Cochlear Implants: Aids for the totally deaf

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**Tonotopic organization**

*The concept of place pitch*

- Travelling wave over basilar membrane
- High frequencies basally (near stapes), low frequencies apically
- The auditory nerve has the same tonotopical organisation
The cochlea in acoustic hearing

Apex
Low frequencies

Nerve fibres

Base
High frequencies
Single channel cochlear implant
Uses time information to provide pitch

Apex
Low frequencies

Nerve fibres

Base
High frequencies
Multi-channel cochlear implant
Uses the tonotopic organisation
Cochlear implants replace hair cell function
Improved spatial selectivity
Individual excitation areas

Apex
Low frequencies

Base
High frequencies

Neural degeneration
Multi-channel cochlear implant
Spatial selectivity & channel interaction

Axon degeneration

Apex
Low Frequencies

Base
High Frequencies

Neural degeneration
Basic components
Cochlear Implant
Basic parts

External part
- RF-link with magnet
- Speech processor with microphone

Internal part
- Receiver with magnet and electronics
- Electrode array in cochlea
Body-worn speech processor

BTE speech processor
Current electrodes
perimodiolar design

Clarion HiFocus

Nucleus Contour
Speech coding strategies
Generic pulsatile processor

(b) Pulsatile processing

Microphone | Bandpass filters | Envelope detectors | Amplitude compressors | Pulse modulators | RF transmitter | RF receiver

Cochlea
Intracochlear electrodes
Round window
Auditory nerve

Skin
Envelope carries speech information
temporal fine structure carries timbre and ITD information
Waveform speech
Waveform music
Generic pulsatile processor

(b) Pulsatile processing

Microphone  Bandpass filters  Envelope detectors  Amplitude compressors  Pulse modulators  RF transmitter  RF receiver

Cochlea
Intracochlear electrodes
Round window
Skin
Auditory nerve
The Clinical side of CI
Cochlear Implantation in children

- Lower age at implantation: better outcome
  - diagnostic problem
  - OAE, SSR, ABR, ECoG
- The complete speech and language development has to take place
  - Full effect after several years
- Critical period: upper age limit 6 years?
- Deaf culture
  - 10% has deaf parents
Procedure CI-team Leiden (CIRCLE)
Adult patients

- Candidacy based on global criteria and questionnaire
- Intake
- Pre-operative investigations
- Surgery
- Post-operative follow up
**Indications for CI**

*Global criteria in postlingually deaf people*

- Tone audiogram: ADS thresholds above 1 kHz $\geq$ 90 dB HL
- Speech audiogram: ADS maximal phoneme recognition $\leq$ 40%
- Post-lingual (deafened after 5 years of age)
- Speaks understandably
CIRCLE

Intake Overview

• Coordinator
  • Explain procedure CIRCLE
  • Show implant and speech processor

• ENT-specialist
  • General medical and ENT examination
  • Cause of deafness
  • Surgery and risks

• Audiologist
  • Examination of residual hearing and use of hearing aids
  • Duration of deafness

• Social worker
  • Expectations
  • How does the candidate cope with deafness?
  • Psychosocial functioning
Intake
Audiologist

• Progress of hearing loss
  • Starting point
  • Progressive or stable?

• Use of hearing aids
  • Has the auditory system been stimulated?
  • What are the benefits of the hearing aid?

• Test speech understanding with hearing aid
  • CVC woorden 65 en 75 dB (NVA CD)

• Lip reading capabilities
  • When not adequate a course is advised
Pre-operative tests

Overview

• Audiological testing (psychophysics)
  • Individual ears with hearing aids

• Speech tracking
  • Standardized procedure

• Objective audiometry

• Promontory stimulation

• Vestibular testing

• CAT and MRI scans
Pre-operative tests
Objective audiometry and promontory stimulation

• Objective audiometry
  • Tympanometry
  • Otoacoestic emissions
  • ABR
  • ECoG

• Subjective promontory stimulation
Fibrosis vs ossification
### Objective audiometry

<table>
<thead>
<tr>
<th>Class</th>
<th>Latency domain</th>
<th>Max Amplitude</th>
<th>Frequency domain</th>
</tr>
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<tbody>
<tr>
<td>Cochlear</td>
<td>0 - 5</td>
<td>20</td>
<td>0 - 10.000</td>
</tr>
<tr>
<td>Brainstem</td>
<td>0 - 12</td>
<td>0.5</td>
<td>10 - 3.000</td>
</tr>
<tr>
<td>Middle latency</td>
<td>8 - 60</td>
<td>2</td>
<td>2 - 200</td>
</tr>
<tr>
<td>Long-latency</td>
<td>60 - 500</td>
<td>30</td>
<td>1 - 50</td>
</tr>
</tbody>
</table>
Electrode positions

Ref

+   -

ABR
ABR Peaks

![Graph showing ABR peaks with annotations for wave V amplitude and wave V absolute latency.](image-url)
ECoG
Electrocochleography

- Measuring the response close to the cochlea
- Transtympanic needle electrode
- Frequency selective audiogram
  - Reliable with losses up to 110 dB
  - Predicts subjective audiogram within 10 dB (≥1kHz)
- Diagnose cochlear pathology
  - Meniere's disease
Electrode positions

Ref

ECOG
Transtympanic electrode
ECoG recording and Promontory stimulation
Pre-operative tests
ECoG recording and Promontory stimulation
ECoG
Measured responses
ECoG
Compound Action Potential (CAP)

• Neural response caused by the synchronous firing of nerve fibres at the onset of the stimulus
• Unitary response
  • Every fibre has the same response
  • Amplitude is a measure of the number of fibres firing
**ECoG**

Sensorineural hearing loss

- Steep IO Curve
- Small SP
- Thresholds conform audiogram
Importance of objective measures Case study

- Comparable audiogram since 1970
- No speech perception with conventional hearing aids
Importance of objective measure Case study

- ECoG thresholds AS around 65 dB
- ABR thresholds ADS around 60 dB
Case study
CONVERSION!

- Patient is fitted with conventional hearing aid based upon objective measures
- Is now able to use a telephone!
Example

ABR threshold at 65-70 dB
Ski slope audiogram
With hearing aids 25% correct (2% words) on CVC word test
Auditory Neuropathy

1. auditory characteristics consistent with normal outer hair cell function and abnormal neural function at the level of the VIIIth (vestibulo-cochlear) nerve

1. normal otoacoustic emissions (OAEs) of cochlear microphonics
2. in the presence of an absent or severely abnormal auditory brainstem response (ABR)
3. Abnormal response on the ECoG
Auditory Neuropathy

- ABR no response
- ECoG abnormal wave form
**Pre-operative tests**

*Other investigations*

- Vestibular investigation
  - predictor of dizziness after implantation
  - Bilateral vestibular areflexia
    - confirmation by history and physical examination
Placing the implant
**Headpiece is linked to the CI**

Sterile sleeve around cable and headpiece
Measurements performed

- Stapedial reflexes
- Electrical field imaging (EFI)
- Electro-ABR
- Neural response imaging (NRI)
eABR vs ABR
NRI/NRT
the electrical evoked Compound Action Potential (eCAP)
IO-curves
Why measure?

• Does the implant function properly?
  • No damage during the surgery

• Is the implant in a proper position?
  • With EFI shorts between contacts can be found
  • Some indication before CT-scan is made

• Several ways to get a response
  • Not all patients show a NRI or eCAP response
Fitting the device
The fitting screen
Custom Sound 2.0
The fitting screen
SoundWave 1.4
Setting the M-levels

Overall level
Setting the M-levels

Overall level
Setting the M-levels

Emphasis
Setting the M-levels
De-emphasis (optional)
FM connections
Rehabilitation program CIRCLE

Technical aspects

• Re-learn to hear
• With and without lipreading
• Intensive training
  • 2 Weeks twice daily
  • 2 Weeks once a day
  • From then on reduced intensity
  • Total duration ±3 months
• Co-therapist
  • To practice at home
    • Environmental sounds
    • Speech
  • Helps with emotional aspects
• CD-ROM
Outcomes
**Group comparisons**

Elderly population stabilizes performance

![Bar chart showing performance over time for different groups.](chart.png)

- Total: 20.3, 45.4, 57.1, 63.2, 68.7, 70.8, 73.5, 75.6, 77.5
- Age > 65: 22.3, 51.1, 62.5, 66.1, 70.7, 70.3, 71.5, 73.2, 70.4
- Age < 65: 20.7, 43.3, 55.0, 62.1, 67.3, 71.0, 73.8, 76.4, 80.0
- Non-positioner: 23.8, 47.1, 57.9, 62.3, 67.0, 68.6, 70.9, 72.9, 74.3
- Positioner: 14.9, 42.0, 55.3, 65.1, 71.0, 75.5, 77.8, 81.3, 83.6

* p < 0.05
Large inter-individual variability

21 µs/phase --- 8, 12 or 16 electrodes?
Check on the criteria
Thank you for your attention