically controlled sentences (high vs. low predictability) in quiet and noisy conditions and were asked to repeat the final words of each sentence.

Results: Children with bilateral CIs had significantly higher word recognition scores than children with unilateral CIs on words embedded in both high- and low-predictability sentences in noisy conditions. The two groups recognized more words in high-predictability sentences than in low-predictability sentences in noisy conditions. The scores on the high-predictability sentences in noisy conditions significantly differentiated children with bilateral CIs from children with unilateral CIs.

Conclusion: Bilateral cochlear implantation is more advantageous than unilateral cochlear implantation at the auditory-linguistic processing level in complex listening conditions.

Bilateral cochlear implantation is more advantageous than unilateral cochlear implantation at the auditory-linguistic processing level in complex listening conditions

Which is Better : Simultaneous or Sequential Bilateral Cochlear Implantation

Comparative Study > J Laryngol Otol. 2021 Apr;135(4):327-331.
doi: 10.1017/S0022215121000931. Epub 2021 Apr 8.

Bilateral cochlear implantation in children: simultaneously or in consecutive sessions?

A Dalgic [1], G Atsal [2], O Yildirim [1], D T Edizer [1], M B Özay [3], L Olgun [3]

Affiliations + expand

PMID: 33829979 DOI: 10.1017/S0022215121000931

If there is no anatomical handicap that would prolong the surgery time or increase anesthesia risk, <u>simultaneous bilateral cochlear implantation can be performed safely.</u>

Abstract

Objective: This study aimed to evaluate and compare cases of simultaneous and consecutive bilateral cochlear implantation from the perspective of the duration of anaesthesia, surgical complications and hospitalisation.

Method: Fifty patients with simultaneous bilateral cochlear implantation (group 1) and 47 patients with consecutive bilateral cochlear implantation (group 2) were included in this study. The two groups were compared in terms of the duration of anaesthesia, the duration of surgery, radiological findings, the complications and the post-operative hospitalisation time.

Results: Group 1 had a significantly shorter operation time than group 2 ($p < 0.01$). The mean total operation time was 189 minutes in group 1. In group 2, the mean operation times for the first and second surgery were 134 minutes and 136 minutes, respectively, and the total operation time for both surgical procedures in group 2 was 270 minutes. The duration of post-operative hospitalisation of the patients in group 1 was significantly shorter than the total post-operative hospitalisation after both operations for the patients in group 2 ($p < 0.01$).

Conclusion: In conclusion, if there is no anatomical problem that may lead to a prolonged operation time or any risk regarding anaesthesia, simultaneous bilateral cochlear implantation can be performed safely.

Laryngoscope. 2014 Apr;124(4):993-9. doi: 10.1002/lary.24395. Epub 2013 Oct 10.

Bilateral cochlear implantation in children and the impact of the inter-implant interval.

Lammers MJ[1], Venekamp RP, Grolman W, van der Heijden GJ.

Author information

Abstract

OBJECTIVES/HYPOTHESIS: To determine the effectiveness of simultaneous versus sequential bilateral cochlear implantation on postoperative outcomes in children with bilateral deafness and to evaluate the impact of the inter-implant interval and age at second implantation on postoperative outcomes in children who already received their first cochlear implant.

DATA SOURCES: PubMed, Embase, and Web of Science.

REVIEW METHODS: All studies comparing the effects of simultaneous with sequential bilateral cochlear implantation on postoperative outcomes and those evaluating the impact of the inter-implant interval and age at second implantation were retrieved.

RESULTS: Four studies compared the effects of simultaneous with sequential bilateral cochlear implantation. All studies lacked randomization. Of these, three reported better speech perception and expressive language development at one year of bilateral experience for simultaneous cochlear implantation. Of the nineteen publications on the impact of the inter-implant interval on postoperative outcomes, the risk of bias was low-moderate for seven studies which were derived from five different study populations. In two of these populations no impact of the inter-implant interval was found, while in three a longer inter-implant interval was associated with poorer speech and language development.

CONCLUSION: Observational studies suggest that simultaneous implantation in children may be associated with improved speech and language development, and that a prolonged inter-implant interval between both implantations may have a negative impact on these postoperative outcomes. Randomized trials are, however, needed to demonstrate whether simultaneous implantation indeed is superior to sequential bilateral implantation in children with bilateral deafness.

Among 5013 publications about pediatric implants 23 publications were evaluated.

Studies have shown that a prolonged inter-implant interval may have negative impact.

COCHLEAR IMPLANTATION IN SINGLE SIDED DEAFNESS

Laryngoscope. 2016 Mar;126(3):713-21. doi: 10.1002/lary.25568. Epub 2015 Sep 7.

Cochlear implantation in children with unilateral hearing loss: A systematic review.

Peters JP[1,2], Ramakers GG[1,2], Smit AL[1,2], Grolman W[1,2].

Author information

1 Department of Otorhinolaryngology and Head & Neck Surgery, University Medical Center Utrecht, Utrecht, the Netherlands.
2 Brain Center Rudolf Magnus, University Medical Center Utrecht, Utrecht, the Netherlands.

Abstract

OBJECTIVES: To systematically review the literature on cochlear implantation (CI) for children with unilateral hearing loss (UHL).

DATA SOURCES: PubMed, Cochrane, CINAHL, and Embase databases were searched for articles up to June 29, 2015 for UHL, children and CI, and all of their synonyms.

METHODS: After screening of titles, abstracts, and full texts for eligible articles, directness of evidence (DoE) and risk of bias (RoB) were assessed for the included articles. Study characteristics and data on our outcomes of interest (speech perception in noise, sound localization, quality of life, and speech and language development) were extracted.

RESULTS: In total, 296 unique articles were retrieved, of which five articles satisfied the eligibility criteria. All of these articles were case series or case reports and had a low to moderate DoE and a high RoB. In these studies, heterogeneous findings were reported in small patient samples. Speech perception in noise and localization ability improved in most patients. Although only measured in one study each, quality of life and speech and language development improved. Most of these results were not statistically significant.

CONCLUSIONS: No firm conclusions can be drawn on the effectiveness of CI in children with UHL, due to heterogeneous findings, small sample sizes, and the lack of high Level of Evidence studies. Based on the findings of this systematic review, cochlear implantation may be an effective treatment option in children with UHL. Laryngoscope, 126:713-721, 2016.

5 of 296 articles related to children were evaluated.

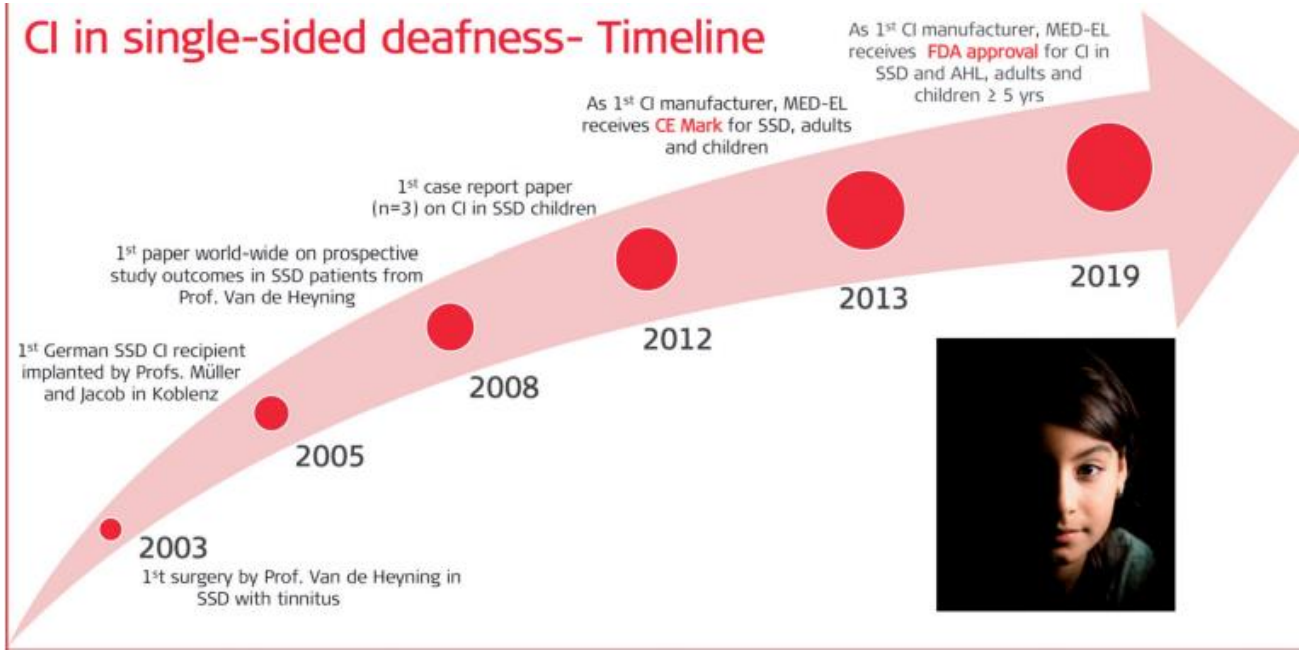
Speech perception in noise and sound localization improved in most patients.

Cochlear implantation may be effective treatment option in children with single sided deafness

Meta-Analysis > JAMA Otolaryngol Head Neck Surg. 2021 Jan 1;147(1):58-69.
doi: 10.1001/jamaoto.2020.3852.

Cochlear Implantation in Children With Single-Sided Deafness: A Systematic Review and Meta-analysis

Liliya Benchetrit [1], Evette A Ronner [2], Samantha Anne [3 4], Michael S Cohen [5]



Conclusions and relevance: This systematic review and meta-analysis found that cochlear implantation for children with SSD was associated with clinically meaningful improvements in audiological and patient-reported outcomes; shorter duration of deafness may lead to better outcomes. These findings can guide future research efforts, refine cochlear implantation candidacy criteria, and aid in family counseling and shared decision-making.

CI in children with SSD is linked to significant improvement in audiological performance and patient-reported outcomes.

Cochlear Implantation in very-early age

Laryngoscope. 2019 May 14. doi: 10.1002/lary.28061. [Epub ahead of print]

Auditory comprehension outcomes in children who receive a cochlear implant before 12 months of age.

Mitchell RM[1,2], Christianson E[3], Ramirez R[3], Onchiri FM[4], Horn DL[1,2], Pontis L[5], Miller C[1,2], Norton S[1,2,3,5], Sie KCY[1,2,3].

Author information

Abstract

OBJECTIVE: The U.S. Food and Drug Administration guidelines for cochlear implantation (CI) include age greater than 12 months. Studies have suggested that implantation in children younger than 12 months with congenital deafness may be associated with better spoken language outcomes. Compare auditory comprehension (AC) outcomes for children with congenital deafness who received CI less than 12 months of age to those implanted at 12 to 24 months of age.

METHODS: Retrospective review of prospectively collected data in consecutively implanted patients under 2 years of age who received CI and had post-CI Preschool Language Scale (PLS)-AC scores. Receptive language was assessed with the AC subtest of the PLS. Patients without pre-CI PLS-AC scores were excluded. The association between age at implantation and post-CI PLS-AC scores up to 2 years after CI surgery was modeled using a linear mixed-effects model. Time from CI surgery, number of implants, risk factors for language delay, pre-CI PLS-AC score, and sex were included in the model. Patients implanted less than 12 months of age were compared to those implanted between 12 and 24 months.

RESULTS: Twenty-nine patients who had CI surgery by 12 months and 82 who had CI surgery between 12 and 24 months were included in the analysis. Younger age at implantation and better pre-CI PLS-AC scores were significantly associated with better post-CI PLS-AC scores.

CONCLUSION: Cochlear implantation in children with congenital deafness less than 12 months of age was associated with better PLS-AC than in children implanted over 12 months of age up to 2 years after implantation.

As time goes cochlear implantation age decreases

1990 FDA approved CI in 2 year olds

2000 FDA approved CI in 12 months

2006 Turkiye the age of CI became 12 months

- Group 1 (cochlear implantation at <12 months of age); 29 patients
- Group 2 (cochlear implantation at 12-24 months); 82 patients

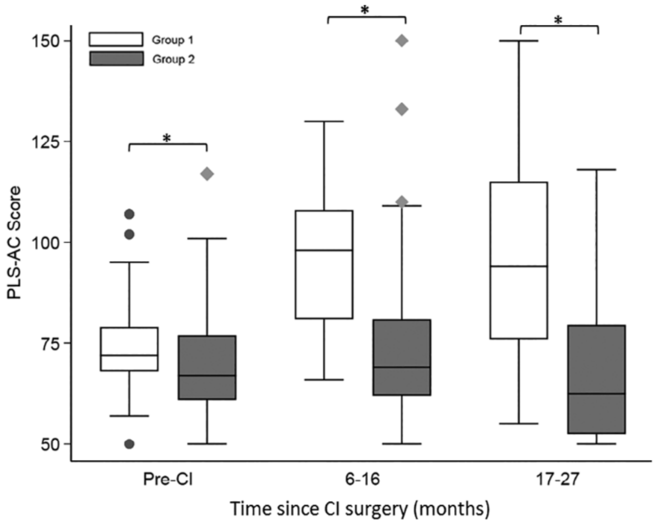


Fig. 1. Box and whisker plot showing the PLS-AC scores for the entire group pre- and post-CI. Group 1 (<12 months) is represented by white bars, and group 2 (12–24 months) is represented by dark bars. Outliers are represented by circle and diamond symbols. A significant result is represented by *. AC = auditory comprehension; CI = cochlear implantation; PLS = Preschool Language Scale.

PLS-auditory perception results were better in the group cochlear implanted younger than 12 months of age.

Otol Neurotol. 2016 Feb;37(2):e82-95. doi: 10.1097/MAO.0000000000000915.

Long-term Communication Outcomes for Children Receiving Cochlear Implants Younger Than 12 Months: A Multicenter Study.

Dettman SJ[1], Dowell RC, Choo D, Arnott W, Abrahams Y, Davis A, Dornan D, Leigh J, Constantinescu G, Cowan R, Briggs RJ.

Author information

Abstract

OBJECTIVE: Examine the influence of age at implant on speech perception, language, and speech production outcomes in a large unselected paediatric cohort.

STUDY DESIGN: This study pools available assessment data (collected prospectively and entered into respective databases from 1990 to 2014) from three Australian centers.

PATIENTS: Children (n = 403) with congenital bilateral severe to profound hearing loss who received cochlear implants under 6 years of age (excluding those with acquired onset of profound hearing loss after 12 mo, those with progressive hearing loss and those with mild/moderate/severe additional cognitive delay/disability).

MAIN OUTCOME MEASURE(S): Speech perception; open-set words (scored for words and phonemes correct) and sentence understanding at school entry and late primary school time points. Language; PLS and PPVT standard score equivalents at school entry, CELF standard scores. Speech Production; DEAP percentage accuracy of vowels, consonants, phonemes-total and clusters, and percentage word-intelligibility at school entry.

RESULTS: Regression analysis indicated a significant effect for age-at-implant for all outcome measures. Cognitive skills also accounted for significant variance in all outcome measures except open-set phoneme scores. ANOVA with Tukey pairwise comparisons examined group differences for children implanted younger than 12 months (Group 1), between 13 and 18 months (Group 2), between 19 and 24 months (Group 3), between 25 and 42 months (Group 4), and between 43 and 72 months (Group 5). Open-set speech perception scores for Groups 1, 2, and 3 were significantly higher than Groups 4 and 5. Language standard scores for Group 1 were significantly higher than Groups 2, 3, 4, and 5. Speech production outcomes for Group 1 were significantly higher than scores obtained for Groups 2, 3, and 4 combined. Cross tabulation and χ^2 tests supported the hypothesis that a greater percentage of Group 1 children (than Groups 2, 3, 4, or 5) demonstrated language performance within the normative range by school entry.

CONCLUSIONS: Results support provision of cochlear implants younger than 12 months of age for children with severe to profound hearing loss to optimize speech perception and subsequent language acquisition and speech production accuracy.

Group	No.	Percent/ n = 403
1. <12 m	151	37.5%
2. 13–18 m	61	15.1%
3. 19–24 m	66	16.4%
4. 25–42 m	82	20.3%
5. 43–72 m	43	10.7%

- **80% of children who received a cochlear implant at <12 months of age, have normal receptive language skills by the time they go to school.**

Review > Otolaryngol Head Neck Surg. 2022 Dec;167(6):912-922.
doi: 10.1177/01945998211067741. Epub 2022 Jan 4.

Safety of Cochlear Implantation in Children 12 Months or Younger: Systematic Review and Meta-analysis

Firas Sbeih[1], Malek H Bouzaher[1], Swathi Appachi[1], Seth Schwartz[2], Michael S Cohen[3], Daniela Carvalho[4], Patricia Yoon[5], Yi-Chun Carol Liu[6], Samantha Anne[1]

Affiliations + expand

PMID: 34982600 DOI: 10.1177/01945998211067741

- Cochlear implantation in patients 12 months of age and younger is a safe procedure with complication rates similar to older groups.

Abstract

Objective: To systematically review the literature to determine safety of cochlear implantation in pediatric patients 12 months and younger.

Data source: Ovid MEDLINE, EMBASE, CINAHL, and Cochrane Central Register of Controlled Trials (CENTRAL) databases were searched from inception to March 20, 2021.

Review methods: Studies that involved patients 12 months and younger with report of intraoperative or postoperative complication outcomes were included. Studies selected were reviewed for complications, explants, readmissions, and prolonged hospitalizations. Two independent reviewers screened all studies that were selected for the systematic review and meta-analysis. All studies included were assessed for quality and risk of bias.

Results: The literature search yielded 269 studies, of which 53 studies underwent full-text screening, and 18 studies were selected for the systematic review and meta-analysis. A total of 449 patients and 625 cochlear implants were assessed. Across all included studies, major complications were noted in 3.1% of patients (95% CI, 0.8-7.1) and 2.3% of cochlear implantations (95% CI, 0.6-5.2), whereas minor complications were noted in 2.4% of patients (95% CI, 0.4-6.0) and 1.8% of cochlear implantations (95% CI, 0.4-4.3). There were no anesthetic complications reported across all included studies.

Conclusion: The results of this systematic review and meta-analysis suggest that cochlear implantation in patients 12 months and younger is safe with similar rates of complications to older cohorts.

Otol Neurotol. Author manuscript; available in PMC 2014 Apr 1.
Published in final edited form as:
Otol Neurotol. 2013 Apr; 34(3): 532–538.
doi: 10.1097/MAO.0b013e318281e215

PMCID: PMC3600165
NIHMSID: NIHMS433609
PMID: 23478647

Spoken Language Benefits of Extending Cochlear Implant Candidacy Below 12 Months of Age

Johanna G. Nicholas, PhD and Ann E. Geers, PhD

Children with CI surgery at 6–11 months achieved higher scores on all spoken language measures as compared to those with surgery at 12–18 months.

The Journal of Laryngology & Otology, 1 of 8.
© JLO (1984) Limited, 2017
doi:10.1017/S0022215117001141

MAIN ARTICLE

Bony cochlear nerve canal and internal auditory canal measures predict cochlear nerve status

E TAHİR[1], M D BAJİN[1], G ATAY[1], B Ö MOCAN[2], L SENNAROĞLU[1]

Otol Neurotol. 2007 Aug;28(5):597-604.

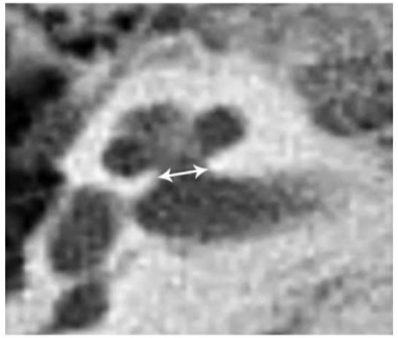
Value of computed tomography in the evaluation of children with cochlear nerve deficiency.

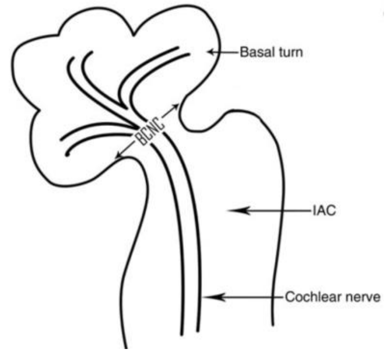
Adunka OF[1], Jewells V, Buchman CA.

Acta Otolaryngol. 2002 Jan;122(1):43-8.

Dimensions of the cochlear nerve canal: a radioanatomic investigation.

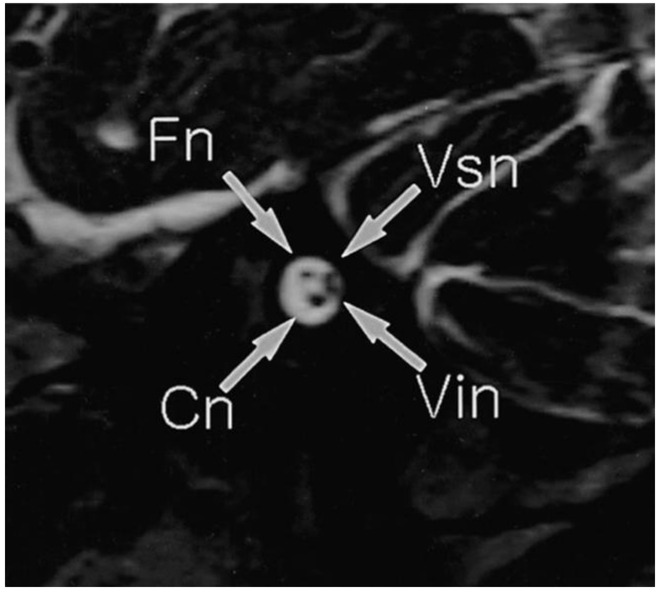
Stjernholm C[1], Muren C.





In axial CT sections, if the bony cochlear nerve canal is less than 1.4 mm, it indicates **cochlear nerve hypoplasia**

In sagittal MRI sections, if the cochlear nerve appears smaller than the facial nerve,



The left IAC shows a normal facial nerve, a cochlear nerve of normal size, and clearly visualized divided vestibular branches.

Ear Hear. 2023 May-Jun;44(3):558-565. doi: 10.1097/AUD.0000000000001299. Epub 2022 Dec 8.

Long-Term Auditory and Speech Outcomes of Cochlear Implantation in Children With Cochlear Nerve Aplasia

Xiuhua Chao [1], Jianfen Luo, Ruijie Wang, Fangxia Hu, Haibo Wang, Zhaomin Fan, Lei Xu

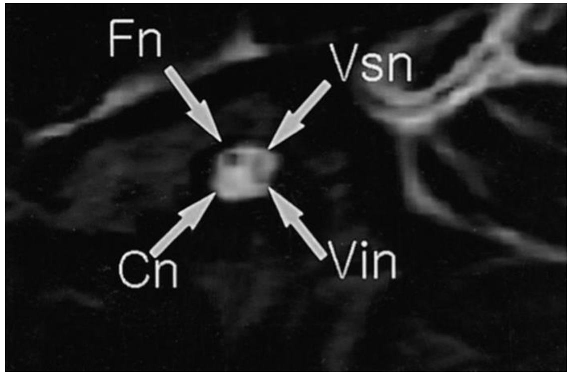
Apparent cochlear nerve aplasia: to implant or not to implant?

Frank M Warren 3rd [1], Richard H Wiggins 3rd, Cache Pitt, H Ric Harnsberger, Clough Shelton

Conclusion: The absence of a visible cochlear nerve or cochlear nerve canal on radiologic imaging does not preclude auditory innervation of the cochlea. Cochlear implantation can be a viable option for patients with apparent cochlear nerve aplasia who have undergone appropriate testing. Electronically evoked auditory brainstem response is critical in the evaluation of this patient group.

The patient with left cochlear nerve hypoplasia has a cochlear nerve that appears thinner in caliber compared to the facial nerve.

Another study recommends 3-Tesla MRI for the cochlear nerve deficiency suspect



> Otol Neurotol. 2021 Jan;42(1):38-46. doi: 10.1097/MAO.0000000000002849.

Audiologic Outcome of Cochlear Implantation in Children With Cochlear Nerve Deficiency

Medhat Yousef [1 2], Tamer A Mesallam [3 4], Soha N Garadat [5], Ayna Almasaad [4], Farid Alzhrani [1 4], Abdulrahman Alsanosi [1 4], Abdulrahman Hagr [1 4]

Affiliations + expand

PMID: 32976344 DOI: 10.1097/MAO.0000000000002849

The benefits of CI in patients with cochlear nerve hypo/aplasia are limited compared to the children without nerve deficiency.

Abstract

Objective/hypothesis: The aim of this study was to investigate cochlear implantation (CI) outcome in children with nerve deficiency.

Study design: Retrospective chart review.

Methods: A total of seven children with prelingual profound deficiency (hypoplasia or aplasia) were included. A control group of 10 CI children with no cochlear nerve anomalies was also included. In addition to implant stimulation levels, children's performance on pure-tone audiometry, speech reception measure, and auditory and speech skills ratings were compared across groups. Additionally, pre- and postoperative audiologic results were evaluated for the group with nerve deficiency.

Results: In general, children with nerve deficiency performed poorer than those without nerve deficiency on all tested measures. Stimulation levels were considerably higher and more variable than the control group. Results further showed that performance was dependent on the diameter of the internal auditory canal.

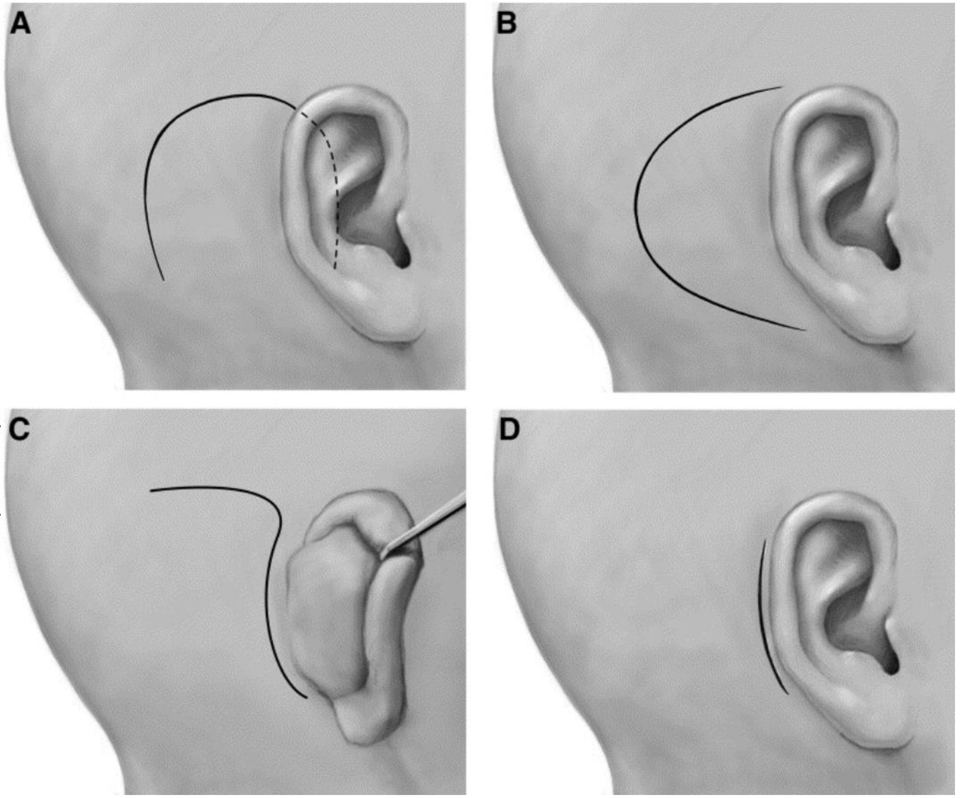
Conclusion: Overall, cochlear implantation outcome in children with auditory nerve deficiency is poorer and extremely more variable than those without nerve deficiency. However, three of the patients had a noticeable improvement in auditory performance postimplantation suggesting that CI is a viable option in this population but expected benefit can be dependent on the status of the cochlear nerve.

Cochlear Implant Incision Became Smaller

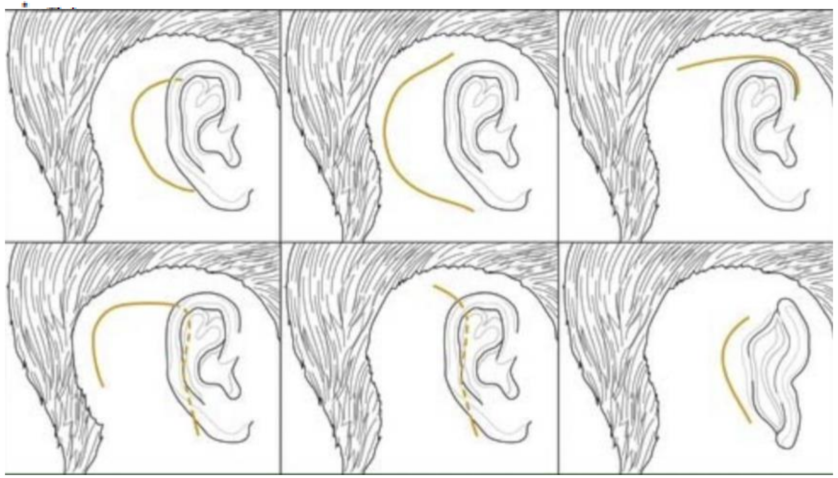
Int J Pediatr Otorhinolaryngol. 2012 Aug;76(8):1102-6. doi: 10.1016/j.ijporl.2012.04.008. Epub 2012 May 16.

Minimal access and standard cochlear implantation: a comparative study.

Prager JD[1], Neidich MJ, Perkins JN, Meinzen-Derr J, Greinwald JH Jr.



Variable	Type of CI technique		
	Standard	Minimal	
Mean age at implantation (SD), years	6 (6.1)	6 (4.6)	
Median age at implantation (range), years	3 (1–22.5)	4.5 (1–24.5)	
Sex			
Male	18	30	
Female	31	43	
Total implants, no. (%)	49	73	
Advanced Bionics®	15 (30.6)	9 (12.3)	
Cochlear Nucleus®	30 (61.2)	64 (87.7)	
Med-El MAESTRO®	3 (6.1)	0	
Clarion®	1 (2.0)	0	
Mean time in operating room (SD), min	255 (49)	200 (31)	<.0001[b]
Mean operative time (SD), min	200 (45)	149.5 (28)	<.0001[a]



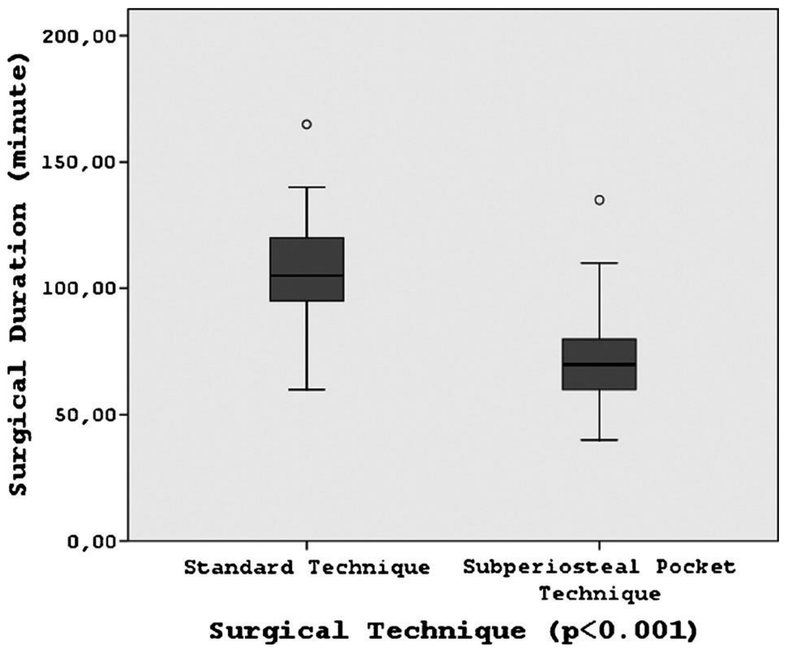
With the reduction in incision size:

- Shorter operation time
- Lower complication rates
- Decreased incidence of wound and flap issues

Subperiosteal Temporal Pocket Versus Standard Technique in Cochlear Implantation: A Comparative Clinical Study

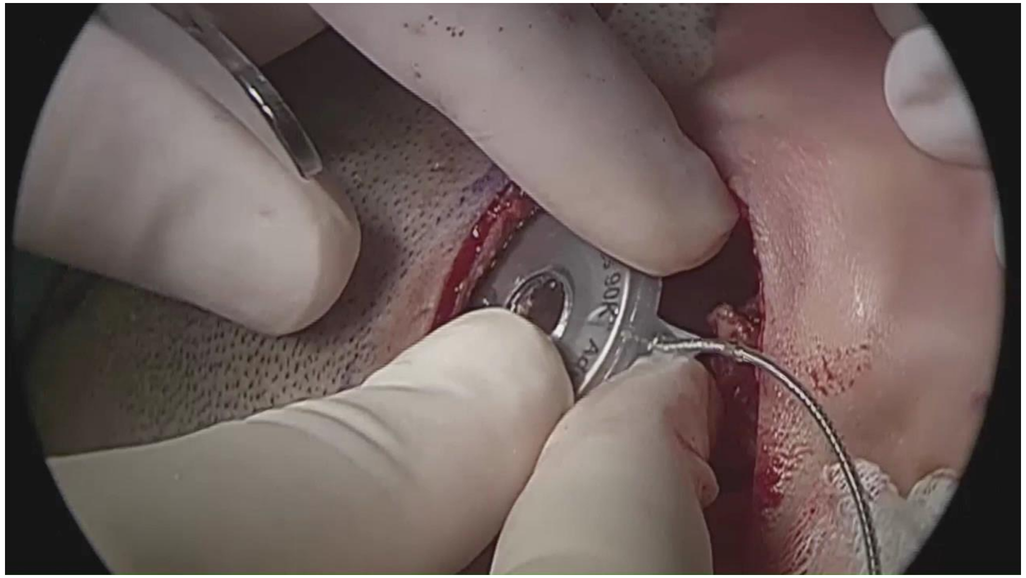
*Yahya Güldiken, *Kadir Serkan Orhan, †Özgür Yiğit, *Bora Başaran, *Beldan Polat, *Selçuk Güneş, †Engin Acıoğlu, and *Kemal Değer

*Otorhinolaryngology Head & Neck Surgery, Istanbul Medical Faculty, Istanbul University; and
†Otorhinolaryngology Head & Neck Surgery, Istanbul Research and Educational Hospital, Istanbul, Turkey



- Safe and effective
- No intracranial complications detected
- 30% reduction in operation time
- No connection problems with the external processor

In our surgical practice, we prefer to use the subperiosteal pocket technique.



Radiologic Evidence of Cochlear Implant Bone Bed Formation Following the Subperiosteal Temporal Pocket Technique

Artunc Kaan Turanoglu, MD[1], Ozgur Yigit, MD[1], Engin Acioglu, MD[1], and Ahmet Mufit Okbay, MD[2]

Otolaryngology–
Head and Neck Surgery
1–5
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DOI: 10.1177/0194599816628456
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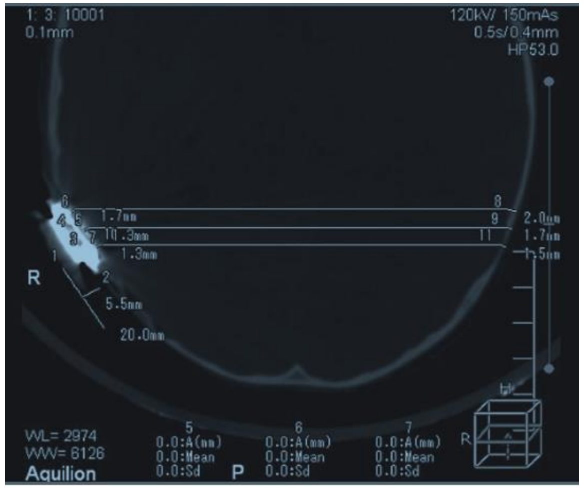
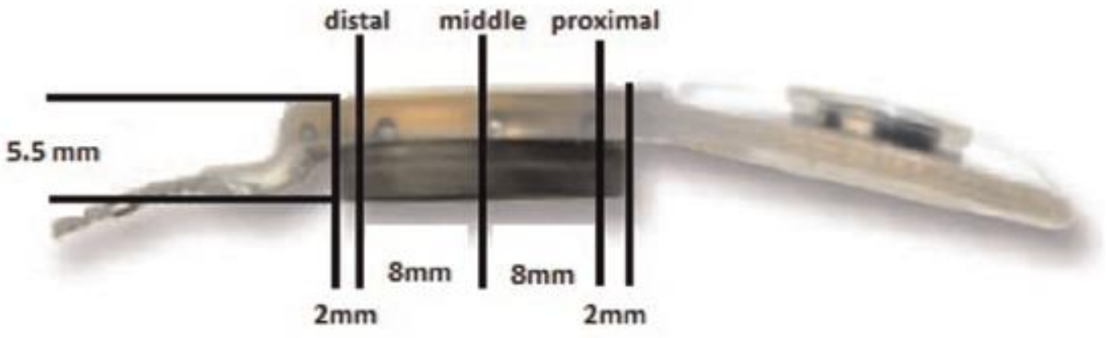
SAGE

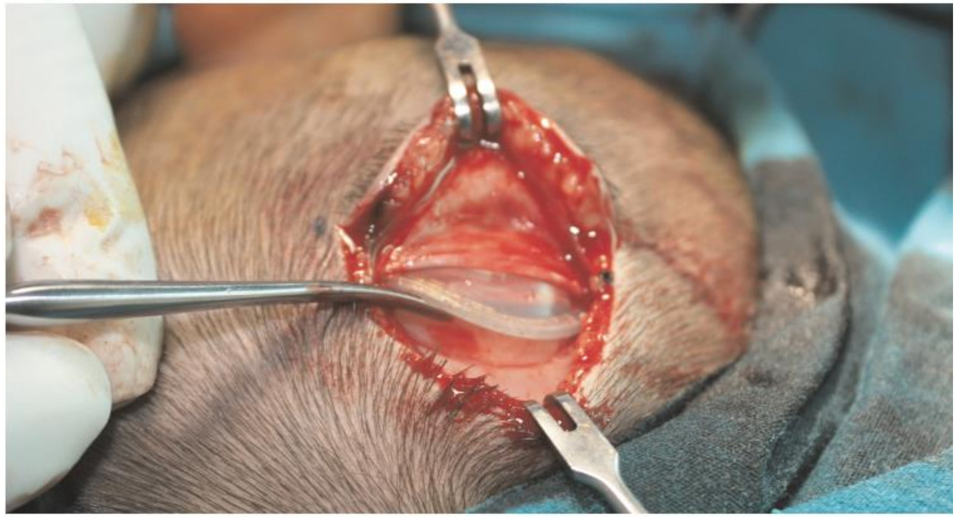


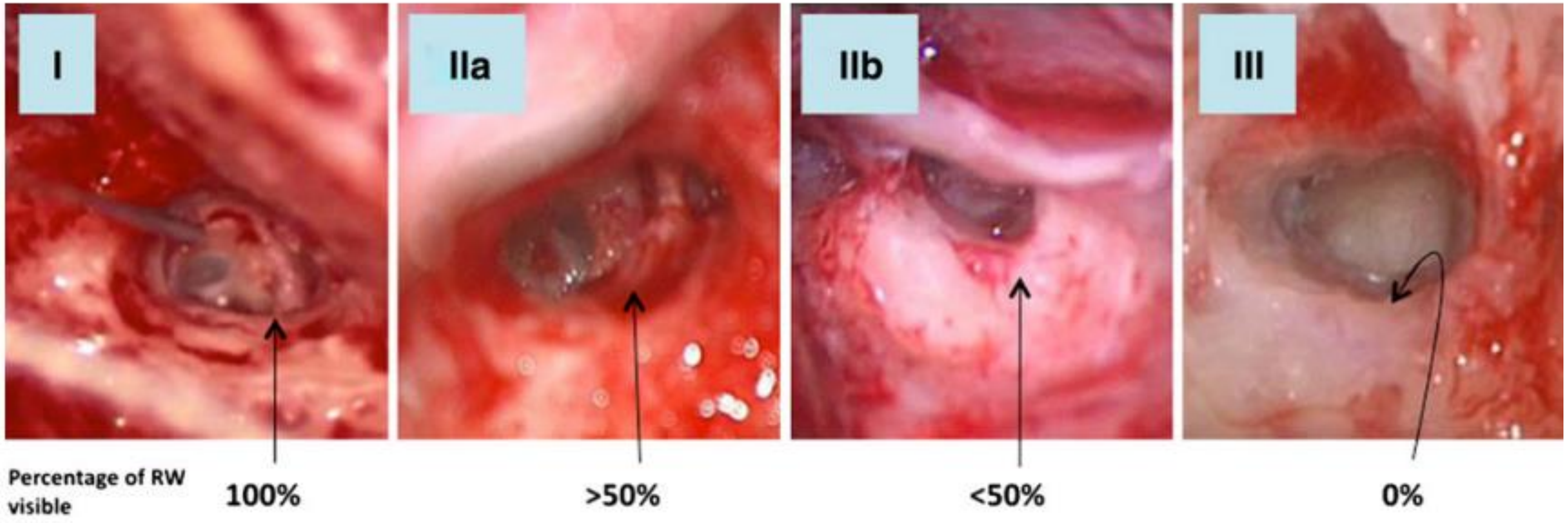


Bone width

[a]Mean values in the proximal segment: unimplanted side, 4.17 ± 1.10 mm; implanted side, 2.40 ± 0.80 mm (*P* = .0001).
[b]Mean values in the middle segment: unimplanted side, 3.02 ± 0.85 mm; implanted side, 1.48 ± 0.33 mm (*P* = .0001).
[c]Mean values in the distal segment: unimplanted side, 3.40 ± 0.61 mm; implanted side, 2.13 ± 0.41 mm (*P* = .0001).

In our study, spontaneous bone bed formation was demonstrated by radiological examination.





Eur Arch Otorhinolaryngol (2013) 270:1237–1242
DOI 10.1007/s00405-012-2106-4

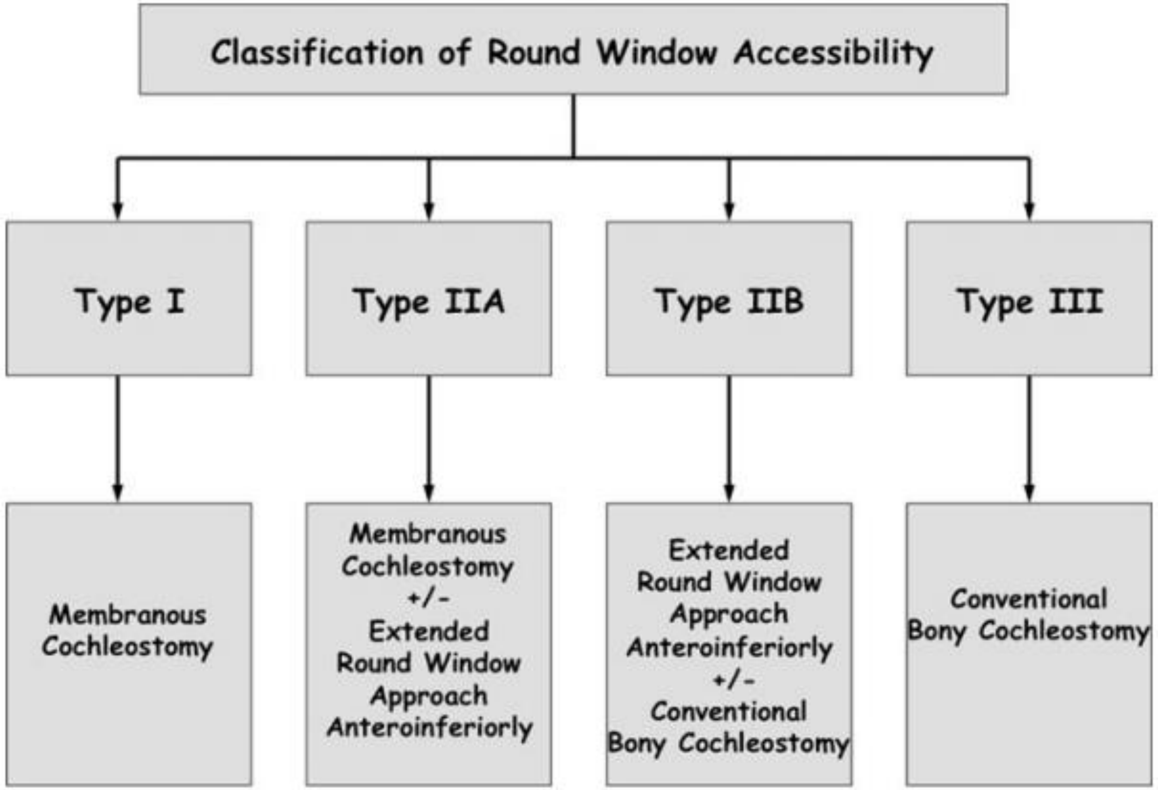
OTOLOGY

Evaluation of round window accessibility to cochlear implant insertion

Annabelle C. Leong · Dan Jiang · Andreas Agger · Alec Fitzgerald-O'Connor

SAINT THOMAS CLASSIFICATION IS USED FOR ACCESS TO THE ROUND WINDOW FROM POSTERIOR TYMPANOTOMY.

BEFORE THE USE OF ENDOSCOPE BECAME COMMON, SUCH CASES REQUIRED AN EXTENDED FACIAL RECES APPROACH OR COCHLEOSTOMY.



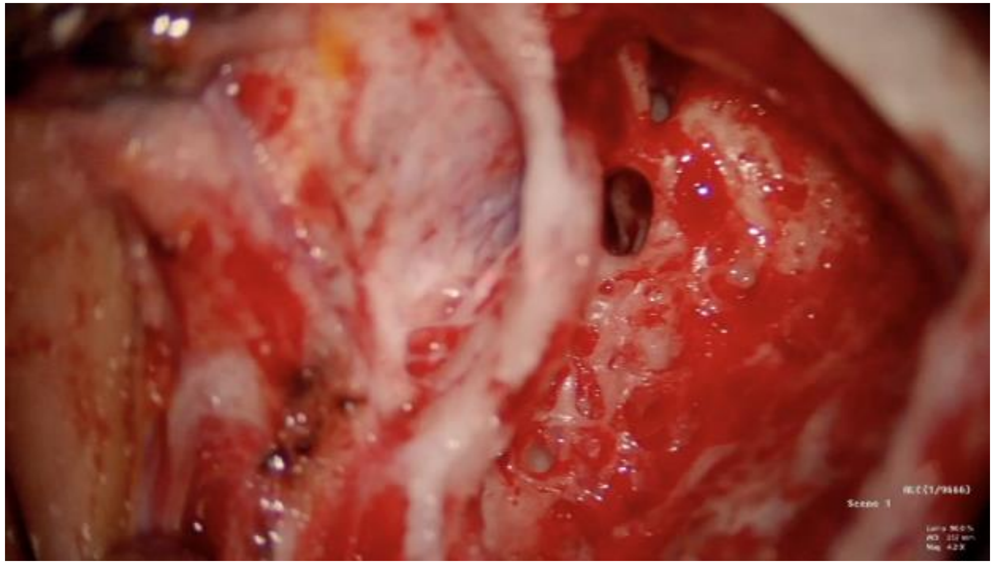
Endoscope-Assisted Cochlear Implantation

CEO *Clinical and Experimental Otorhinolaryngology* 2017 December 1 [Epub ahead of print]
https://doi.org/10.21053/ceo.2017.00927
pISSN 1976-8710 eISSN 2005-0720
Original Article

Endoscope-Assisted Cochlear Implantation

Enis Alpin Güneri · Yüksel Olgun

Department of Otorhinolaryngology, Dokuz Eylül University School of Medicine, Izmir, Turkey

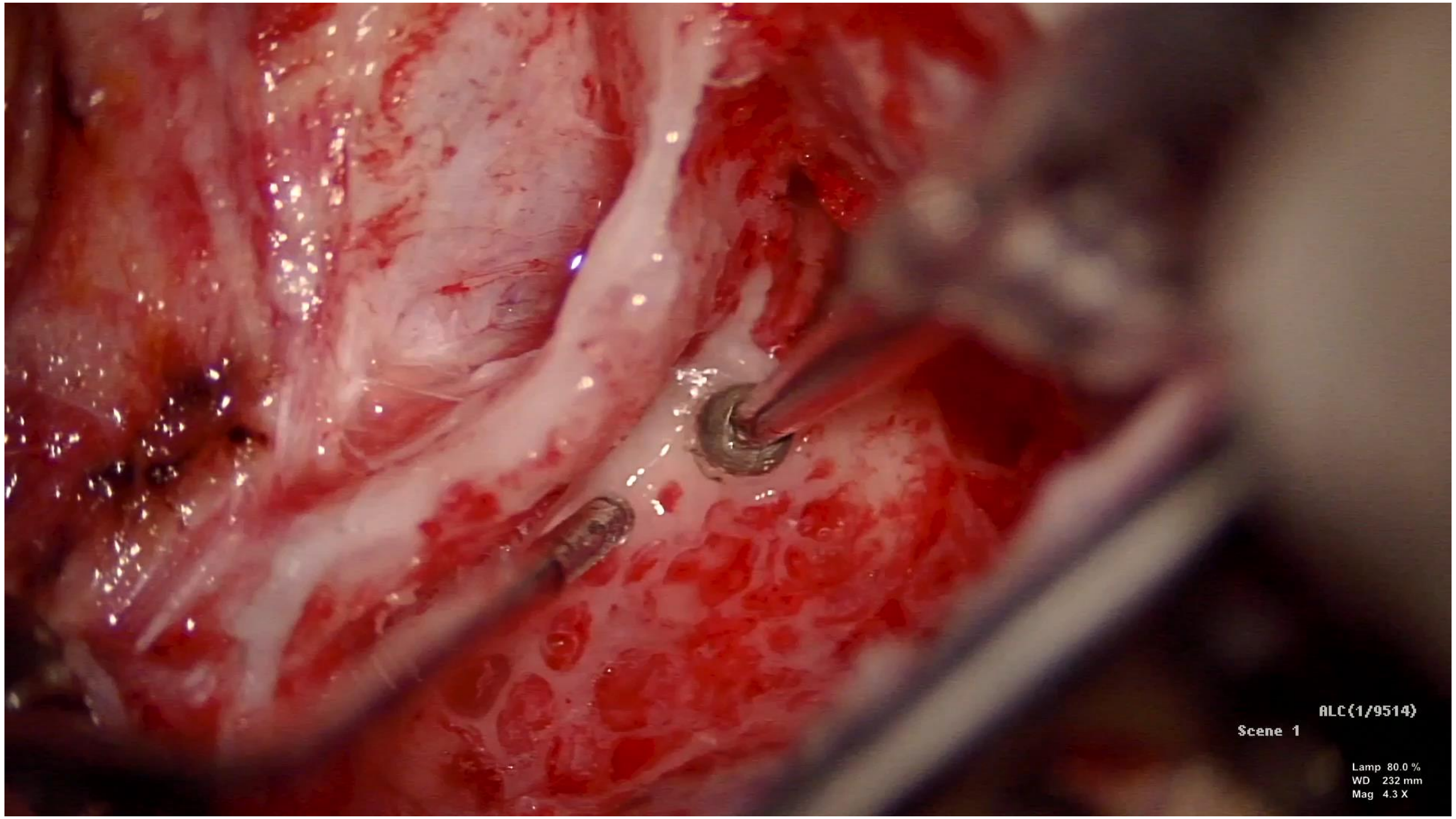


- 179 cochlear implantations (27 adults, 152 children)
- 14 cases (7.8%) identified the round window with an endoscope
- All cases were classified as STH 2b

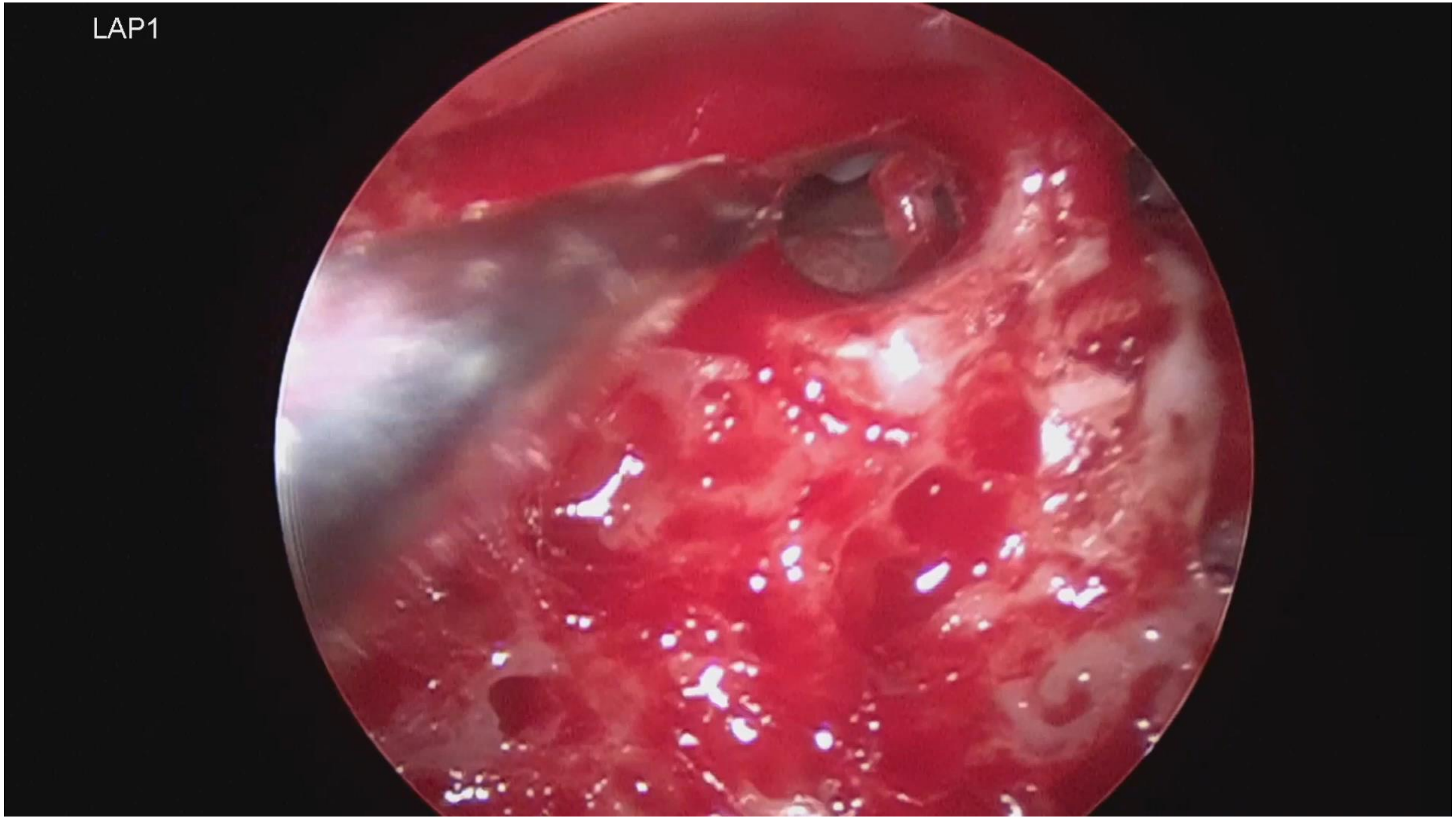
Successful identification of the endoscopic round window was achieved in all cases, eliminating the need for cochleostomy.

Difficulty in seeing the Round Window from posterior tympanotomy (left ear)

microscopy

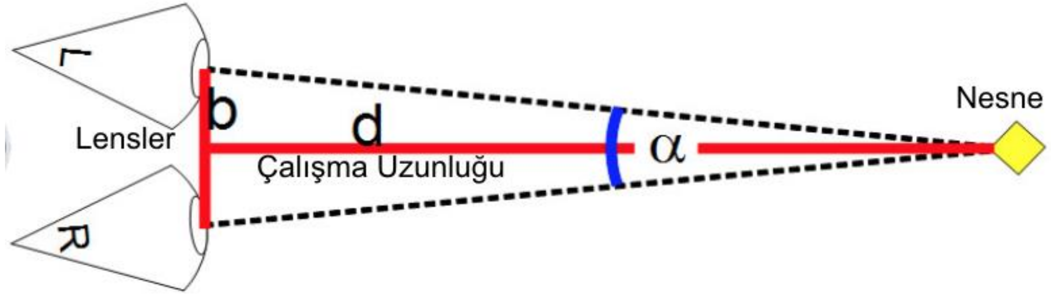


Endoscopy



Exoscope

Endoscope ➡ Monocular vision



Exoscope provides Binocular vision

VITOM® 3D Handle

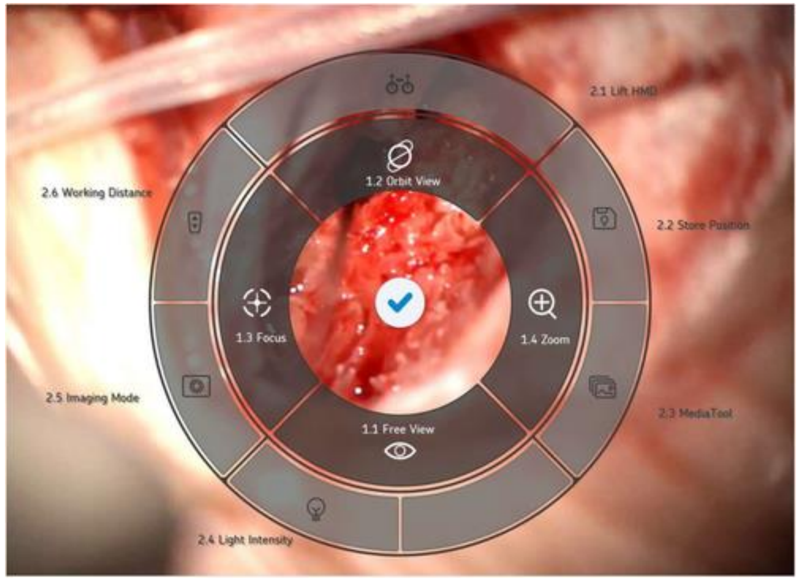
New Technology in Cochlear Implantation

Acta Otolaryngol. 2017 Apr;137(4):447-454. doi: 10.1080/00016489.2017.1278573. Epub 2017 Feb

Robotic cochlear implantation: surgical procedure and first clinical experience

Marco Caversaccio [1,2], Kate Gavaghan [2], Wilhelm Wimmer [1,2], Tom Williamson [2], Juan Ansò [2],

- In 2016 Prof. Marco Caversaccio applied a robotic approach to the middle ear cavity using a robotic system.



A path leading to the round window is opened directly allowing the surgeon to place the electrode into the scala tympani.

Review Otol Neurotol. 2021 Aug 1;42(7):e825-e835. doi: 10.1097/MAO.0000000000003165.

Robotics for Cochlear Implantation Surgery: Challenges and Opportunities

Kush Panara [1], David Shahal [1], Rahul Mittal [1], Adrien A Eshraghi [1,2,3,4]

ROUND WINDOW APPROACH > COCHLEOSTOMY

The round window approach has become a standard part of modern cochlear implantation surgery since approximately 2010.

Advantages of the Round Window Approach:

Minimally Invasive Surgery: (prevents bone dust from entering the cochlea during drilling)
Soft Insertion Technique: Control of the angle and speed of electrode placement
Reduced Risk of Misplacement in the Scala Vestibuli
Fewer Postoperative Complications (vertigo etc.)

* Skarzynski H, Lorens A, Piotrowska A, et al. Partial deafness cochlear implantation in children. Int J Pediatr Otorhinolaryngol 2007;71:1407–13.

* Todt I, Basta D, Ernst A. Does the surgical approach in cochlear implantation influence the occurrence of postoperative vertigo? Otolaryngol Head Neck Surg 2008;138:8–12.

Preserving Residual Hearing

Adv Otorhinolaryngol. 2018;81:66-73. doi: 10.1159/000485544. Epub 2018 Apr 6.

Hearing Preservation Cochlear Implant Surgery.

Bruce IA, Todt I.

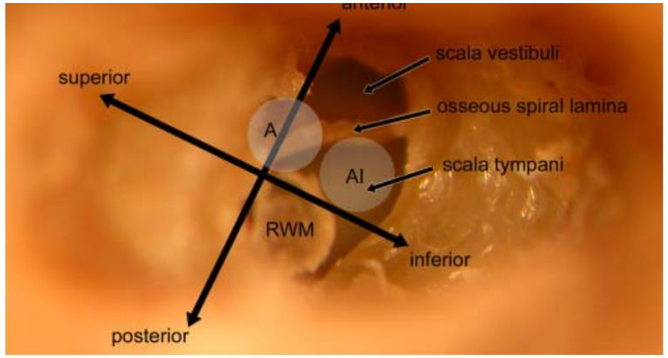
- **Minimal Invasive Surgery (Soft surgical technique)**

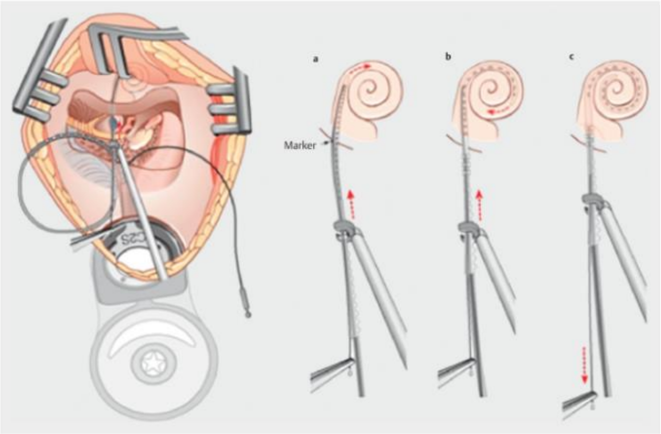
1. Avoidance of bone contact during drilling
2. Prevention of bone dust and blood from entering the cochlea
3. Care should be taken not to increase intracochlear pressure while opening the round window membrane

- **Round window approach > Cochleostomy**
- **Soft Insertion Technique (Gentle insertion)**

1. insertion speed → slower insertion associated with less cochlear trauma
2. length of the cochlear duct → to choose the right electrode for the patients

- **Atraumatic electrodes**
- **Use of protective agents**





Minimizing intracochlear trauma is the most critical factor

* Bruce IA, Todt I. Hearing Preservation Cochlear Implant Surgery. Adv Otorhinolaryngol. 2018;81:66-73.
* Bruce IA, et al: Hearing preservation via a cochleostomy approach and deep insertion of a standard length cochlear implant electrode. Otol Neurotol 2011; 32:1444–1447.
* Lenarz T. Cochlear implant - state of the art. GMS Curr Top Otorhinolaryngol Head Neck Surg. 2018 Feb 19;16:Doc04.

Cochlear Implant Electrodes from Past to Present

Based on Placement Location

Lateral Wall Electrodes

(1980s)

Perimodiolar Electrodes

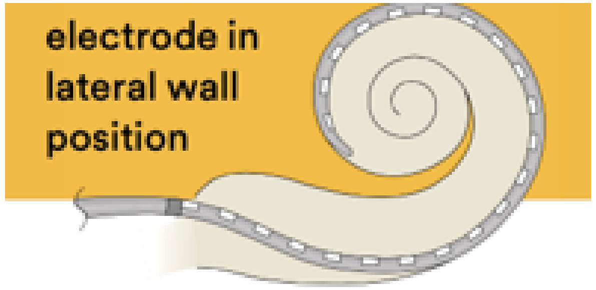
(1990s)

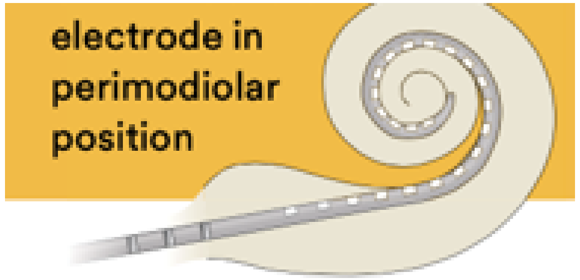
Midscala Electrodes

(2000s)

Hybrid electrodes (2010'lar)

Developed to preserve residual hearing.





Changes Over Time in the Classification of Inner Ear Malformations

Carlo Mondini (1791), first to describe inner ear malformations

TABLE I.
Classification of Congenital Malformations of the Inner Ear.

A. With an absent or malformed cochlea:

1. Complete labyrinthine aplasia (Michel deformity): no inner ear development
2. Cochlear aplasia: no cochlea, normal or malformed vestibule and semicircular canals
3. Cochlear hypoplasia: small cochlear bud, normal or malformed vestibule and semicircular canals
4. Incomplete partition: small cochlea with incomplete or no interscalar septum, normal or malformed vestibule and semicircular canals
5. Common cavity: cochlea and vestibule form a common cavity without internal architecture; normal or malformed semicircular canals

B. With a normal cochlea:

1. Vestibule-lateral semicircular canal dysplasia: enlarged vestibule with a short, dilated lateral semicircular canal; remaining semicircular canals are normal
2. Enlarged vestibular aqueduct: accompanied by normal semicircular canals, normal or enlarged vestibule

Jackler's Classification (1987)

Jackler, R. K., Luxford, W. M., & House, W. F. (1987). Congenital malformations of the inner ear: a classification based on embryogenesis. *The Laryngoscope*, *97*(3 Pt 2 Suppl 40), 2–14.

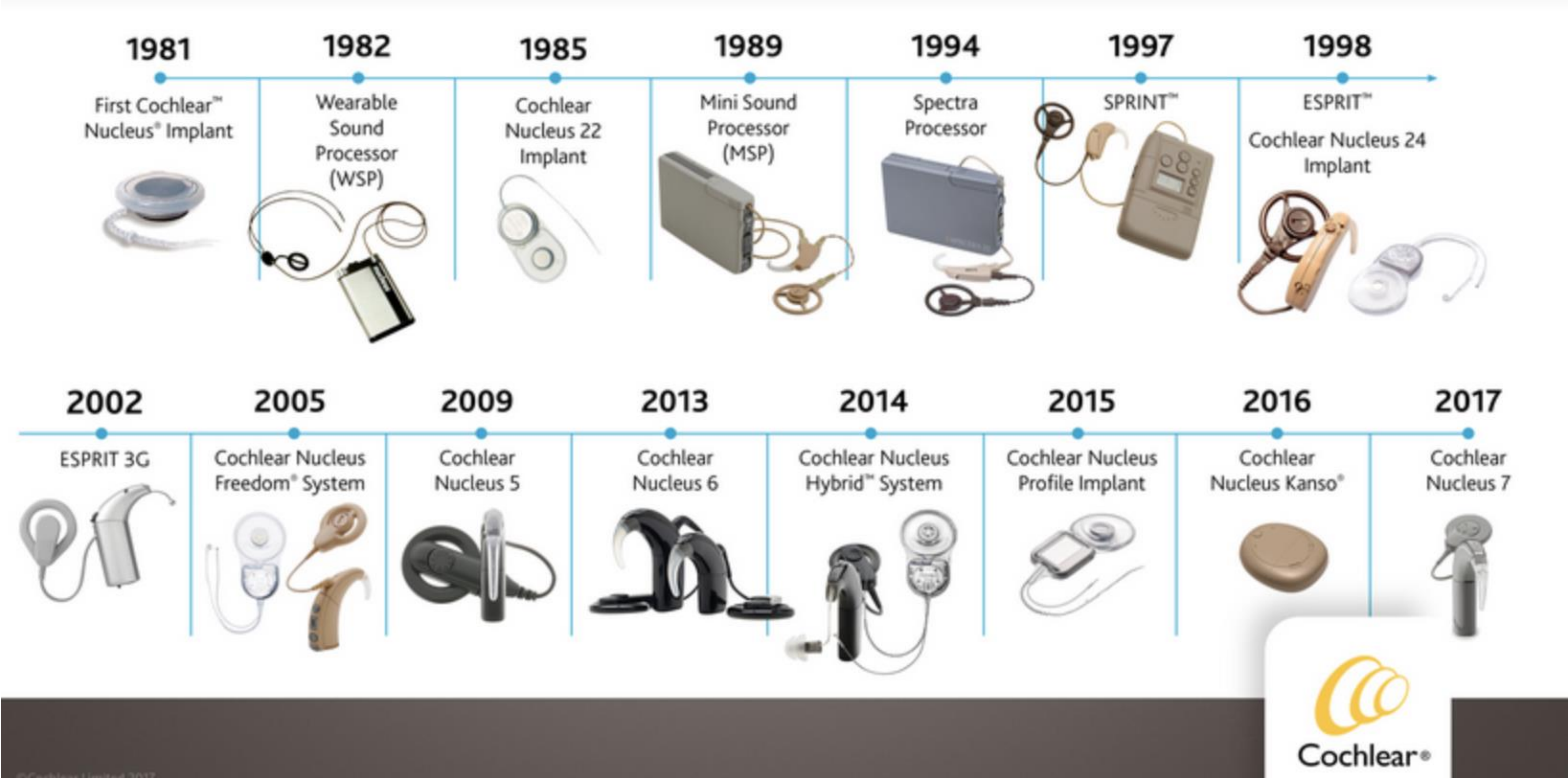
Sennaroğlu's 2017 classification is the most up-to-date classification used for the radiological evaluation of inner ear anomalies.

Sennaroglu (2002)	Sennaroglu (2017)	Subgroups (2017)
Michel deformity	Complete labyrinthine aplasia	With hypoplastic or aplastic petrous bone With otic capsule Without otic capsule
	Rudimentary otocyst	No subgroups
Cochlear aplasia	Cochlear aplasia	With normal labyrinth With a dilated vestibule (CAVD)
Common cavity deformity	Common cavity	No subgroups
Incomplete partition type 1	Incomplete partitions of the cochlea (differentiation of cochlea and vestibule, normal external dimensions)	Incomplete partition type 1
Incomplete partition type 2		Incomplete partition type 2
		Incomplete partition type 3
Cochlear hypoplasia (corresponding to CH-I)	Cochlear hypoplasia (external cochlear dimensions are smaller than normal)	Type1 Type 2 Type 3 Type 4

Sennaroğlu (2002 – 2017)

Sennaroğlu, L., & Bajin, M. D. (2017). Classification and Current Management of Inner Ear Malformations. *Balkan medical journal*, *34*(5), 397–411.

Development of Cochlear ® Over Time



Cochlear Latest Sound Processors

Nucleus

Nucleus 6

Nucleus 7

Nucleus 8

Kanso 2

Cochlear Latest Internal Processors

Nucleus CI 24RE

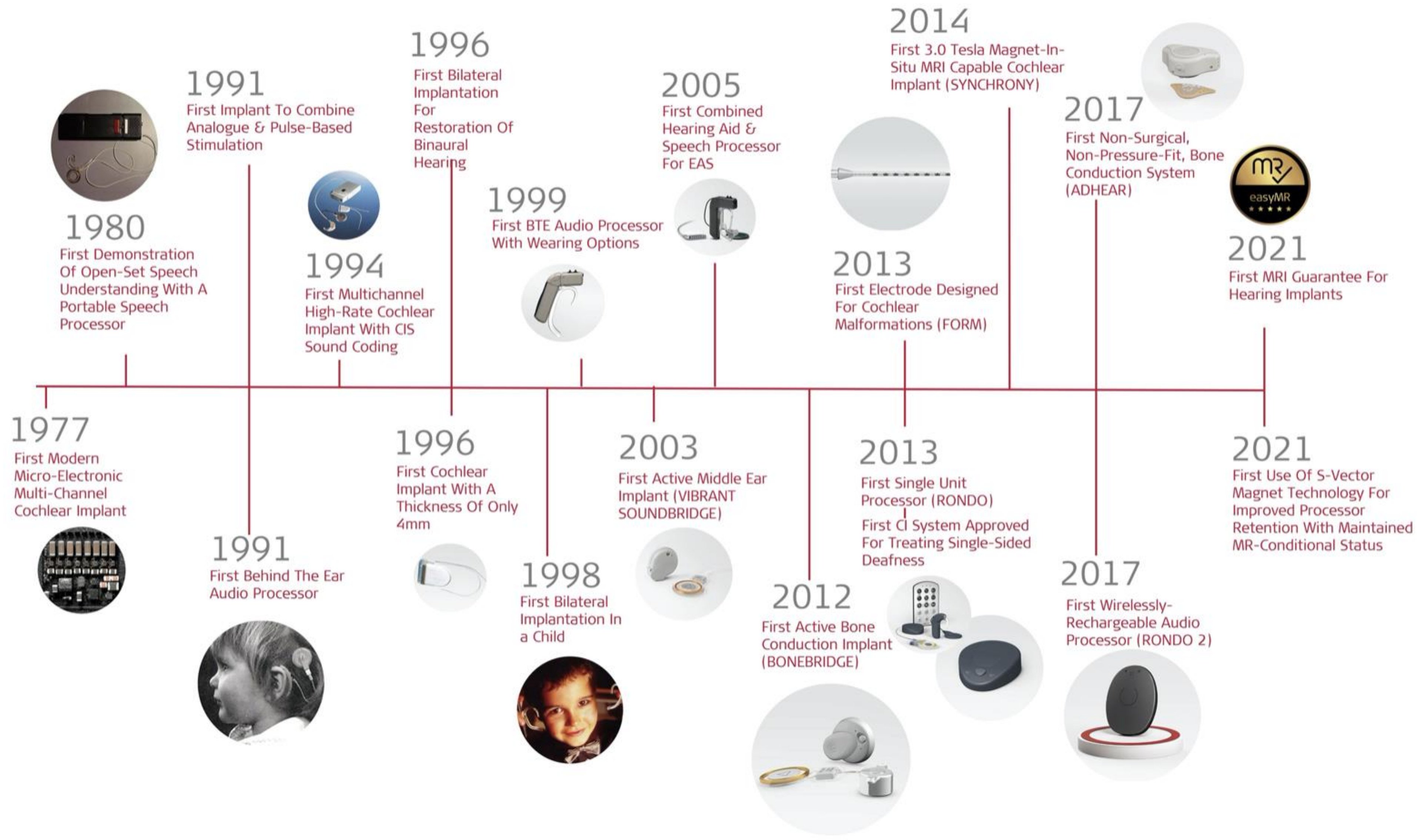
Nucleus CI 422

Nucleus CI 522 (Profile)

Nucleus CI 622 (Profile Plus)

PROFILE (CI512, CI522, CI532)

Development of MED-EL ® Over Time



Medel Latest Sound Processors

OPUS 2

SONNET 2

SONNET 3

RONDO

RONDO 2

RONDO 3

Medel Latest Internal Processors

SONATA 2

CONCERTO 2

SYNCHRONY

SYNCHRONY 2

SmartNav Software

Produced by one of the leading implant companies which aim to help the surgeon during implantation of electrode into cochlea.

Insertion Angle
(Lateral Wall Electrodes Only)

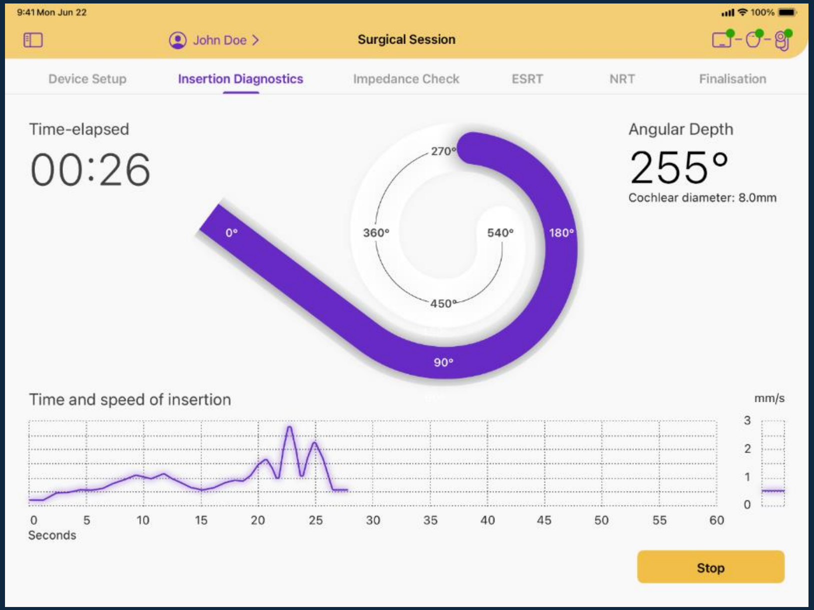
- Insertion Angle is real time measurement
- Allows surgeons to insert to their desired angular depth

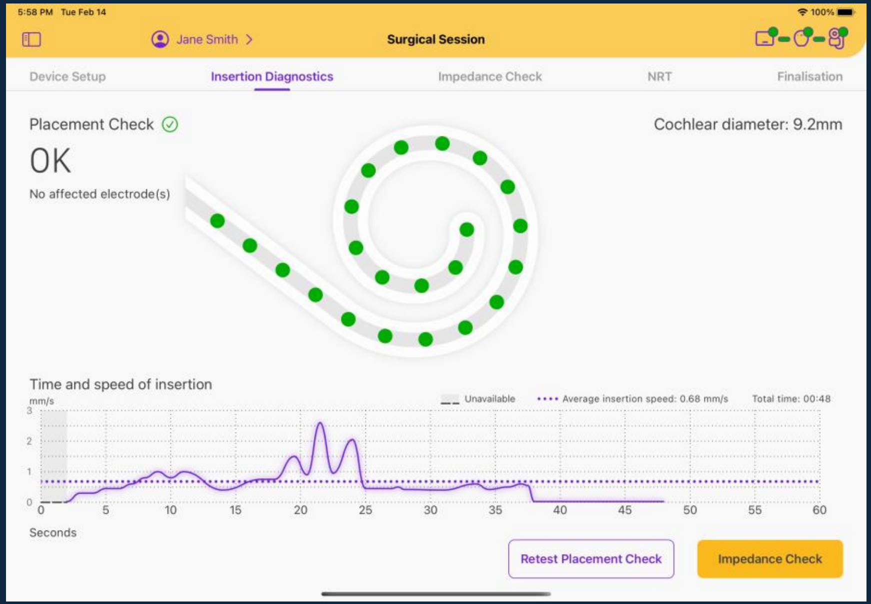
Insertion Time
(for all electrodes)

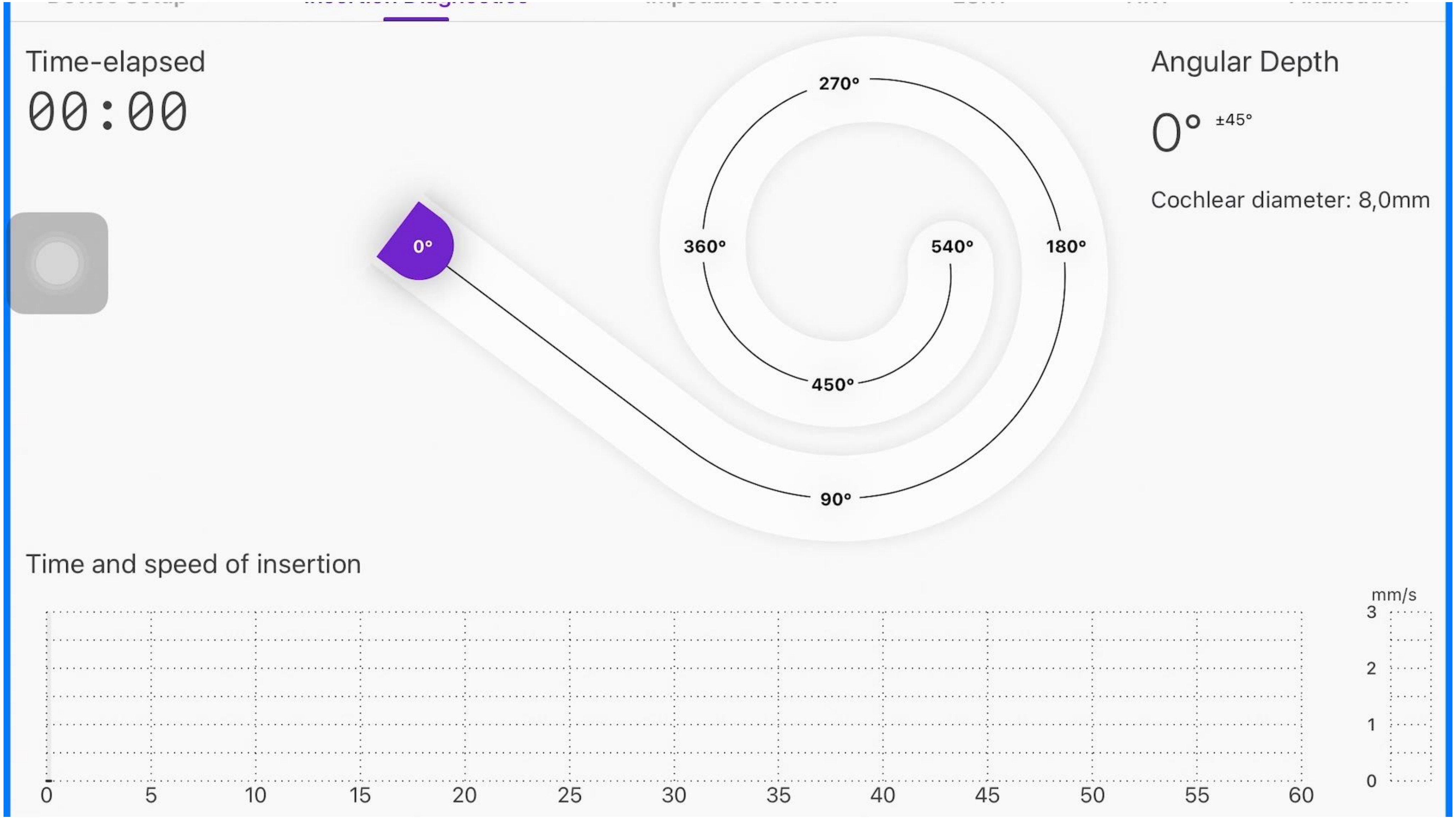
- Slow and consistent insertion speed has been shown to be associated with less intracochlear trauma.

Insertion Control

- Transimpedance matrix measurement is used to evaluate whether there is tip foldover in intracochlear electrodes.






Time-elapsed
00:00
0°
270°
360°
540°
180°
450°
90°
Angular Depth
0° ±45°
Cochlear diameter: 8,0mm
Time and speed of insertion
mm/s
3
2
1
0
0 5 10 15 20 25 30 35 40 45 50 55 60

OTOPLAN Software

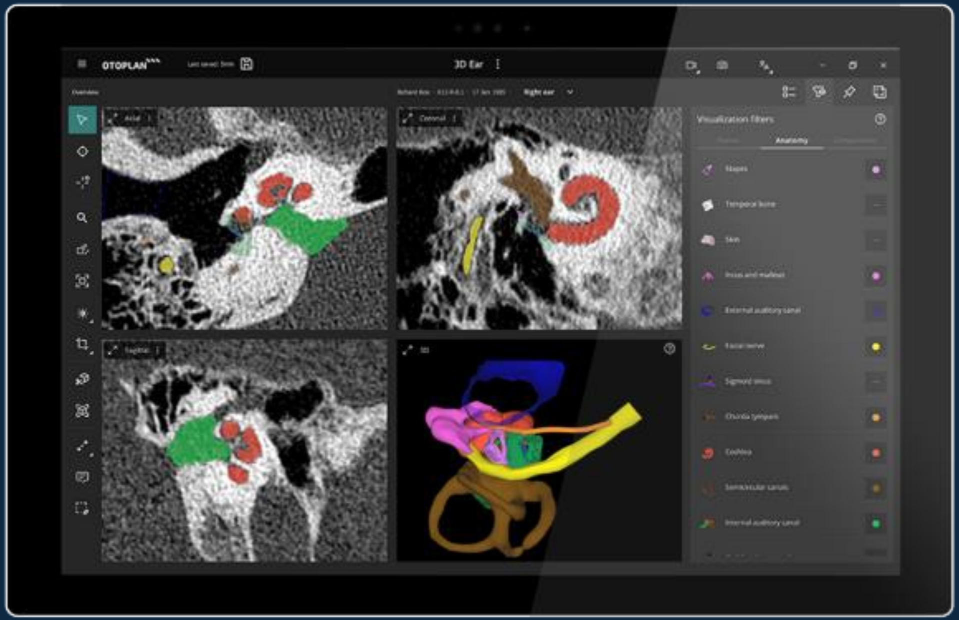
Advanced surgical planning software developed to optimize cochlear implantation

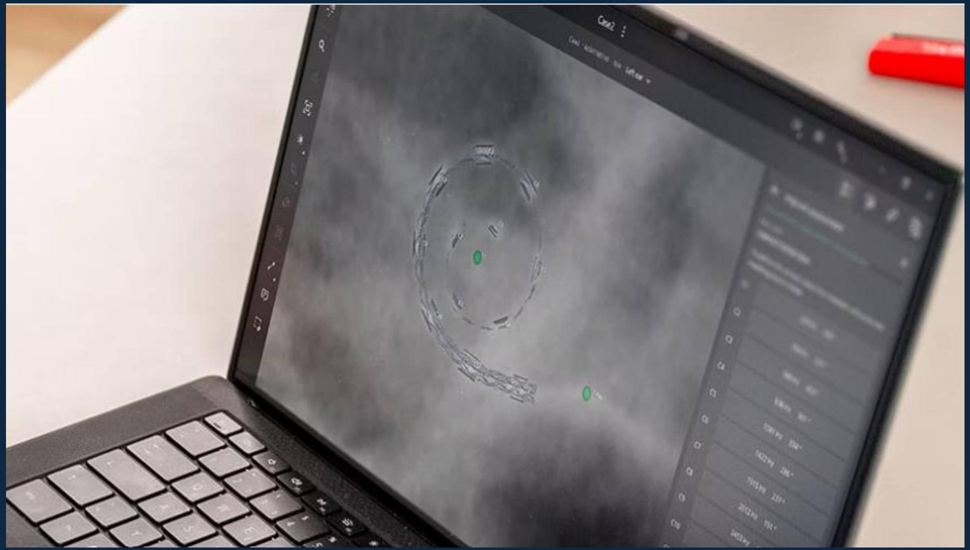
✓Generate detailed 3D reconstructions and measure anatomical parameters

✓Visualize how each electrode would fit each individual cochlea

✓Confirm electrode insertion status and generate detailed patient reports

✓ Accurate place-pitch stimulation of the natural tonotopic map of the cochlea





Cochlear Implantation Distant Monitoring

In the past, the follow-ups were performed in the clinics, but nowadays fitting operations can all be performed distantly.

Otol Neurotol. 2019 Mar; 40(3): e260–e266.
Published online 2019 Feb 12. doi: 10.1097/MAO.0000000000002119
PMCID: PMC6380526
PMID: 30741905

Remote Programming of Cochlear Implants

Heidi K. Slager,* Jamie Jensen,† Kristin Kozlowski,† Holly Teagle,‡ Lisa R. Park,‡ Allison Biever,§ and Megan Mears||

▸ Author information ▸ Copyright and License information PMC Disclaimer

Original articles

Cochlear implant telemedicine: Remote fitting based on psychoacoustic self-tests and artificial intelligence

Matthias Meeuws, David Pascoal, Sebastien Janssens de Varebeke, Geert De Ceulaer & Paul J. Govaerts

Pages 260-268 | Published online: 13 May 2020
Cite this article https://doi.org/10.1080/14670100.2020.1757840 Check for updates

Self Care

- ✓ Patients can perform self-assessments through the application.
- ✓ It is designed to complete the fitting and rehabilitation processes.
- ✓ This minimizes the number of in-hospital follow-up appointments for patients.

Remote Care

A new service that establishes a connection between the company and the patient through the application, allowing users to perform all device settings remotely.

FUTURE ELECTRODES

Review > GMS Curr Top Otorhinolaryngol Head Neck Surg. 2018 Feb 19:16:Doc04.
doi: 10.3205/cto000143. eCollection 2017.

Cochlear implant – state of the art

Thomas Lenarz [1]

Affiliations + expand

PMID: 29503669 PMCID: PMC5818683 DOI: 10.3205/cto000143

The Journal of International Advanced Otology

J Int Adv Otol 2018; 14(3): 382-91 • DOI: 10.5152/iao.2018.6372

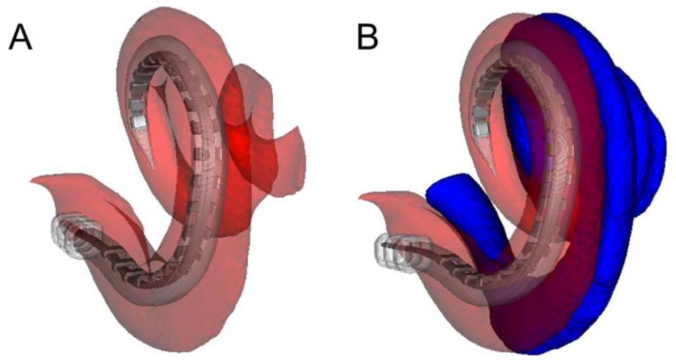
Invited Review

Considerations and Rationale for Cochlear Implant Electrode Design – Past, Present and Future

Frank Risi

Group Product Manager, Surgical & Implants, Cochlear Limited, New South Wales, Australia

- Better touch point
- Closer to modiolus
- Silicone electrodes (Michigan group)
- Hybrid electrodes bearing silicon segments
- Electrodes that release growth factor



NEXT-GENERATION COCHLEAR IMPLANTS

Review > Adv Otorhinolaryngol. 2018:81:105-113. doi: 10.1159/000485540. Epub 2018 Apr 6.

The Future of Cochlear Implant Design

Alistair Mitchell-Innes, Shakeel R Saeed, Richard Irving

PMID: 29794452 DOI: 10.1159/000485540

DOI: 10.1039/D3MA01105D (Review Article) *Mater. Adv.*, 2024, **5**, 4958-4973

The past, present, and future of *in vivo*-implantable recording microelectrodes: the neural interfaces

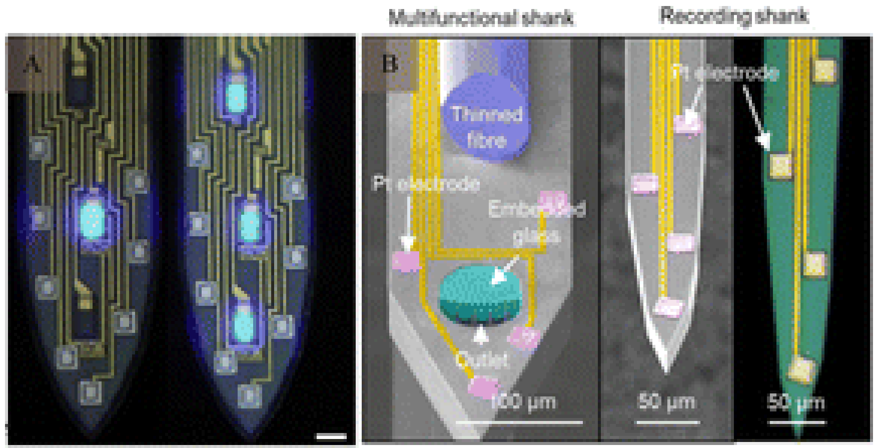
Kun Liu† [a], Hao Zhang† [a], Minghui Hu [b], Zifa Li [b], Kaiyong Xu [b], Dan Chen [b], Wenqiang Cui [c], Cui Lv [d], Ran Ding *[e], Xiwen Geng *[a] and Sheng Wei *[a]

- Restoration of nerve functions
- Implants very close in structure to the normal cochlea
- Optoacoustic & optogenetic stimulation
  - Can provide more specific stimuli
- New signal processing strategies
- Combined acoustic and electrical stimulation

  Improved differentiation in noise

  Music

  Localization

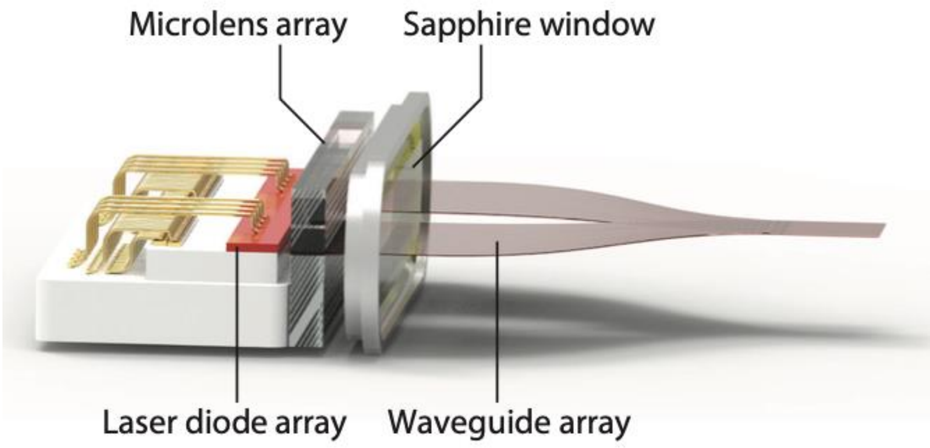


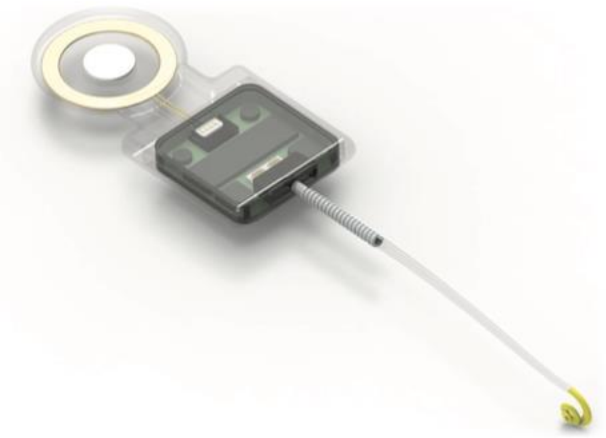
Optical probes and injectable optoelectronics.

Review > Annu Rev Neurosci. 2024 Aug;47(1):103-121.
doi: 10.1146/annurev-neuro-070623-103247. Epub 2024 Jul 1.

Toward Optogenetic Hearing Restoration

Antoine Huet [1] [2] [3], Thomas Mager [4] [5] [6], Christian Gossler [6] [7] [3], Tobias Moser [6] [4] [2] [3]





Abstract

The cochlear implant (CI) is considered the most successful neuroprosthesis as it enables speech comprehension in the majority of the million otherwise deaf patients. In hearing by electrical stimulation of the auditory nerve, the broad spread of current from each electrode acts as a bottleneck that limits the transfer of sound frequency information. Hence, there remains a major unmet medical need for improving the quality of hearing with CIs. Recently, optogenetic stimulation of the cochlea has been suggested as an alternative approach for hearing restoration. Cochlear optogenetics promises to transfer more sound frequency information, hence improving hearing, as light can conveniently be confined in space to activate the auditory nerve within smaller tonotopic ranges. In this review, we discuss the latest experimental and technological developments of optogenetic hearing restoration and outline remaining challenges en route to clinical translation.

Cochlear optogenetics : promises improved hearing by enabling light to activate the auditory nerve in more spatially confined, smaller tonotopic areas, allowing for the transmission of more detailed sound frequency information.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THANK YOU