Recent advances in cochlear implant provision & technology

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Outline

1) The „classical“ indication for cochlear implants: A device for the profoundly deaf.

2) Broadening the inclusion criteria: The combination of electric and acoustic hearing.

3) The growing together of hearing aid and cochlear implant technology.
Cochlear Implants: From basic research...
... to real world products.
20 years – a long time ago?

1995 BMW Z3
CI Indication Criteria 20 years ago...

bilateral profound hearing loss, PTA > 100 dB HL (National Institute of Health, 1995)

no open-set speech recognition ability with hearing aids

In the US, children had to be at least 2 years of age to be implanted

Avg. score monosyllables in 1995 at MHH: 19.4%

1994 Clarion 1.0 speech processor
CI Indication 2000 / 2001

Some speech perception with hearing aids (<30% monosyllabic words)

PTA > 70 dB HL
(Lenarz, Balkany, 2001)

In the US, children had to be at least 12 months of age to be implanted

Avg. score monosyllables in 2001 at MHH: 38.5%
CI Indication 2007

„Integrated Care“ contracts with selected health insurance companies:

- PTA secondary (but poorer than 50 dB)
- Monosyllables up to 50% (best aided @65 dB)

(Contract btw. Medizinische Hochschule & Techniker KK, Dec. 2006)

Avg. score monosyllables in 2007 at MHH: 51,1%
Signal processing in Cochlear Implants has come a long way

- F0F2 (1981)
- F0F1F2 (1984)
- MPEAK (1989)
- SPEAK (1994)
- ACE (1999)

% correct vs. total stimulation rate increased by:
- 7 x
- 20 x
- 100 x
Problem:
The electrode-nerve bottleneck

Audio-signal

electrode-nerve interface

??

Auditory System
Cochlear Implants have come a long way:
  • from devices for the profoundly deaf to systems for subjects with significant residual hearing

Significant advances have been made in the field of signal processing and stimulation pattern design

Together with these advancements, indication criteria have been more and more relaxed
The next level: Electric-acoustic stimulation

- MedEl
- Advanced Bionics
- Cochlear
Idication range: electric-acoustic stimulation

Frequency (Hz)

Hearing Threshold (dB HL)

Aided FMS $\geq 10\%$ but $\leq 60\%$ in ear to be implanted

Hearing Aid

HiFocus MS

Hybrid-L

Hybrid-S
Advantages of Electric – Acoustic Hearing: Bimodal Condition

Advantages of Electric – Acoustic Hearing: Hybrid Systems

HSM sentence test in noise (10dB SNR) (n=7)

- HA
- CI
- HA + CI

“Historic” MHH Hybrid-L results

OISa sentence test in noise @ 6 months after surgery (n=21)

Audiometric thresholds pre and post surgery: Cochlear Hybrid-L electrode
Simulation of an EAS hearing perception

CI-System with a frequency response of 300 Hz to 8000 Hz:

Residual Hearing only (ski slope hearing loss):

Bimodal CI+HA:

Original:
Residual acoustic hearing, even if limited to below 500 Hz, can significantly enhance hearing in noise.

Music perception, usually poor with electric stimulation only, is vastly improved when using some residual low frequency hearing.

As more and more cochlear implant candidates show residual hearing on both ears, the use of new atraumatic electrodes becomes increasingly essential for cochlear implant provision in general.
What else can we do?

Technically enhance the acoustic signal

- adaptive AGC systems
- scene dependent signal processing
- noise reduction algorithms
- adaptive directional microphones

→ These features have been available in hearing aids for many years
Noise Management with the Naida CI Q90

Listening situations

360°

Front Focus

Single Front Speaker

Lateral or Rear Speaker

Audio Sources

Naida CI Features

Omni

T-Mic

Auto UltraZoom

StereoZoom

ZoomControl Rear Focus

Audio Streaming

DuoPhone

ClearVoice

SoundRelax

EchoBlock

WindBlock

enhanced speech signal
Loudspeaker Configurations

6 Loudspeakers
1. Speech from 0°
2. 5-LS Olnoise, 65dB

8 Loudspeakers
2. Speech from 0°
3. 8-LS Olnoise, 65dB
4. IFFM “Competing Talker”, 63.4dB, moving every 1.5s

6 Loudspeakers
3. Speech from 0°
4. 5-LS Olnoise, 60dB

Speech signal
Noise signal
Configuration 1: UltraZoom & ClearVoice

- Improvement in SRTs of 6.0 dB with UltraZoom (n=10)
- Additional 0.8 dB improvement with ClearVoice
  - 6.8 dB improvement in combination
Configuration 2: UltraZoom & ClearVoice

- Improvement in SRTs of 4.4 dB with UltraZoom in quasi diffuse noise
- Additional 0.9 dB improvement with ClearVoice
  - 5.3 dB improvement in combination
Configuration 3: UltraZoom & ClearVoice

- 6 Loudspeakers
- Speech from 0°
- 5-LS Olnoise, 60 dB
- IFFM “Competing Talker”, 63.4 dB, moving every 1.5s

- Improvement in SRTs of 6.8 dB with UltraZoom in complex, dynamic situation
  - 7.0 dB improvement in combination with ClearVoice
Final Conclusions

Cochlear Implant devices have been significantly improved over the last two decades.

Indication criteria have been more and more relaxed, and users of hearing aids with significant residual hearing consider implantation encouraged by the impressive outcomes.

Residual hearing can significantly improve hearing with a cochlear implant and should be preserved to the largest possible degree. Therefore, atraumatic electrodes and soft surgery techniques have been developed and are constantly being improved.

The frontend-processing know-how of the HA industry has finally found its way into cochlear implant processors improving speech perception in difficult listening scenarios.
Listening Strategies at “Cocktail-Parties”

The human auditory system is able to decompose the acoustic world into discrete objects of perception. Today it is believed that the auditory system uses the fundamental frequencies of different talkers to segregate talkers from each other.*

Only if the fundamental frequencies of the voices are too much alike, directional information of the sound source comes into play to differentiate between talkers.

→ Cochlear Implant subjects have not yet access to temporal fine structure in the low frequencies.

→ A reconstruction of the missing fundamental from harmonics is not possible in CI subjects due to insufficient frequency resolution of current implant systems.

*Auditory Cortical Contrast Enhancing by Global Winner-Take-All Inhibitory Interactions
Phenomenon of the missing fundamental

The auditory system can reconstruct a missing f0 from the information present in the overtones. The precise way in which it does so is still a matter of debate, but the processing seems to be based on an autocorrelation involving the timing of neural impulses in the auditory nerve.

Sample 1:
Two competing talkers: full frequency spectrum

Sample 2:
Two competing talkers: 300 Hz highpass filter applied

The example containing f0 sounds richer, but the pitch of the talkers' voices can be perceived and identified in both samples.
Reconstructing missing details in the visual system