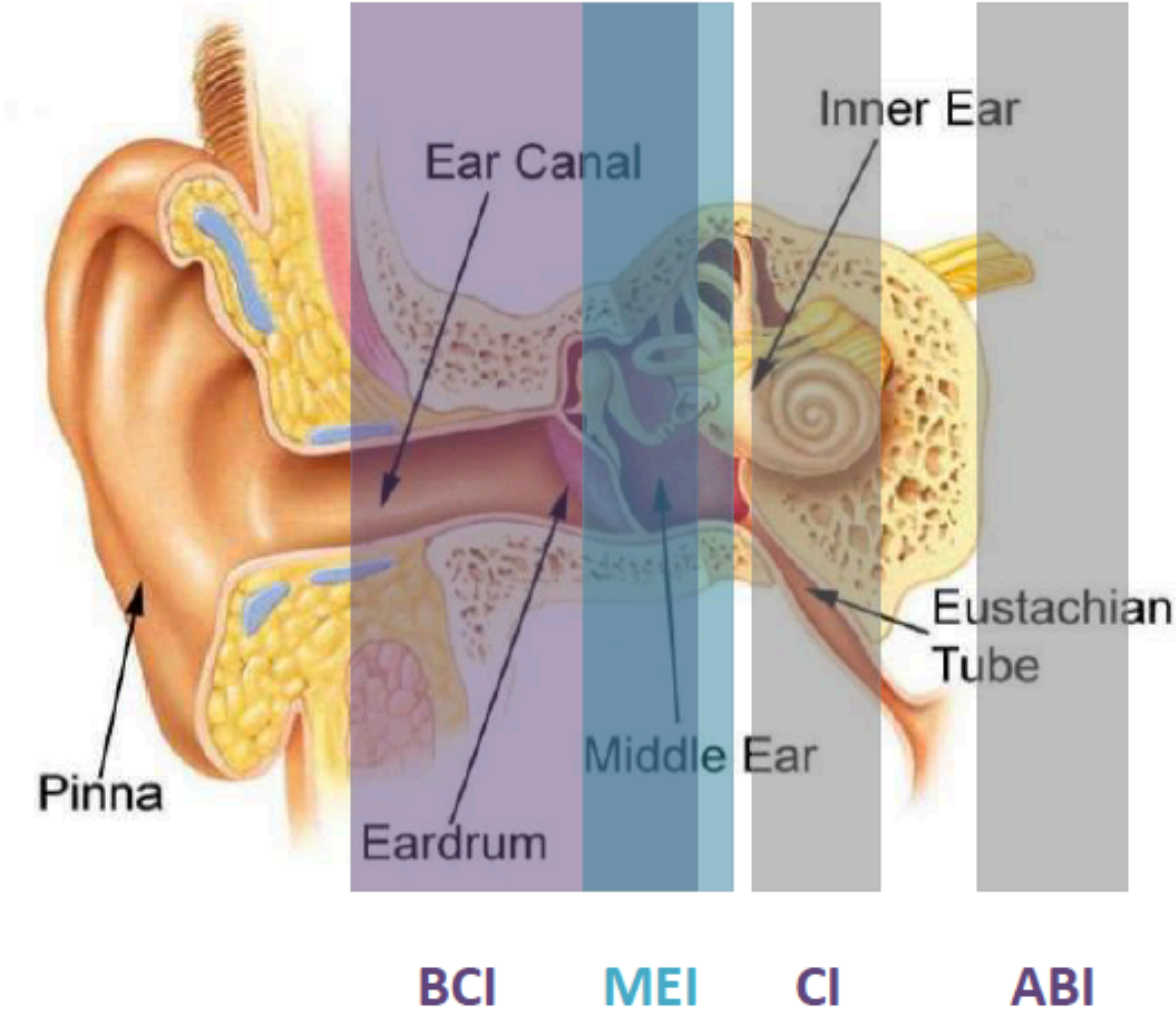
SPAU338
Hearing Aids II

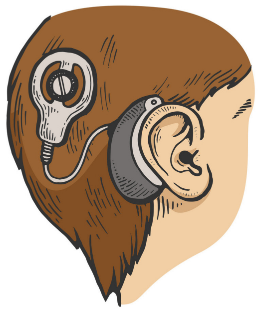
Dina Budeiri MSc

Spring 2020


Inner Ear
Ear Canal
Eustachian Tube
Middle Ear
Pinna
Eardrum
BCI
MEI
CI
ABI

Introduction to Cochlear Implants:

- What are CI's?
- CI assessment and candidacy criteria for adults and paediatrics
- Outcomes from CI's
- Surgical and medical aspects of CI's
- Basic terminology of cochlear implant programming
- Basic principles of cochlear implant programming



Consequences of a more impaired auditory system

- The greater the HL the poorer the temporal and spectral resolution along with a more reduced dynamic range
- the existence of dead regions not predictable from the audiogram but results suggest where the loss exceeds 70dB [Adhadi et al., 2015; Munro 2106 (Hearing Review)]
- This poses a dilemma as children with severe-to-profound SNHL need high output levels from HA's to hear the stimuli
- However their ability to resolve the stimulus difference decreases as the stimulus level increases
- Background noise makes it worse as the person becomes less able to separate the masking noise from the target speech

Severe-to-Profound HL

- When hearing impairment is severe-to-profound, amplification for audibility in the high frequencies is both more difficult to attain and more controversial

- While it is intuitive that HA's for SPHL need to deliver higher output and gain compared to those designed for a milder loss the reality is that fitting SPHL HA wearers requires considerably more than just higher gain/output as cochlear resolution ↓

- Individuals with SPHL are more dependent of good SNR for optimal speech understanding

- Therefore, inadequate high frequency amplification results in perception of sounds that lacks the quality and clarity important for word discrimination and speech understanding in noise

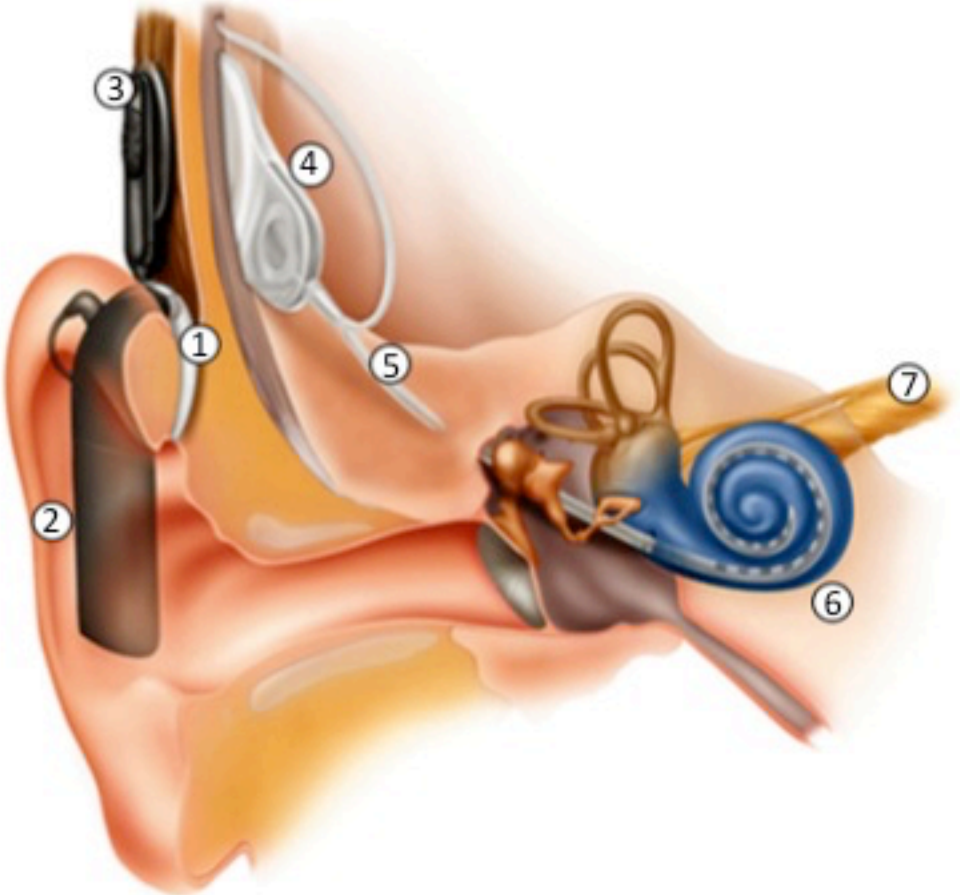
Cochlear Implants

- It could be argued that cochlear implantation is the 20th century success story in otology and is one of the great successes in healthcare provision generally

What is a cochlear implant?

- A management option for people with severe- profound HL
- A surgically implanted auditory prosthesis
- Consists of internal and external parts
- Does not require presence of functioning hair cells within cochlea
- Can achieve stimulation of auditory nerve **irrespective** of hearing thresholds

Cochlear ®

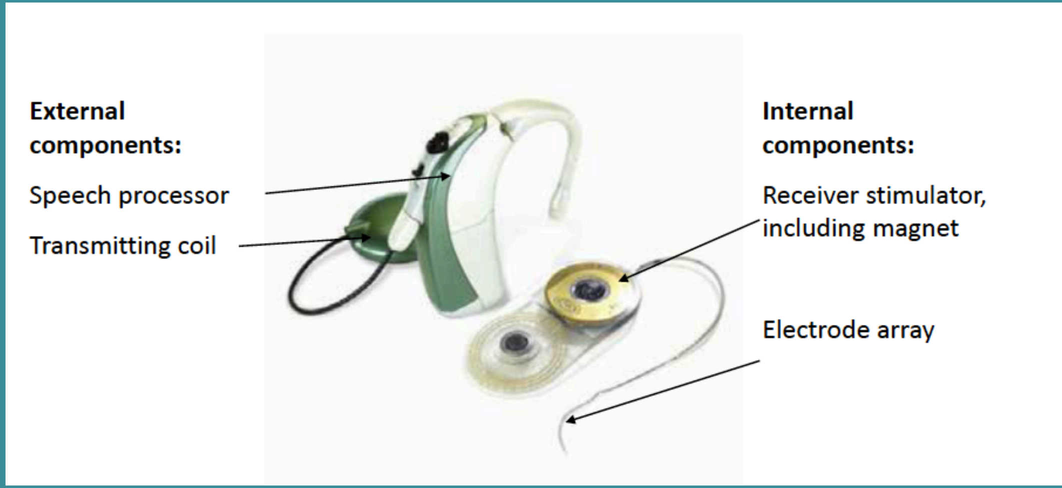


Internal part

1. Microphone
2. Speech processor
3. Transmitter
4. Receiver/stimulator
5. Electrode array
6. Cochlea
7. Auditory nerve

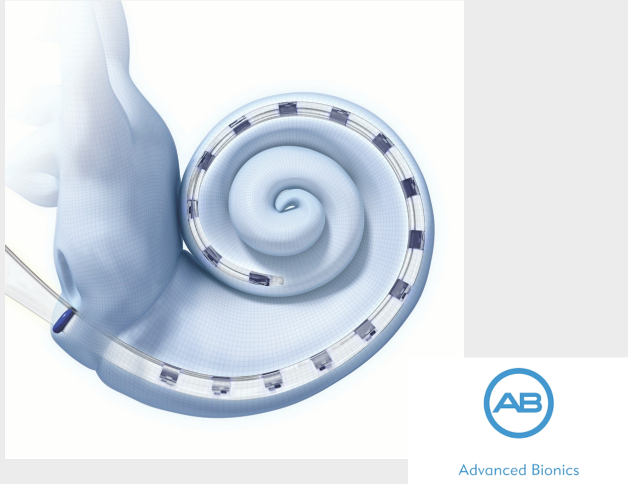
External part

1. Sound waves are picked up by a small microphone
2. Signal is then sent to a speech processor
3. The speech processor codes the signal
4. Coded signal is then sent to the coil
5. Signal is sent through intact skin to implant (transcutaneous)
6. Implant decodes the signal
7. Electrode array stimulates the auditory nerve
8. Nerve impulses are sent to the brain to get processed.



The Electrode Array

- a pack of a group of electrode wires
- Each electrode provides a slightly different signal based on the frequency incoming signal
- Number of electrodes depends on device, typically 12 –22 electrodes



Candidacy – Now primarily for:

those obtaining *insufficient* benefit with hearing aids

with intact auditory systems

likely to be able to make use of the input, resulting in improvements in QoL – e.g. speech perception, oral language development, etc.

Current NICE guidelines - Children

Bilateral CI to be offered to children with:

- Severe to profound hearing loss, defined as thresholds of **>90dBHL at 2 and 4 kHz**
- Lack of benefit from hearing aids, defined as failure to develop speech, language and listening skills appropriate to age, developmental status and cognitive ability

Sequential cochlear implantation can be offered to those who previously received unilateral CI, who meet above criteria in second ear, and who clinicians assess would receive sufficient benefit

Assessment by MDT

3-month hearing aid trial

What factors do we consider when deciding whether to consider a child for CI?

- If we wait for children to show speech and language delays before considering them for CI referral we miss a golden opportunity to help, children will not bridge the gap
- As a result we must err on the side of referring children if there is any evidence that amplification may not be effective
- Much better to be proactive and find out that implantation may not be the best management at that time than to let delay set in
- Remember when the referral is made it is for CI assessment not implantation

Current NICE guidelines - Adults

Unilateral CI to be offered to adults with:

- Severe to profound hearing loss i.e. **>90dBHL at 2 and 4 kHz**
- Lack of benefit from hearing aids, defined as score **<50% on BKB sentences presented at 70dBSPL**

Bilateral CI (sequential or simultaneous) only for adults who are blind or have other additional difficulties that increase their reliance on auditory stimuli

Assessment by MDT

3 month hearing aid trial

BKB Sentences

- Many UK centres have major concerns about the use of BKB sentences as a CI criteria because?

BKB Sentences

- Gap filling especially by those with late onset/ progressive HL's
- Non English speakers
- Cognitive factors
- Test conditions prescribed are 70 dBSPL with no background noise which is not representative of real life function

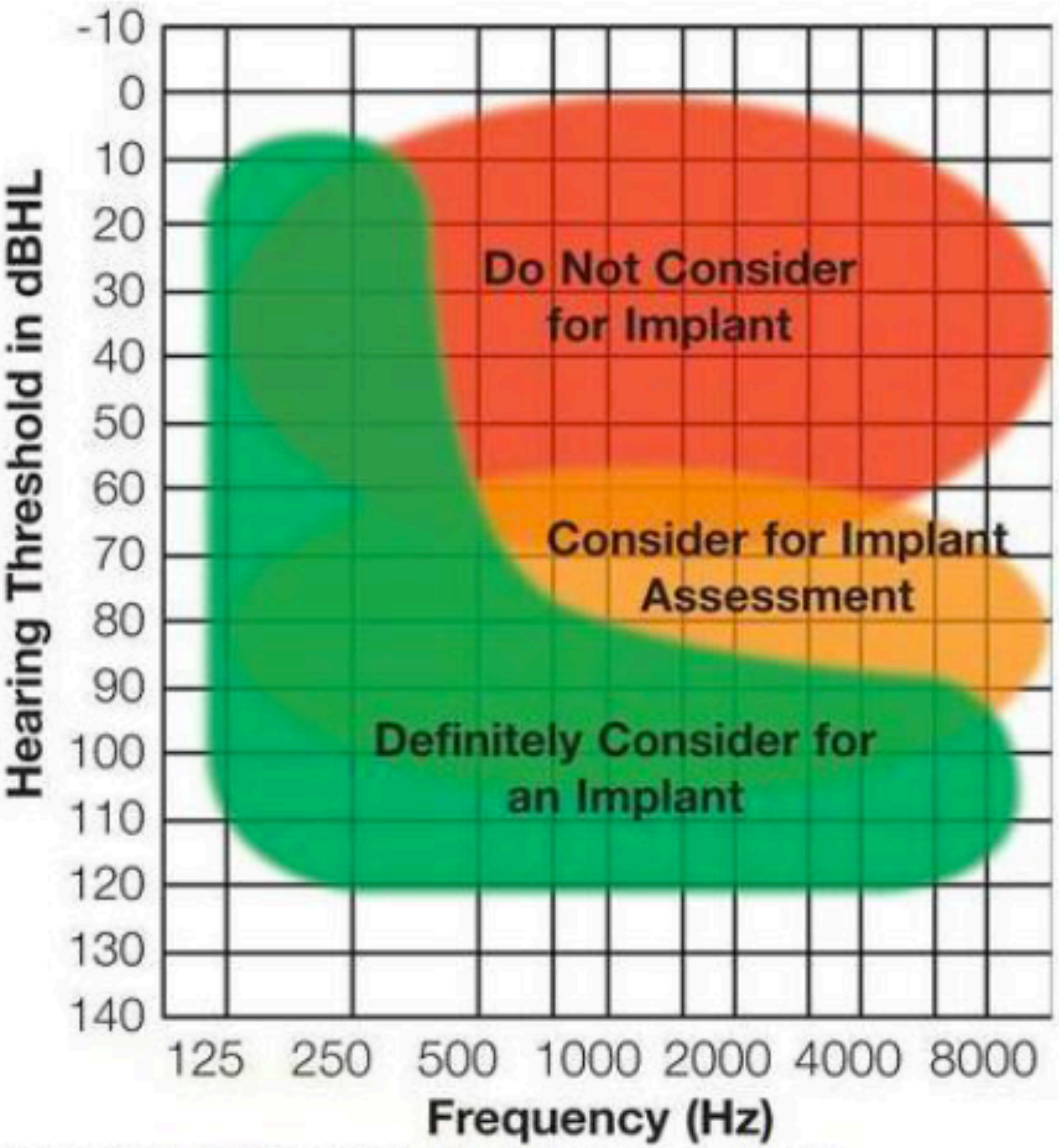
(Centers are trialing AB words and other assessments)

Revised NICE guidelines: possible outcome

Profound hearing loss to be defined as hearing thresholds greater than 80dBHL at two or more frequencies (at 500Hz, 1000Hz, 2000Hz, 3000Hz and 4000Hz) bilaterally without acoustic hearing aids

Insufficient benefit from acoustic hearing aids to be defined as

For adults, a phoneme score of less than 50% on the AB word test	For children, speech, language and listening skills not appropriate to age and developmental stage



(Image provided with permission from The Ear Foundation)

Paediatric Assessment

- Information provision
- Case history (onset, duration, additional difficulties, meningitis)
- Medical
- Imaging (CT and MRI)
- Audiology (objective and subjective)
- Speech and language therapist (communication skills, expressive and receptive language, speech perception)
- Teacher of the Deaf (functional hearing and communication skills)
- Psychologist (development and cognitive skills, expectations, acceptance of deafness, deaf community)

Informational session (the pre-operative assessment process and activation and post-operative FU appointments)

- Psychology
- Medical/ Surgical (ENT, radiology and neurology in complex cases)
- Audiology (HA trial, ABR ..)
- Speech and Language
- Education

Can take up to 3 months for the MDT to finish the assessment and make the final decision

Adult Assessment

- Similar to paediatric (with omission of teacher of the deaf)
- Also includes:
  - Expectations questionnaire
  - Psychological assessment when indicated
  - Counselling
  - Speech perception measures (BKB sentences in quiet)

Outcome of Team Discussions

Offer	Offer CI
Decline	Decline CI and refer back to local services (with details of assessment, the decision, and suggestions for future management)
Defer	Defer (action plan made, e.g. further assessments required)

It's a commitment!

Activation mapping sessions:

- Days 1 & 2 of activation
- 1 week post activation
- 6 weeks post activation
- Further mapping as needed

Reviews

- 3 months
- 6 months
- 1 year
- 18 months
- 2 years
- Annual reviews thereafter (hormonal changes)

Ongoing audiological management

- Regular reviews of:
  - Programming of device
  - Auditory awareness and progress
  - Telemetry
  - Sound field thresholds
  - Middle ear status
  - Function of external equipment
  - Speech perception

Habilitation of children

- Access to sound vs attaching meaning and understanding to it
- Family-based
- Model of auditory learning:
  - Awareness/ detection
  - Discrimination
  - Recognition/ identification
  - Comprehension

Listening with a CI

- Less time at each listening level
- Less dependent on low frequency information than hearing aid users
- Recognize high frequency consonant information more than hearing aid users
- Listening skills will not develop merely because the child has a cochlear implant!

Adults: Auditory training

- Continuous versus broken
- Contrasting syllable number
- Contrasting vowels
- Contrasting consonants
- Simple sentences
- Live, web based, use of apps
- Telephone training where appropriate

Outcomes from cochlear implants

- Provided that:
  - a. the implant electronics are functioning
  - b. the system is appropriately programmed
  - c. there is an in tact auditory nerve
- then **all** patients will achieve:
  - Soundfield thresholds at around 30dBHL from 250 to 8000Hz
  - Detection of Ling 6 sounds (Ling D, 1989. Foundations of Spoken Language for Hearing-Impaired Children)

Observed outcomes (adults)

- Vast majority able to identify environmental sounds
- Improved speech perception in quiet and noise
- Improvements in quality and intelligibility of speech
- Reduced the requirement for additional help / helpers
- Majority report attenuation or elimination of tinnitus
- Almost all judge quality of life has improved
- Depression reduced
- Reported distress reduced

Adults' observations of limitations of cochlear implants

- Difficulties when there is background noise
- Difficulty in working out the direction of sounds (if not implanted bilaterally?)
- Difficulties in group situations
- Music (late onset HL: They compare it to how it used to sound like)

Assessing benefit - Children

- Speech perception
- Language development
- Speech production
- Educational achievements
- Quality of life
- Use of device(s)

Children implanted before 4 years of age

1 month:	Full time user without resistance
3 months:	Change in vocalisation with CI use
6 months:	Spontaneous response to name and to common environmental sounds
12 months:	Evidence of attaching meaning to sound

Children implanted before 18 months

- Language levels can approach those of normally hearing peers
- A child implanted before the age of 2 years can be expected to acquire age-appropriate speech and language by the age of 5 years
- Potential to attend mainstream school with minimal support
- Speech intelligibility may equate to that of normal hearing peers
- Improved ability to localize sound direction
- It also has employment implications and therefore positive economic implications (work = tax payers)

Variables affecting outcomes

- Age at onset of profound deafness (pre / peri / post lingual)
- Duration of deafness
- Communication mode
- Family commitment / personal motivation
- For children -Educational environment
- Radiological status
- Etiology
- General health

Surgical and medical aspects of CI's

Principles

- Electrode array within scala tympani, first 1-2 turns of cochlea
- Tonotopicity preserved
- Electrode stimulation (frequency and intensity information coded and transmitted by speech processor)
- Stimulation of spiral ganglion cells
- Action potential generated within auditory nerve

CI Biomedical Requirements

- A Cochlear structure that can support the electrode array placement
- An Intact/functioning auditory nerve
- Adequate population of “spiral ganglion cells” that communicate the electrical signal to the auditory nervous system
- An intact auditory nervous system

Surgical considerations

- Etiology of deafness- Cochlear ossification/abnormalities
- Patient's anatomy:
  - Inner Ear structures
  - Head size and skull thickness
- ME fluids?

Meningitis and CI's

- Small increased risk of **bacterial meningitis** as a consequence of CI operation
- Prophylactic antibiotics given to patients undergoing CI surgery
- Meningitis can lead to **cochlear ossification**
- Ossification results in more difficult electrode insertion
- Impedances get larger resulting in poorer frequency resolution

Radiology

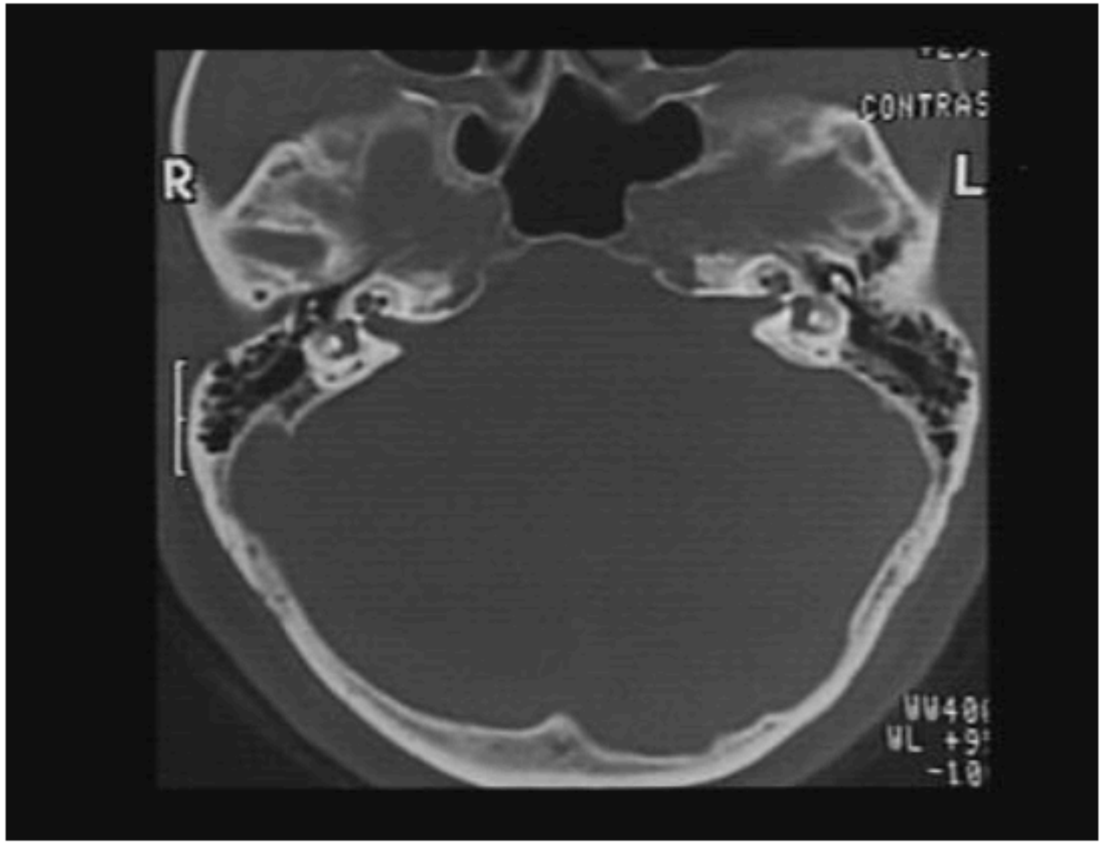
Computerized Tomography (CT) Scans:

- Anatomical orientation of the cochlea: How to open up and insert
- Disease/abnormalities of the bony labyrinth (e.g. Mondini syndrome)

Magnetic Resonance Imaging (MRI):

- Any fibrosis or ossification?
- Any cochlear tissue abnormalities?
- Any auditory nerve abnormalities?

CT scan



MRI scan

Cochlear Implant Surgery

Electrode array inserted into scala tympani via cochleostomy or through round window

Receiver-stimulator placed in bed drilled in skull behind pinna and housed within the mastoid bone

Cochlear implant function tested intra-operatively

Approx a 3-hour surgery

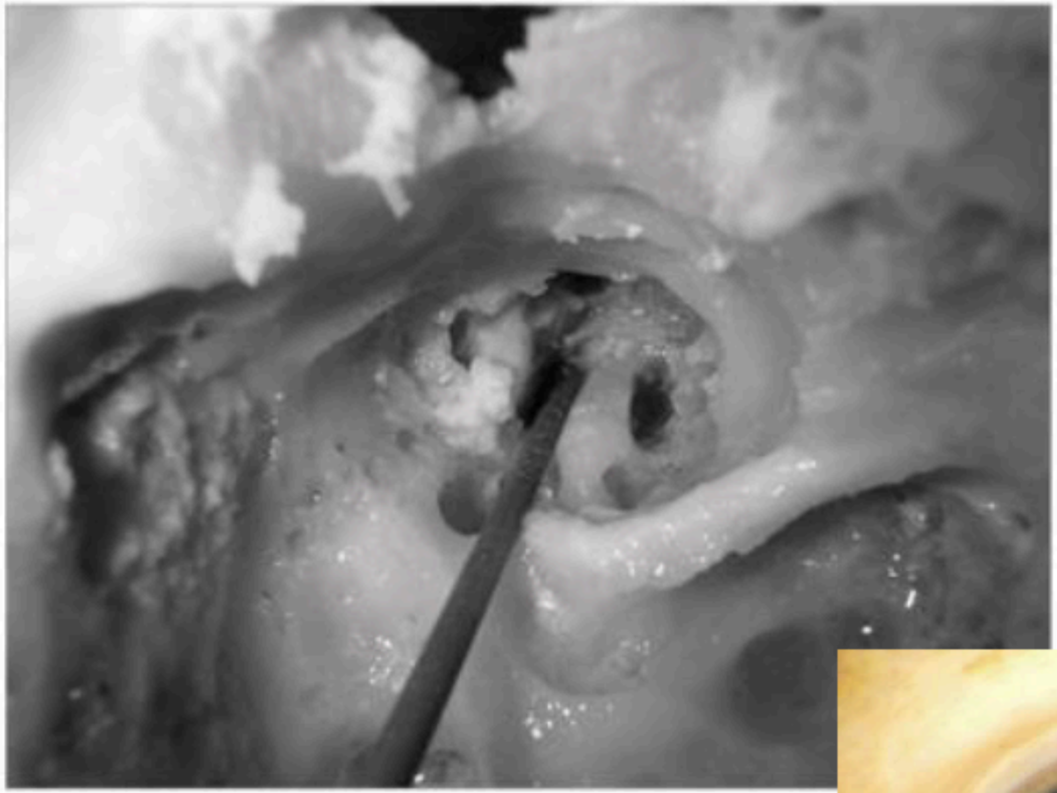


Figure 2. Doing the measurements using the instrum
millimeters.

Cochlear Implant Surgery - Continued

- Surgery is completed under general anesthesia
- A child receives the same internal components as adults because the size of the internal ear structures does not change with age
- Surgery is completed using a minimal incision while constantly monitoring the nearby nerves - the facial and glossopharyngeal nerves (CN V & CN IX)

Factors affecting Residual hearing Preservation

- Surgical approach
  - Electrode array hitting the cochlea and causing inflammatory response
- Use of steroids
- Electrode array
  - Flexible?
  - Short?
  - Pre-curved?
- Patient characteristics
  - Etiology
  - pathophysiology

Possible complications of CI surgery

- Scalp flap problems (external skin infections: managed by antibiotics)
- Facial nerve paralysis or stimulation
- Vertigo or tinnitus (usually temporarily)
- Loss of residual hearing
- Meningitis
- Internal device failure (requiring revision surgery)

Electrode array placement

- How the electrode array sits within the cochlea affects speech perception:
  - We want the electrode to sit as close to the nerves as possible (if they're further away, you end up with a broader spread of current)
  - Neural dead regions: Some nerves in the dead regions aren't functioning as well, which will require increased electrical stimulation for functioning neighbour neurons to detect the stimulus instead.
- Increased channel interaction leads to loss of spectral resolution causing poorer speech discrimination & SIN perception

Objective physiologic measures

- Electrically-evoked Compound Action Potential (ECAP)
- Electrically-evoked Stapedial Reflex Threshold (ESRT)
- Electrical Auditory Brainstem Response (EABR)

ECAP

- Electrically-evoked Compound Action Potential
- Threshold represents lowest stimulus level (electrical current NOT intensity level) that elicits an auditory nerve response
- Implant processor delivers electrical stimulus and measures subsequent response
- Integrated into the software & sound processor
  - **AB**: Neural Response Imaging **(NRI)**
  - **Cochlear**: Neural Response Telemetry **(NRT)**
  - **MED-EL**: Auditory Nerve Response Testing **(ART)**

ESRT

- Electrically-evoked Stapedial Reflex Threshold
- Lowest electrical stimulus level that elicits a reduction in admittance (attributed to stapedial reflex contraction)
- Electrical stimulus delivered through implant but stapedial reflex measured with conventional immitance analyzer (ipsi- or contra-laterally)
- A strong correlation between ESRT thresholds and maximum comfort loudness levels
- Bilateral implantation? Not very useful as best if tested contra-laterally
- Hx of ME disease? Not very useful! (Otoscopy and tympanometry should be performed prior to ESRT)
- May still be absent (measurable in ~65-80% of CI users)
- More-likely to be absent in bilateral implant recipients

EABR

- Electrical Auditory Brainstem Response
- Less popular than ECAP & ESRT
- Similar to conventional ABR but uses electrical stimulation
- Uses conventional ABR system
- Latencies are earlier than typical ABR