Background

- Hearing allows us to be conscious of what goes on around us
- Always “working” to warn us of danger
- Hearing allows communication
- Hearing loss affects 28 million Americans (1/10)
- Isolation from society
All Hair Cells Have Two Functions
Mechano-Electrical Transduction

Outer Hair Cells Carry Out
Electro-Mechanical Transduction

Passive Cochlear Model
- Mass
- Stiffness
- Damping

Sensorineural Hearing Loss
- Mechanisms of sensorineural hearing loss
  - Congenital malformations (otic capsule may or may not be involved)
  - Stria vascularis
  - Spiral ganglion cells
  - Organ of Corti / hair cells
- Presbyacusis (age related hearing loss)
- Noise induced hearing loss
  - Loss of OHCs (12,000 max)
Normal Cochlea

- Hair Cells
- Auditory Nerve

Hearing-Impaired

- Hair Cells
- Auditory Nerve

Common Components of all Cochlear Implant Systems

- Microphone & Cable
- Speech Processor
- Antenna/Transmitter
- Receiver/Stimulator
- Electrode Array

Sound enters microphone on headpiece

Sound travels down cable to processor
Advances in Implant Technology

- Technological advances have resulted in improvements in patient performance
- In turn, improvements in patient performance have resulted in expanded audiological criteria!
Advances in Electrode Design

Spiral Electrode (1990)
HiFocus Electrode with Positioning System (EPS) (1999)

Design changes implemented so that the electrode closely hug the modiolus

Mean Most Comfortable Levels
Three Electrode Configurations
Monopolar Pulsatile Stimulation

Nucleus Contour Electrode

Insertion traumas: K117L, 11.5 mm el. #2
K117L, 12.5 mm el. #1

Slide from Pat Leake, UCSF
**External Equipment**

**Speech Processors**
- Automatic, Continuous Functionality Check of All External and Internal Components
- Multiple Indicator Lights
- Programmable Acoustic Alarm
- ESD Resistant
- Easy to Adjust Controls
  - Built-in microphone tester
  - Multiple Signal-to-Noise ratio options for FM/Accessories

**BTE Sound Processor**
- Runs all processing strategies plus new ones under development
- Rechargeable batteries for low operating cost
- Compatible with all CLARION internal implants
- Same functionality as Body worn PSP, except no warning lights/alarms
- Check functionality with Sensor

**CLARION Sound Processor Development**
- Million Instructions Per Second (MIPS)

**Continuous Two-Way Telemetry**
- Ongoing monitoring achieved with two distinct carrier frequencies
- Normal concurrent signal operation
- Benefit for children who are unable to communicate
Input Dynamic Range (IDR)

- The normal ear captures widely fluctuating speech intensities ranging over 50 dB as well as speech from talkers when they are far away or speaking softly.
- CLARION captures the widest range of incoming sounds through its electronics and software.

"Narrowed" IDR (30 dB)

"Widened" IDR (60 dB)

Acoustic Signal → AGC & Low Pass
→ Pass band 1 → Envelope → Compression → Ch 1
→ Pass band 2 → Envelope → Compression → Ch 2
→ Pass band N → Envelope → Compression → Ch N

Pulse Train Carrier

BTE Decals

Six interchangeable color headpiece caps

Nucleus
Spectral Resolution (Number of Channels)

- Most important factor is the number of spectral channels of information
  - number of distinct pitch channels
- Number of effective channels is not the same as the number of electrodes
Spectral Cues in Music

- While spectral and temporal fine structure are not necessary for speech recognition, they constitute the very heart of music, illustrating the different demands of speech and music on peripheral sensory processing.
- Melody recognition requires many more spectral channels than speech.
- "The cochlea isn’t designed for speech… the cochlea is designed for music" (Ed Burns)

Who is a CI Candidate?
Who Should Get a Cochlear Implant?

**Children**
- Children aged 12 mos-17 years
- Profound sensorineural hearing loss of 90 dB or greater in both ears (No Response ABR)
- Lack of benefit from high powered hearing aids
  - 3-6 month Required Hearing Aid Trial
  - ≤ 2 on Questions 3, 5, & 6 on the IT-MAIS Questionnaire
- Older child (>6yrs): Some auditory skills
  - 0-20% on tests of open-set word recognition (PB-K or MLNT)

**Adults**
- Healthy adult over 18 years of age, no upper age limit
- Severe-Profound sensorineural hearing loss of 70 dB or greater in both ears
- Postlingual onset of deafness (after age 6 yrs)
- Prelingual adults that are members of the hearing community (lip readers, verbal intent)
- Lack of benefit from hearing aids
  - HINT Sentence score < 50%

**Audiological Measurement:**

<table>
<thead>
<tr>
<th>86 Yr. Old Adult</th>
<th>PTA=103dB AS</th>
<th>PTA=105dB AD</th>
<th>CNC Words: =0% AS =0% AD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CI Candidate?</strong></td>
<td><strong>YES</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>56 Yr. Old Adult</th>
<th>PTA=83dB AS</th>
<th>PTA=75dB AD</th>
<th>CNC Words: =12% AS =14% AD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CI Candidate?</strong></td>
<td><strong>YES</strong></td>
<td></td>
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</tr>
</tbody>
</table>
Evaluation & Expectations

Adult Evaluation: Pre-Operative

- Thorough Audiological assessment to determine degree and type of hearing loss and amount of benefit from acoustic amplification
- Include OAEs &/or Acoustic Reflex Testing
- Medical work up, including CT scan or MRI
- Counseling for realistic expectations

Cochlear Implant Surgery

- About 2.5 hours
- General anesthesia, Outpatient
- Procedure
  - Incision
  - Drill facial recess
  - Trough for electrode lead
  - Bony bed for receiver/stimulator
  - Secure receiver/stimulator with sutures
  - Cochleostomy for electrode insertion
  - Pack with fascia and close incision

Covered by Insurance
Don’t take “NO” for an answer

72 year old male with progressive sensorineural hearing loss

A Post-Auricular Incision
Exposure of the Mastoid Cortex

Drilling the Mastoid and Countersinking the Implant

Securing the Implant

The Facial Recess

Placement of the Electrode

Complications

COMMON
- Hearing loss - in everyone
  - New techniques to reduce HL
- Variable outcomes
- Chorda tympani nerve injury

UNCOMMON
- Infections - uncommon
- Flap necrosis - uncommon
- Tinnitus & Imbalance - usually self limited
- Facial nerve injury - congenital abnormality
- MENINGITIS - a problem of mythic proportions
Risk factors for meningitis

- Inner Ear Malformations
- Prior history of meningitis
- Young children (esp. < 5 yrs)
- Otitis media
- Immune dysfunction
- Prior ear surgery

Meningitis in Cochlear Implantation

- 91 people worldwide (N=60,000)
- 17 deaths
- 53 US cases (N=25,000)
  - Ages 18 mos to 84 yrs; Most under 7 years of age (n=33)
  - Signs and Sx < 24 hrs to > 6 yrs
  - 50% developed meningitis < 1 year postop (N=32)
- 29 Advanced Bionics CLARION (1996; N=7500)
- 22 Cochlear Nucleus (1985; N=16,500)
- 2 MED-EL (2001; N=770)

Design Flaws?

- Higher incidence with Clarion positioner
- Removed from the market
- HF1 electrode now available without the positioner

Post-Operative Evaluations: Device Fitting and Follow-up

- Initial stimulation: 3-6 weeks post surgery
- Adjustments made regularly based on feedback from patients, parents, therapists and educators
- Speech perception evaluations semi-annually to annually

Evolution of Implant Outcomes

- Single-channel implants
  - Sound detection, perception of speech rhythm, lipreading enhancement
- First generation multichannel implants
  - Closed-set word identification, some open-set sentence recognition; poor open-set word recognition

Current Expectations

- Sound Field thresholds 20-45dB @ 250-6K Hz
- Cannot return to Hearing Aid in implanted ear
- >80% Postlingual Adults use the telephone
- >50% of Postlingual Adults enjoy music
- Near peak performance by 3 months!
**Open-Set Speech Recognition**

N=56 Postlinguistic Patients
Six-Month Scores

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>1 Month</th>
<th>3 Month</th>
<th>6 Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNC Words</td>
<td>3%</td>
<td>35%</td>
<td>45%</td>
<td>47%</td>
</tr>
<tr>
<td>CID Sentences</td>
<td>20%</td>
<td>15%</td>
<td>13%</td>
<td>11%</td>
</tr>
<tr>
<td>HINT in Quiet</td>
<td>79%</td>
<td>71%</td>
<td>76%</td>
<td>78%</td>
</tr>
<tr>
<td>HINT +10 S/N*</td>
<td>67%</td>
<td>41%</td>
<td>31%</td>
<td>22%</td>
</tr>
</tbody>
</table>

* Note: Only patients who score > 20% on HINT Sentences in quiet are administered HINT Sentences in noise.

**Individual CNC Word Scores at 3 Months**

and Duration of Deafness (n= 67)

High levels of CNC word recognition were achieved by patients with long as well as short duration of deafness.

**Individual CNC Word Scores at 3 Months and Age at Implant (n=67)**

31% of the sample was implanted at > 70 years of age. Some of these older patients show high levels of word recognition at three months. Others may require more implant experience before they demonstrate open-set word recognition abilities.

**SPIRAL GANGLION CELL DEGENERATION FOLLOWING NEONATAL DEAFNESS**

Slide from Pat Leake, UCSF

**Why Research Cochlear Implant Alternatives?**

- Outcomes with a cochlear implant are good... but not as good as normal hearing
- Cochlear implants can not be used for mild or moderate levels of hearing loss
Pie in the Sky?

Modulation of Cochlear Mechanics
- Drug therapy
- Gene therapy
- Physical manipulations

1) Measure hearing with various cochlear potentials (CAP, DPOAES, CM, & EP)
2) Measure basilar membrane motion using laser doppler vibrometer (2 picometer sensitivity)

Ventral Exposure of the Guinea Pig Cochlea

Perfusion Technique

Research Implications:
Developing a Treatment for Cochlear Hearing Loss

- Techniques for performing surgery of the inner ear
- Potential surgical objectives:
  - Change mass, stiffness, or damping of organ of Corti
    - Laser
    - Physical manipulations
  - Drug therapy
    - Modulate outer hair cell electromotility
    - Modulate stereociliary transduction
  - Genetic manipulations:
    - Insert exogenous motor proteins (prestin)
    - Modulate tectorial membrane passive mechanics
  - Electronic device implantation (bionic OHC’s)
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