Continuing Developments in Cochlear Implants

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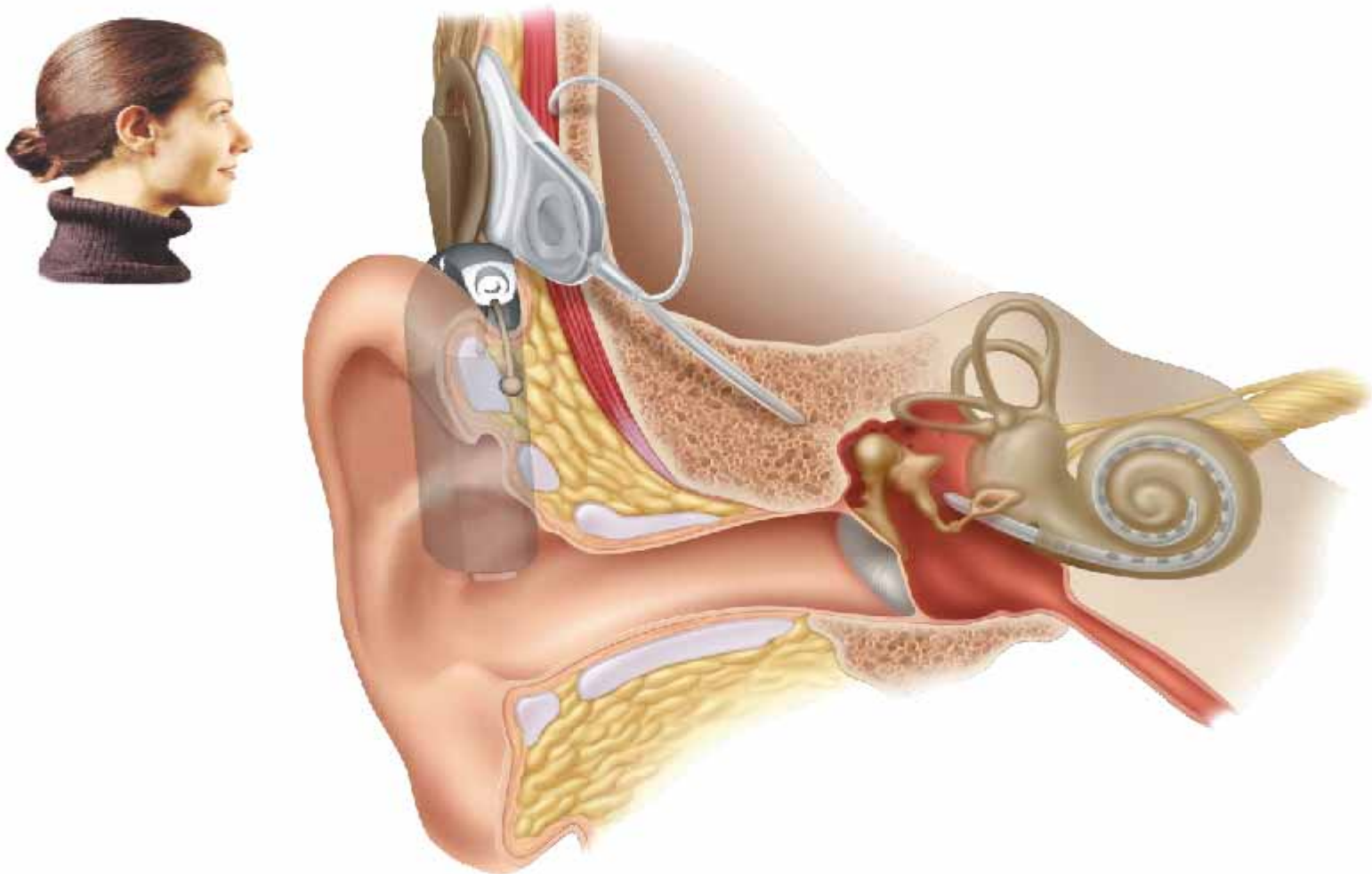
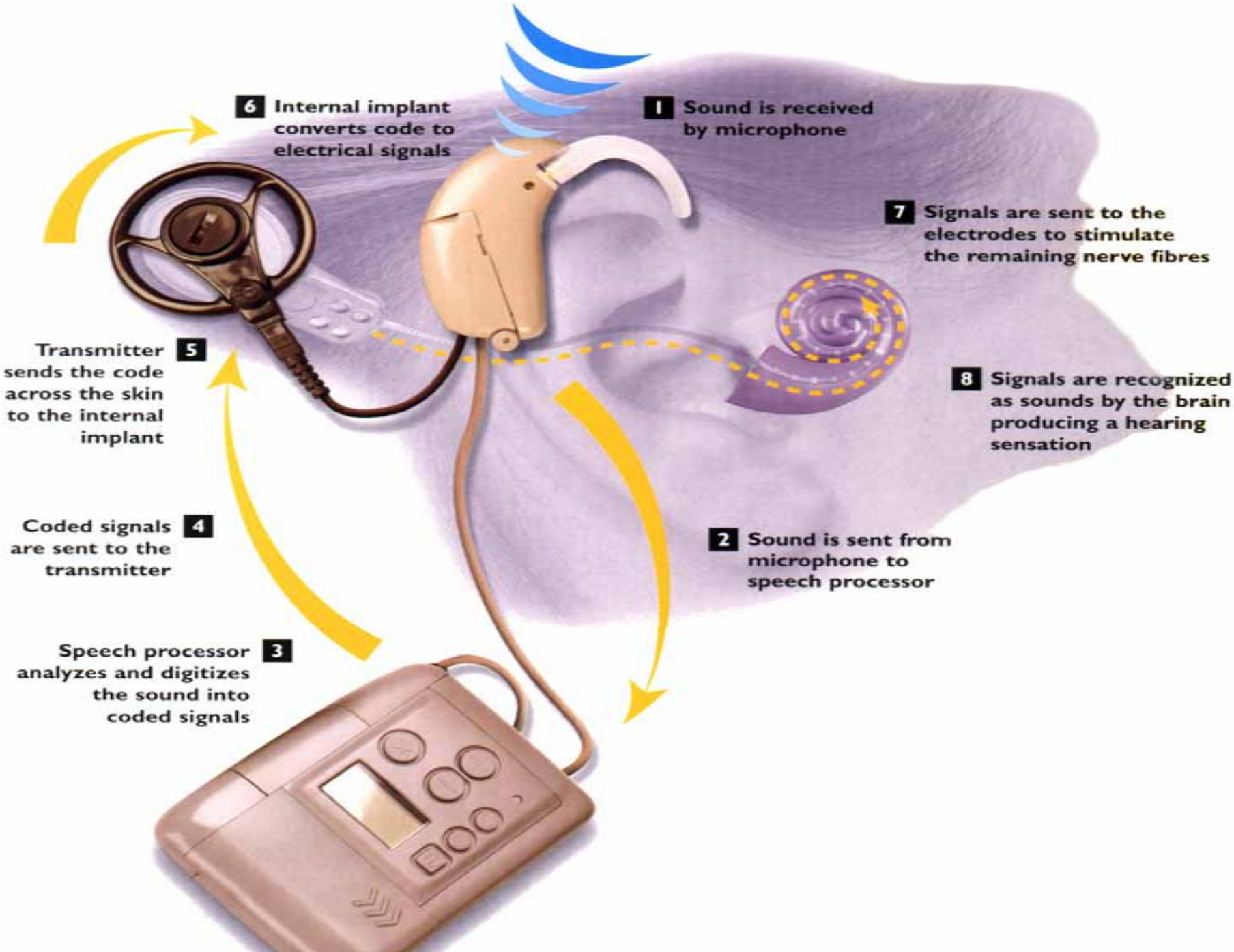
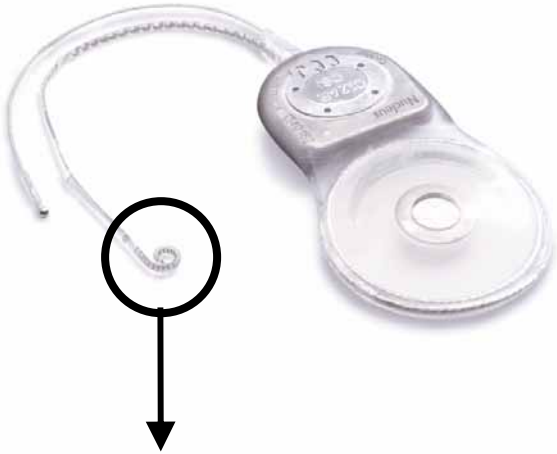
How the Cochlear Implant System works



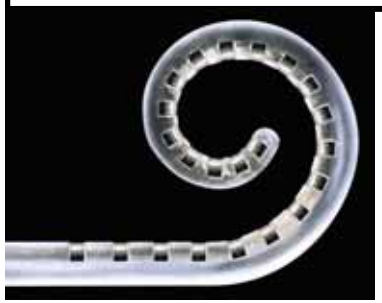

6 Internal implant converts code to electrical signals
1 Sound is received by microphone
7 Signals are sent to the electrodes to stimulate the remaining nerve fibres
Transmitter 5 sends the code across the skin to the internal implant
8 Signals are recognized as sounds by the brain producing a hearing sensation
Coded signals 4 are sent to the transmitter
2 Sound is sent from microphone to speech processor
Speech processor 3 analyzes and digitizes the sound into coded signals

Internal Components



Nucleus® 24 Contour Array held straight with stylet

Nucleus® 24 Contour Array in its natural shape



Nucleus 24 Contour (CI24R)

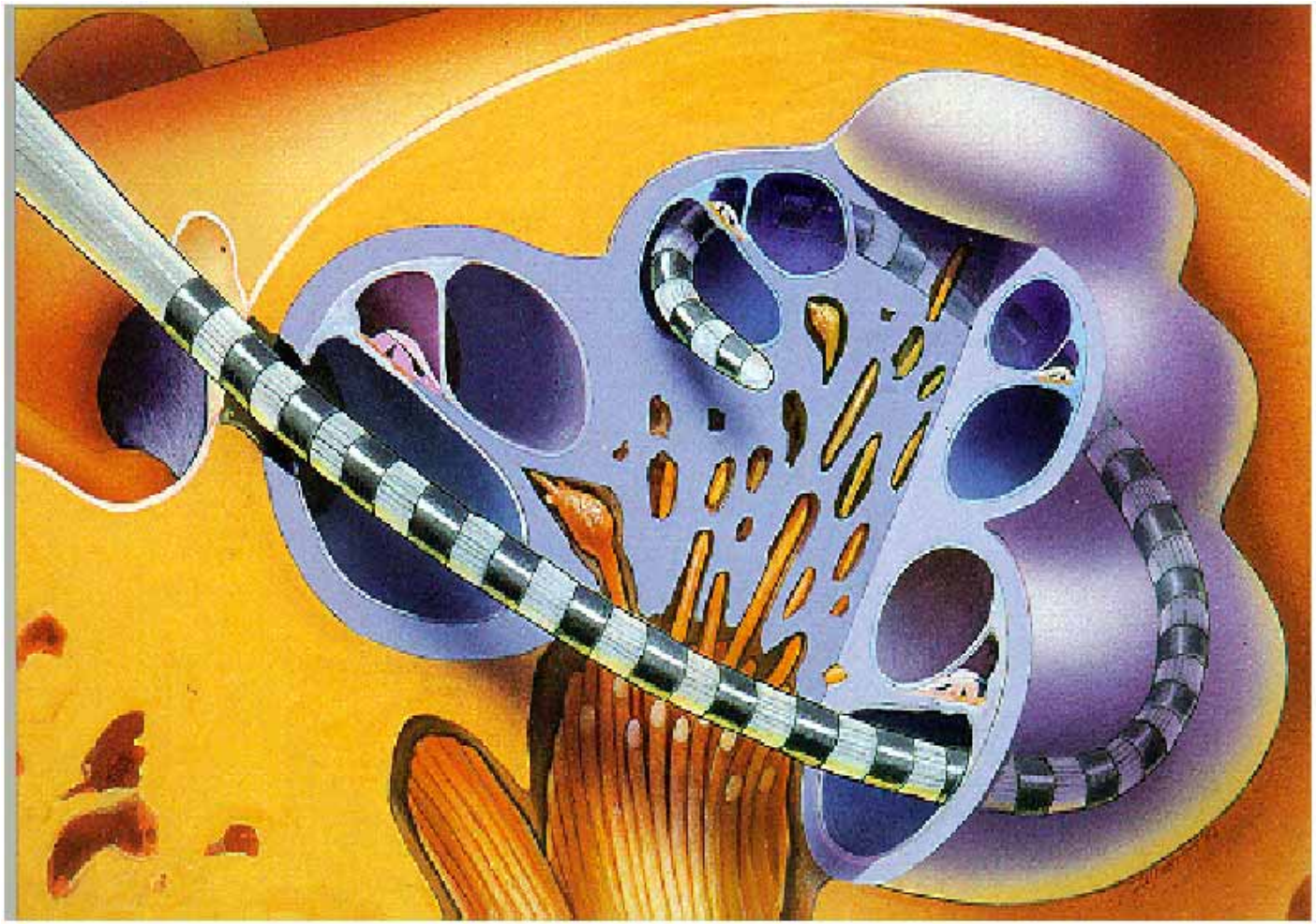
- Receiver/stimulator and plate electrode
- Ball electrode
- Intra-cochlear electrode
- Self curling tapered array
  - Close proximity to modiolus
  - Focused stimulation
- 22 half banded electrodes

Cochlear

Electrode Options

- Nucleus 22 Series (1985 FDA release)
- Nucleus 24 (straight) (1997 FDA release)
- Nucleus 24 K (straight) (1999 FDA release)
- Nucleus 24 Contour (1999 FDA release)
- Nucleus 24 Contour Softip (2000)
- Nucleus 24 Double Array (1997)

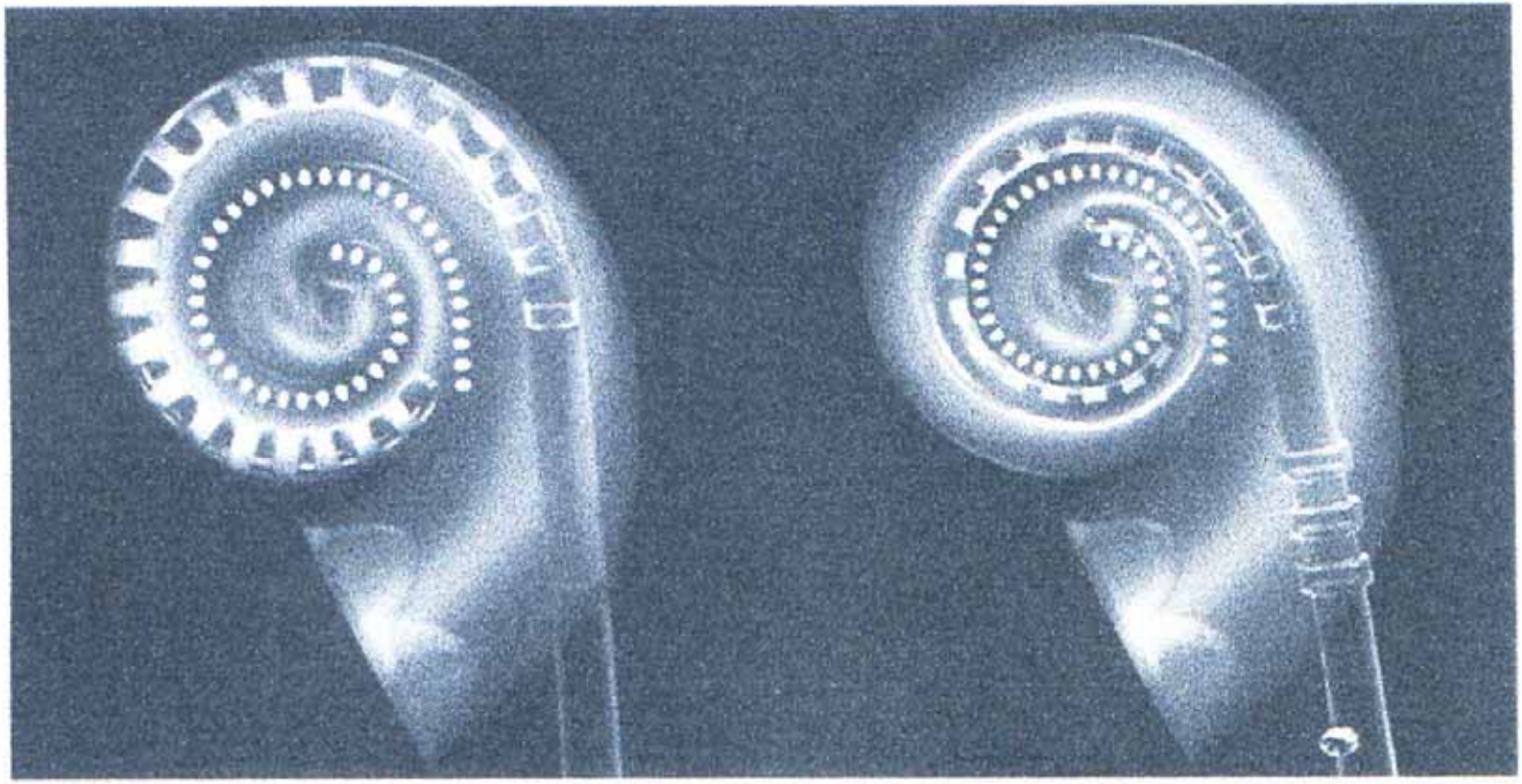
Nucleus 22 series



Nucleus 24 Contour

Nucleus 24 Contour

- Self-curling electrode array
- 22 half-band electrodes
- Adjacent to the inner wall of the cochlea
- Cast *pre-curved* to regain pre-designed shape & size



Conventional electrode array:
positions close to lateral wall

Nucleus® 24 Contour™ electrode array:
places 22 stimulation sites closest to the spiral ganglion cells

Nucleus 24 Double Array

Nucleus Hybrid CI

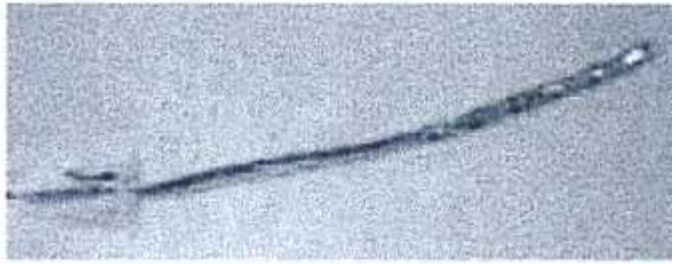


Figure 1. The 10 mm array used with the Nucleus Hybrid research system showing the 6 half-banded electrodes and PET mesh collar

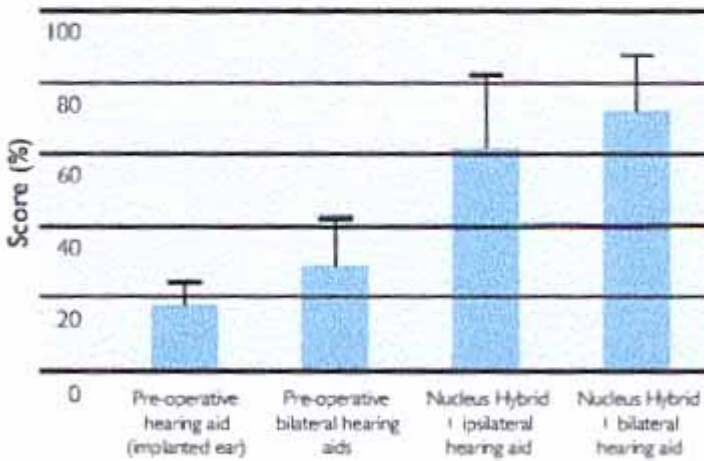


Figure 2. Average pre-operative and the most recent post-operative scores for CNC monosyllabic words from four recipients using the Nucleus Hybrid system at the University of Iowa

Speech Processors

ESPrit 3G (Behind the Ear)

- Small and Lightweight
- Design and Colours
- Full range of Speech Coding Strategies
- In-Built telecoil (T)
- Whisper Setting
- Long battery life
- Integrated FM Technology

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Speech Processors

SPrint (Body worn)

- Full range of Speech Coding Strategies, including ADRO
- Four user selectable listening programs
- Programmable volume and sensitivity controls
- LCD panel to display control setting and system status
- Warning alarms for low batteries (single and double)
- Optional button lock
- Full line of accessories

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Speech Coding Strategies

- Speech Coding represents a set of ‘rules’ that define how the incoming acoustic speech signal will be analysed and coded by the speech processor

Types of Speech Coding Strategies:

- SPEAK (Spectral Peak Selection)
- CIS (Continuous Interleaved Sampling)
- ACE (Advanced Combination Encoders)

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Speech Coding Strategies
(cont.)

- Apical end processes low frequency information
- Basal end processes high frequency information
- Natural tonotopic organisation of the cochlea
- Spectral Information processed through 22 electrodes

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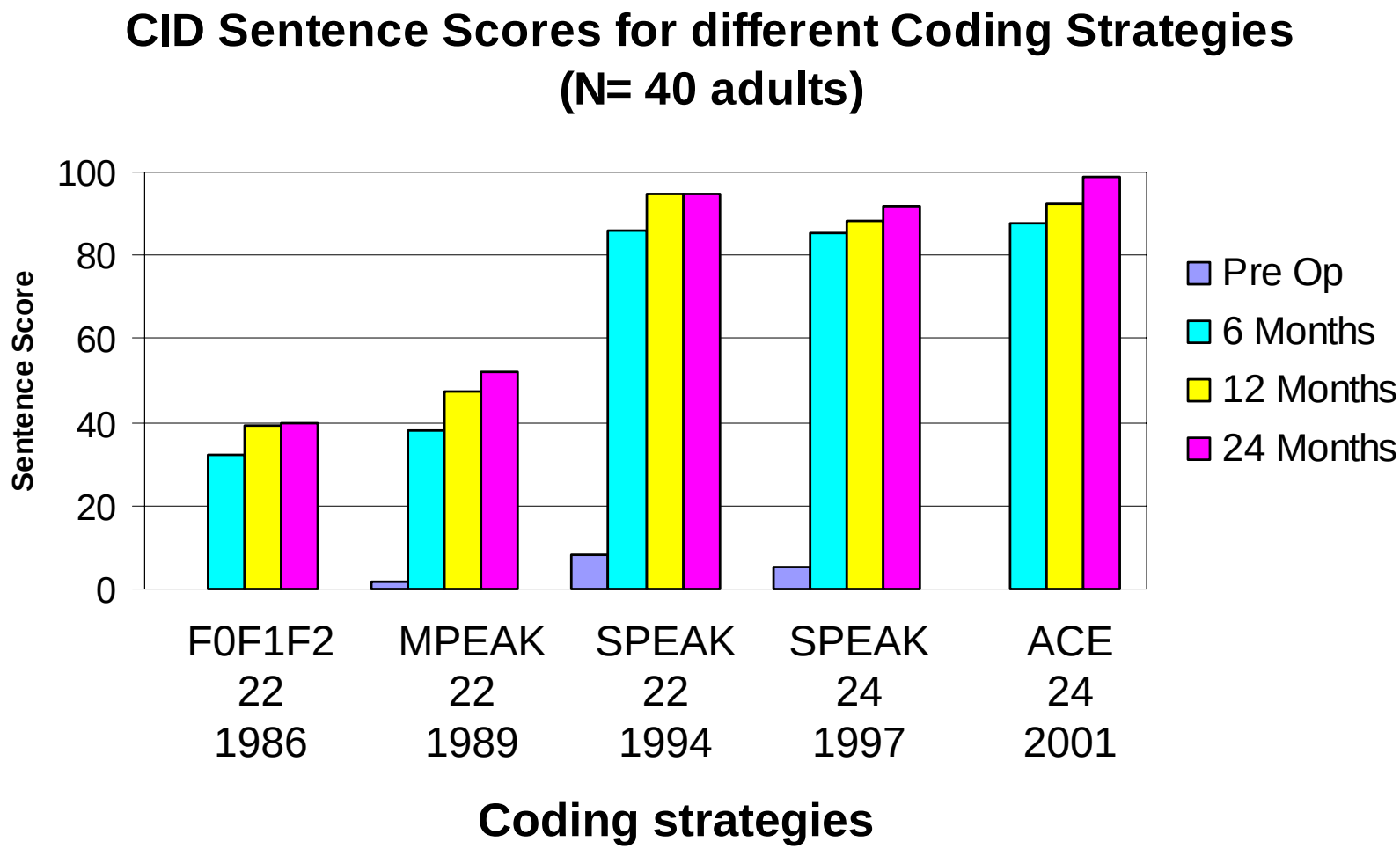
OUTCOME: Speech Processing Strategies



Advanced processing algorithms

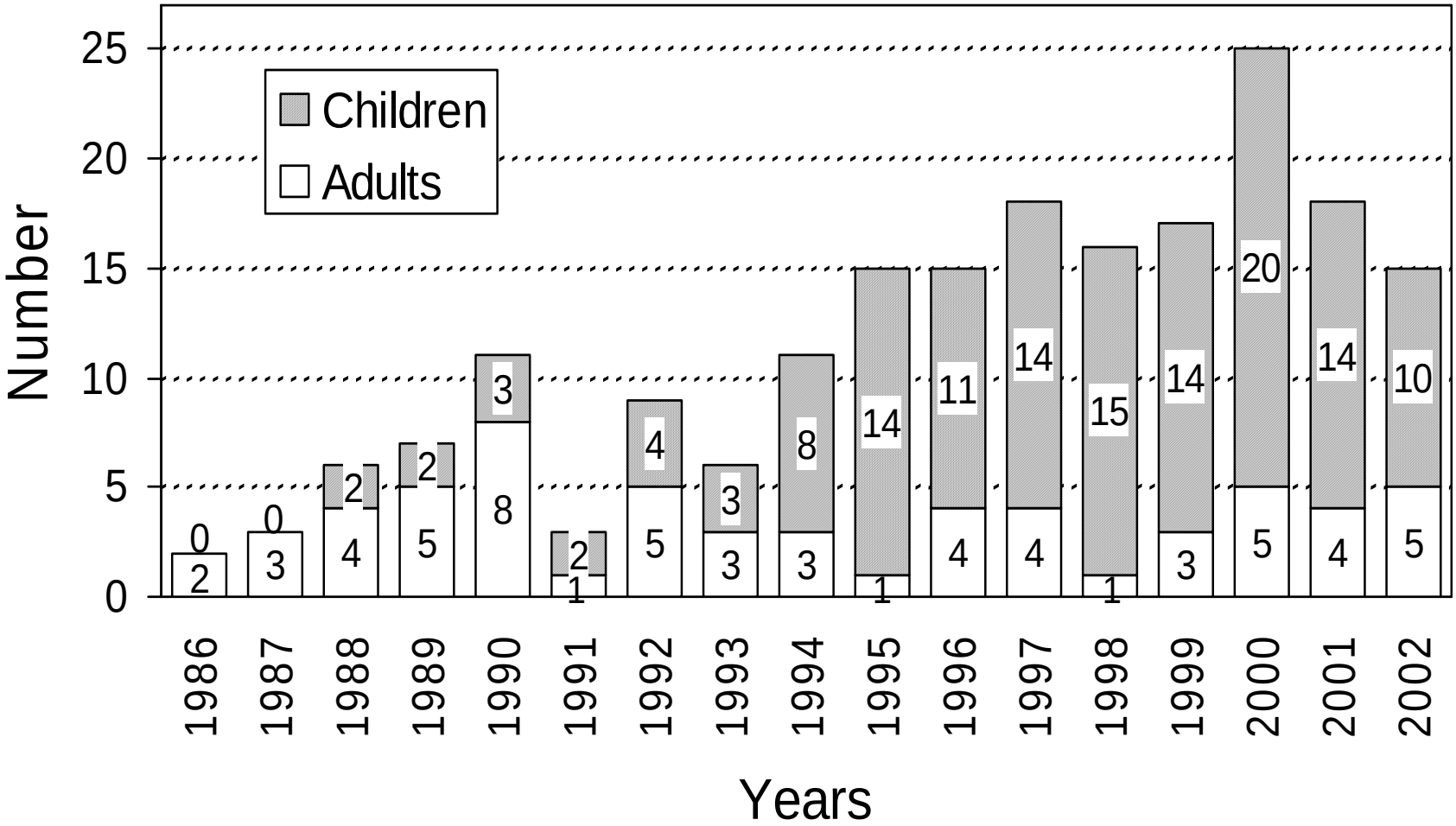
- Effect of noise on speech perception
- Directional microphone
- Multi-microphone techniques

Introduction of Cochlear Implants in South Africa

- 1986 US-Tygerberg Hospital
- 1991 Pretoria & Johannesburg
- 2003 Bloemfontein
- Multidisciplinary teams:

  ENT surgeons, audiologists, radiologists, pediatricians, speech therapists, educators, social workers, psychologists

Number of implants per year 1986-2002
US-TBH Cochlear Implant Unit



Selection Considerations

- Philosophy:
  Ensure potential for significant
  benefits from the device and the procedure

- Specific considerations:
  - degree of hearing loss
  - age at onset of hearing loss
  - CTScan & MRI
  - medical
  - (re) habilitation support
  - informed consent

Referral Criteria and Patient Selection

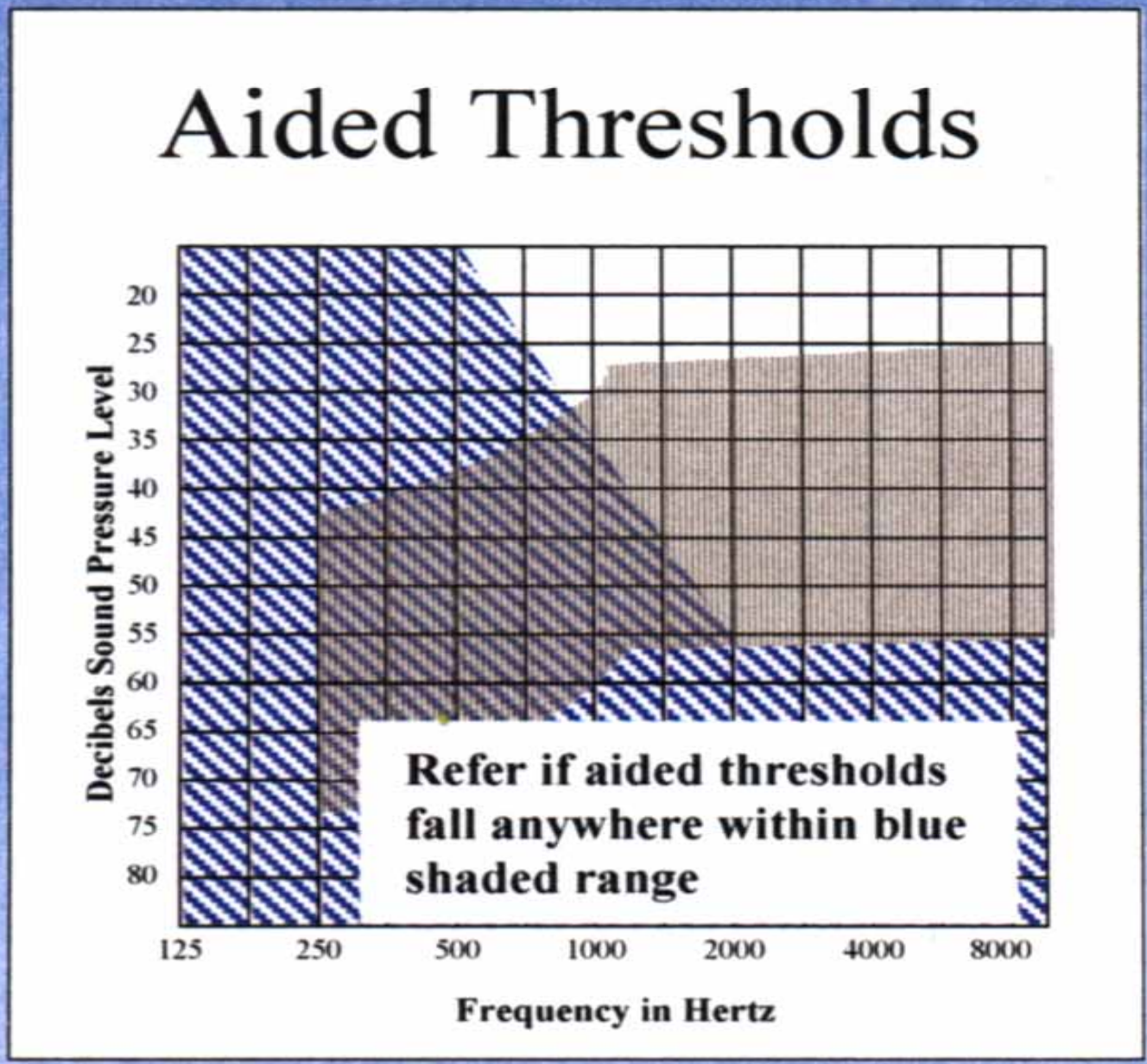
- Previously restricted to patients over 2 years with profound HL
- Extended to severe HL, and children under 2 years
- Abnormal cochleas
- Additional handicaps

Selection Criteria for Cochlear Implants in Adults

Ages 18 years and over

- Severe to – profound sensorineural hearing loss in both ears
- Post-lingual onset of hearing loss
- Receive little or no useful benefit from hearing aids
- Score of 50% or < on sentence recognition tests in the ear to be implanted and 60% or < in the non-implanted ear or bilaterally

Guideline Audiogram



New candidacy guidelines: adults (cont.)

- Dowell, Hollow & Winton* (2003) Melbourne
- Retrospective study post-operative speech perception scores from 92 implantees
- Statistical method developed
- Outcomes: Adults with post-lingual hearing loss & some useful pre-operative aided speech perception are now candidates if:
  - open-set sentences in quiet in best aided condition is < 70%
  - open-set sentences in quiet in the implant ear is < 40%

*Changing selection criteria for cochlear implants, the Melbourne experience. 9th Symposium Cochlear Implant in Children, Washington DC, May 2003

Selection Criteria for Children

- Bilateral severe-to-profound sensorineural hearing loss
- No useful benefit from HA:
  Birth – 2 years: restricted access to speech sounds with HA (aided thresholds outside speech spectrum at 2000Hz and above)

  2-5 years: lack of progress in development of auditory skills (speech & language delay)
  > 5 years: <50% or less open-set sentence discrimination

Selection Criteria for Children (cont.)

- Realistic expectations of results
- Family or caregiver is proactive and committed with re/habilitative exercises
- Has to be in an oral environment

Selection Criteria (cont.)

- Implantation of pre-lingually deafened adults and teenagers
- Have to be primarily oral communicators

Selection Criteria: Disadvantaged Patients

- ADULTS:
  - skill to enable re-entry to workforce
  - motivated to be gainfully employed
  - access to rehabilitation program
- CHILDREN:
  - adequate family support
  - parent/s be employed
  - accessible, appropriate educational and audiological facilities

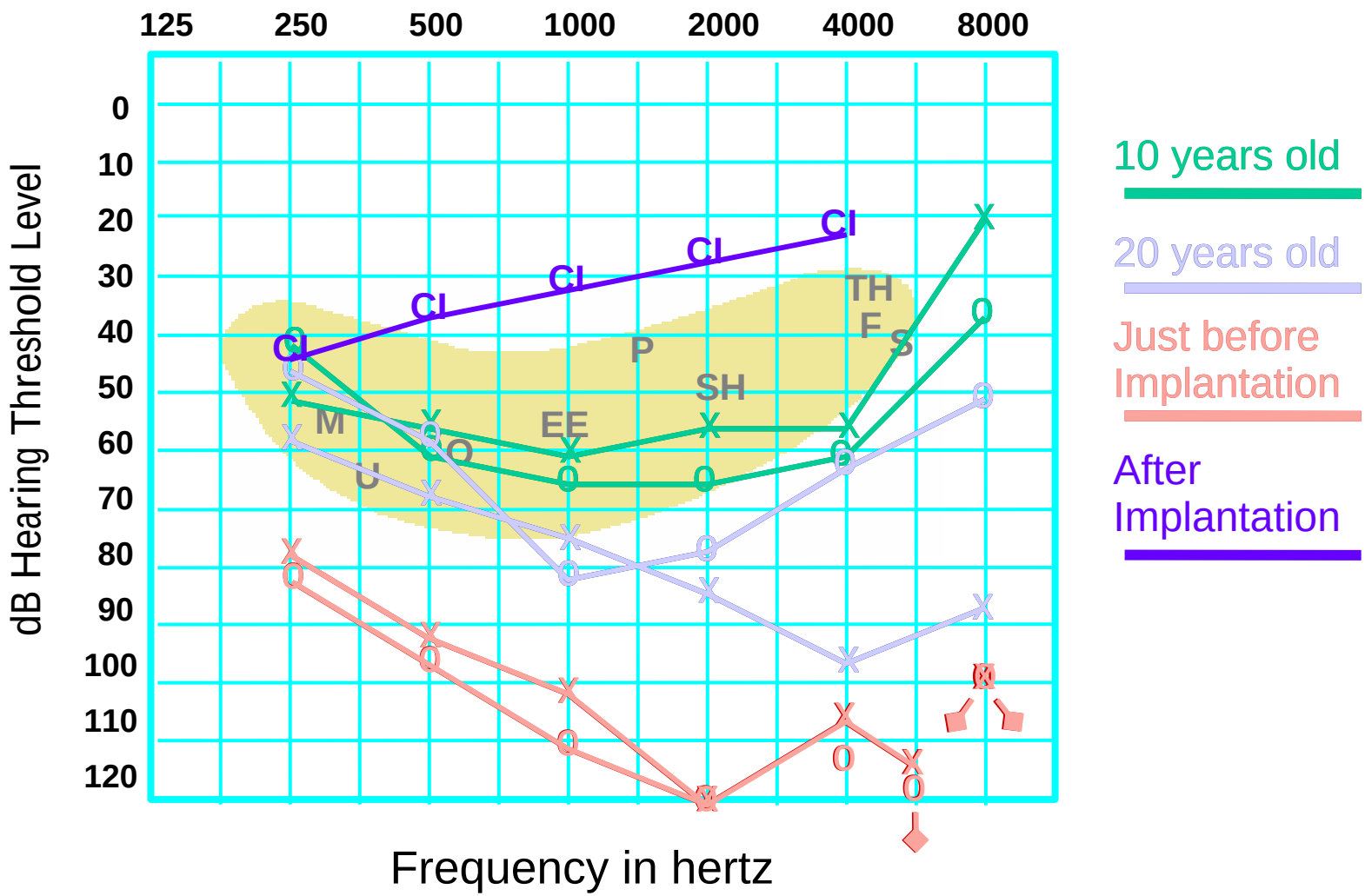
Selection Criteria in Developing Countries

- Lifetime commitment: maintenance of device, sociological aspects and educational placement
- Limited resources and allocation of funds
- Every effort made to ensure optimal utilization of device, and avoid non-usage

Outcomes

- Majority are successful users
- The cochlear implant gives access to all speech and environmental sounds
- Sound-field thresholds 30dB average
- Improved quality of speech production
- Gives young children the potential to develop spoken language

Audiogram History

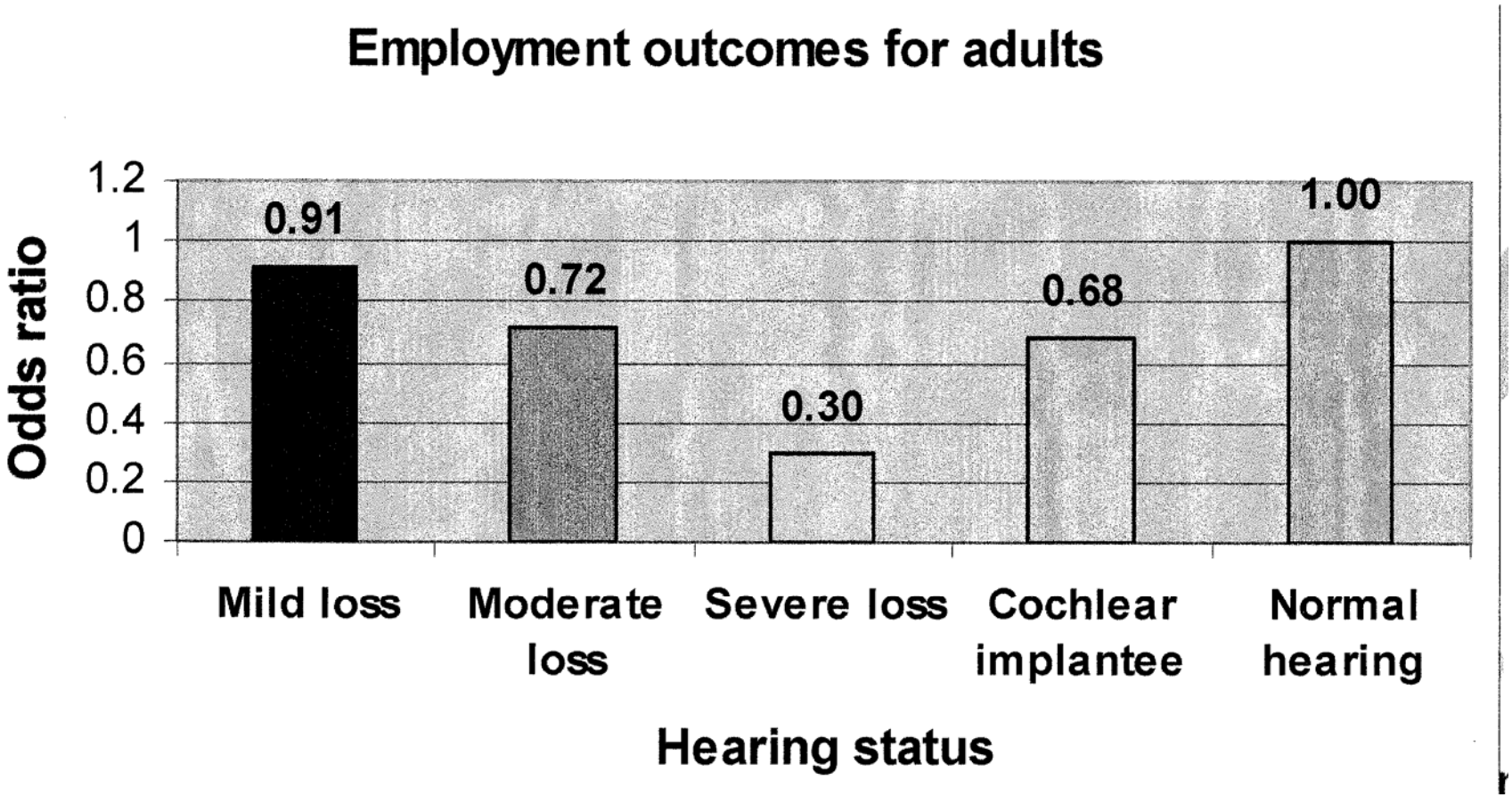


Outcomes in adults

- 60% with current generation of cochlear implants achieve scores of 80-100% on open-set sentence recognition tests
- Telephone use
- Improved quality of life

Improved employment

Adults with a CI are twice as likely to be in paid work, compared to adults with severe hearing loss.



Outcomes in Children

- Spoken language acquisition and improved speech intelligibility are the primary benefits of CI
- Benefits for children in reading comprehension and language knowledge may lead to mainstream education

Age at implantation

- Age at onset of hearing loss, communication mode, amount of residual hearing and duration of implant use are factors that influence performance
- Neural plasticity and deprivation

OUTCOME: Age at implantation in children

- Age at implantation is a prognostic variable for congenitally deaf children
- Biological bases

- Study:
  Compared progress in speech perception of a group of children implanted before 2 yrs (Group I) with a group implanted between 2-3 yrs (Group II)

Rate of Speech Perception Development

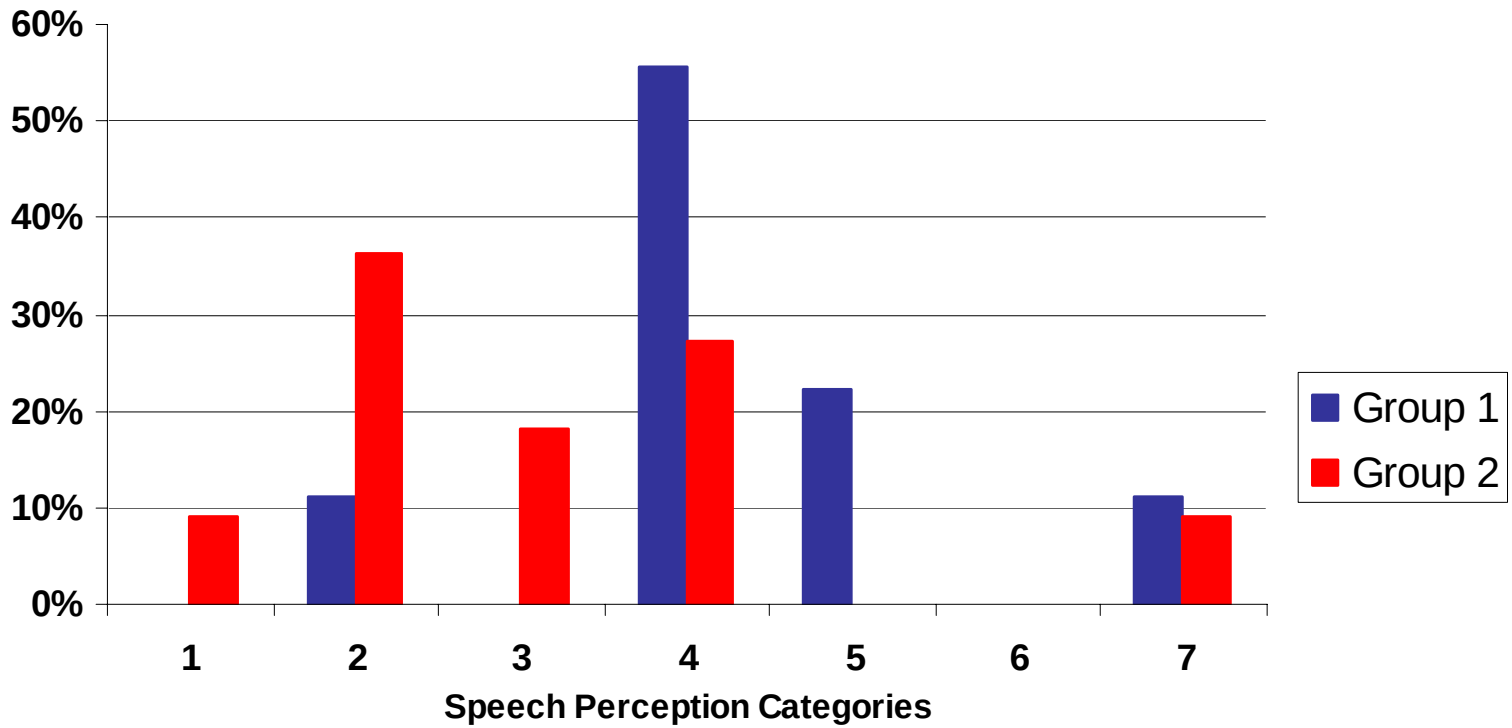


Figure 4. Speech Perception Categories after 12 months

Rate of Speech Perception Development

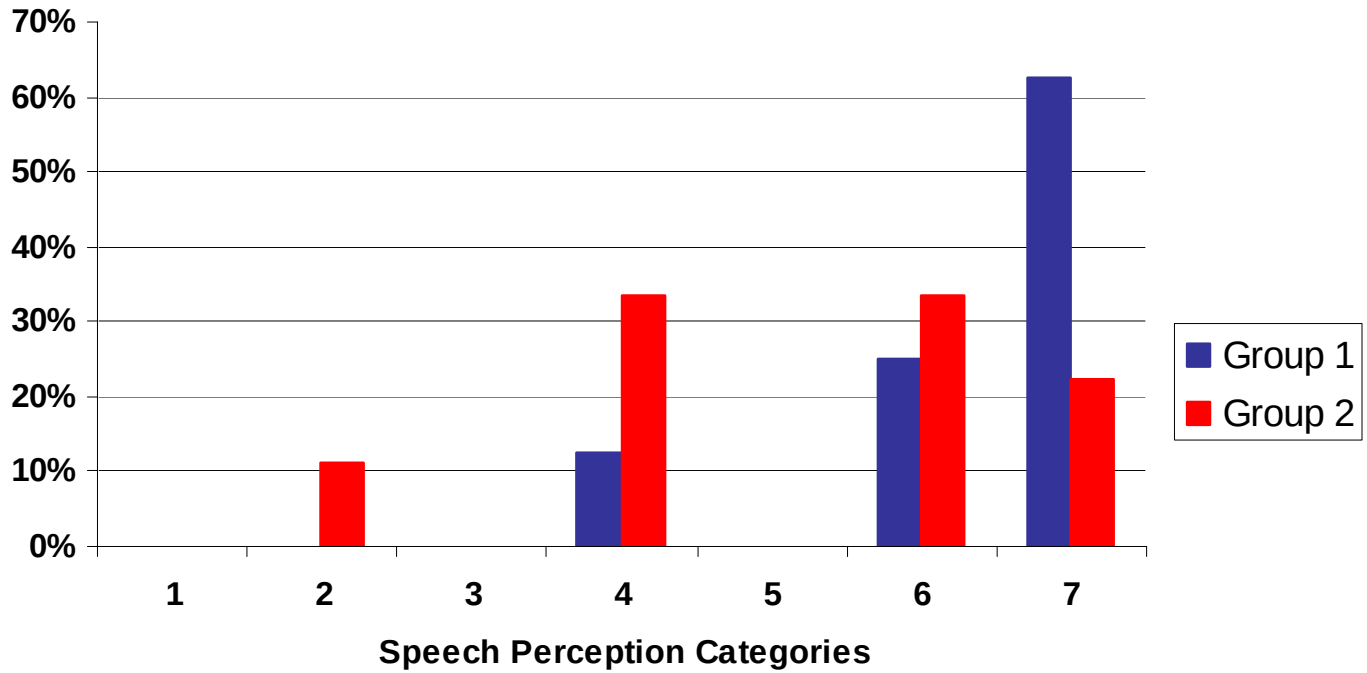


Figure 6. Speech Perception Categories after 24 months

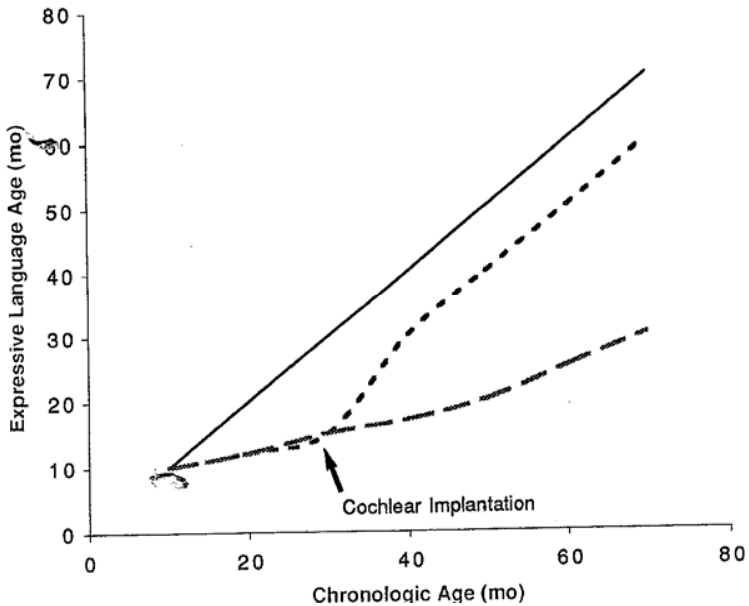
- Children implanted before 2 years of age showed considerable progress in speech perception development that matched and even surpassed the progress of children implanted at later ages
- Earliest possible implantation would lead to the most normal development of hearing, speech and language

Improved language development

<u>After cochlear implantation:</u>

Increased rate of language development that exceeds that of non-implanted children

Rizer & Burkey 1999



Consequences of un-managed hearing loss

Cost to society

- Delayed and limited language development
- Limited access to education
- Underemployment/Unemployment
- Difficulty participating in social activities
- Negative impact on physical and mental health

Funding in SA

- Between 1985 & 2003, 439 patients were referred to US-TBH CIU for CI evaluation
- 46% adults, 56% children
- 241 of 439 were NOT implanted
- Main reason: financial and socio-economic constraints
- SA population: 43.1 million
- Huge division in health market between public and private health sector

New and future directions

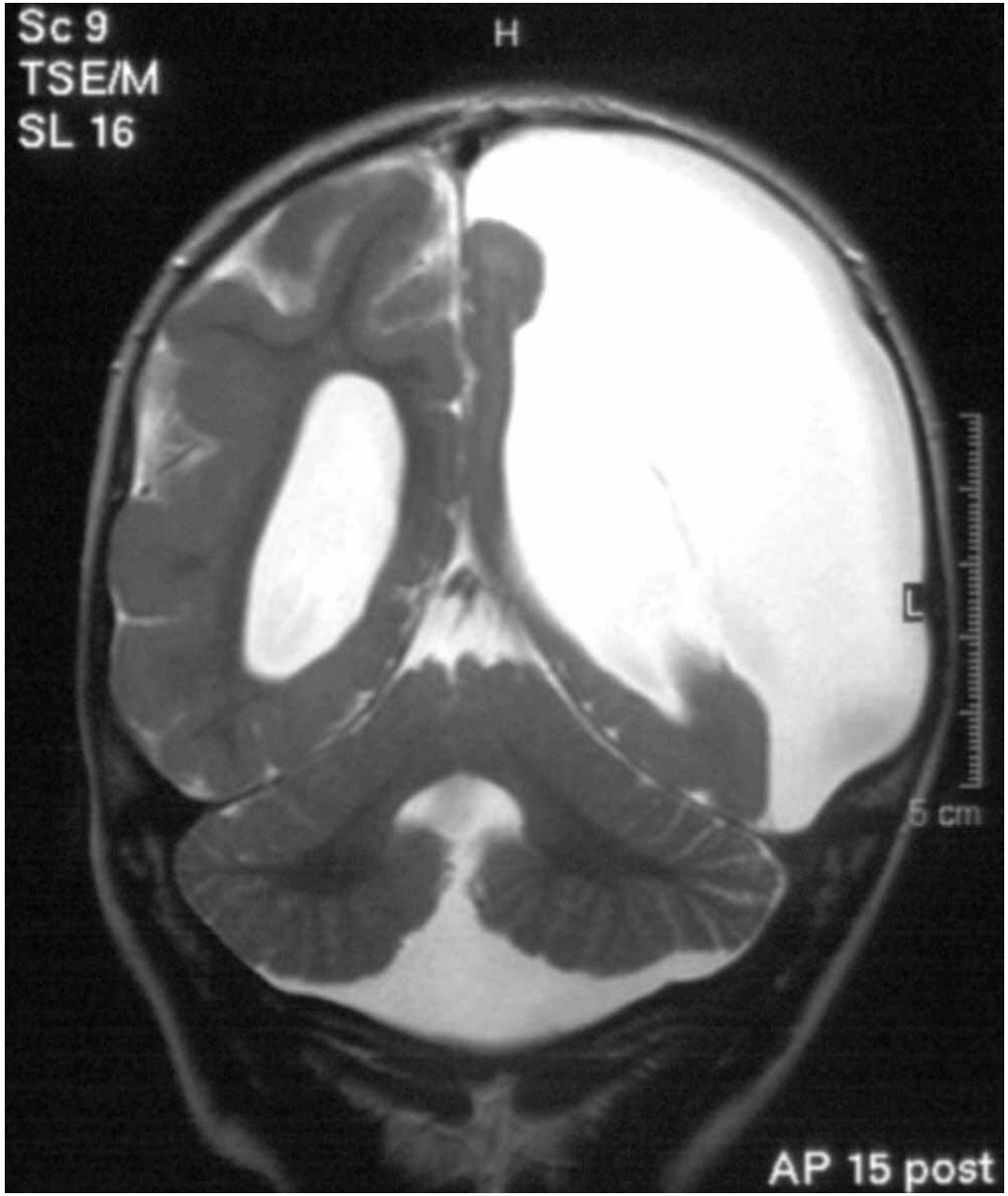
- Bilateral implantation
- Hybrid electro-acoustic stimulation
- Totally Implantable Cochlear Implant (TIKI)

Bilateral Implantation

- Bilateral benefit is the ability to listen using the ear with the better signal-to-noise-ratio
- Sound localisation
- Binaural advantage of using the signal from both ears
- Capturing the better ear

Cochlear Implantation in a child with Schizencephaly

- Schizencephaly: cortical malformation resulting from late neural migration and disruption of early cortical organization before 25th week of gestation
- Cause: CMV during pregnancy
- Multi-handicapped: quadriplegic cerebral palsy, profound hearing loss, global developmental disability


Sc 9
TSE/M
SL 16
H
L
5 cm
AP 15 post

Cochlear Implantation in a child with Schizencephaly

- Criteria for selection: had to show intentional communicative behaviour
- Implanted at age 2;11
- Left ear (contra-lateral pathway)
- Intra-operative stapedius reflex & NRT plus behavioural responses guided programming of electrodes.