The Importance of Bilateral Cochlear Implantation in Children who are Profoundly Deaf in Both Ears

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Children need binaural hearing
Can we promote binaural hearing with bilateral cochlear implants?

**Sequential implants**
- n=156
- Age at 1st implant = 3.3 ± 3.1 yrs
- Age at 2nd implant = 9.3 ± 4.7 yrs
- Inter-implant delay = 5.9 ± 3.8 yrs

**Simultaneous implants**
- n=166
- Age at implant = 2.8 ± 3.2 yrs

Recruitment as of May 2012
Spatial unmasking: better hearing in noise

(noise at 0°) vs. (noise at 90°)
Spatial unmasking: better hearing in noise

(noise at 0°) vs. (noise at 90°)
Spatial unmasking: better hearing in noise

(noise at 0°) vs. (noise at 90°)
Spatial release from masking

Noise moved to 1st implanted ear
Noise moved to 2nd implanted ear

P < 0.001

Chadha et al., *Otol NeuroOtol*, 2011
Spatial release from masking

Chadha et al., *Otol NeuroOtol*, 2011
Spatial release from masking

- Noise moved to 1st implanted ear
- Noise moved to 2nd implanted ear

P = 0.001
P > 0.05

Chadha et al., *Otol NeuroOtol*, 2011
How does binaural hearing work?

- Sound reach one ear before the other and at different levels

- These cues must be detected by the central auditory system
Can we promote binaural hearing with bilateral cochlear implants?
Will binaural processing be limited by deafness in early development?

Reduced activity

Activity no longer reduced

Neural competition in development

Development

Neural competition in development

Development

Maturity


Phonak Latin American Pediatric Conference III, Buenos Aires, Argentina, October 11-13, 2012
Unilaterally driven development
Neural competition in development

Development

Maturity in auditory brainstem with 2 years CI use

Restricted auditory brainstem plasticity after 2 years of unilateral implant use

Unilateral CI use: nil  Unilateral CI use: 6-12 months  Unilateral CI use: > 2 years

Gordon, et al., 2010
Auditory evoked cortical responses are abnormal in the naïve ear.

Experienced ear

Naïve ear

- P1
- N1
- P2

Cz

All other channels

Latency (ms)
Imaging brain activity in cochlear implant users

![Graph showing brain activity latency](image1)

![Image of cochlear implant users](image2)

![Graph showing electric potential](image3)

![Brain imaging](image4)
Imaging brain activity in cochlear implant users
Abnormal cortical activity after right cochlear implant use

Clicks/pulses presented to right ear

<table>
<thead>
<tr>
<th>% Activity in Left Auditory Cortex</th>
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<tbody>
<tr>
<td>[(R-L)/(R+L)x100]</td>
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<table>
<thead>
<tr>
<th>Group</th>
<th>Dipole Moment (nAm)</th>
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<tbody>
<tr>
<td>Normal Hearing (n=7)</td>
<td>5</td>
</tr>
<tr>
<td>Right CI Users (n=8)</td>
<td>15</td>
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</tbody>
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*Right CI Users (n=8)

*Normal Hearing (n=7)
Normal cortical lateralization after simultaneous bilateral cochlear implantation

a) Right/CI-1 Stimulation

b) Left/CI-2 Stimulation
Increasing abnormality in cortical activity with unilateral cochlear implant use

**c)** Right (1st Implant) Stimulus

**d)** Left (2nd Implant) Stimulus

Lateralization (%)

Duration of Unilateral Implant Use (yrs)
Significant change in cortical activity with $\geq 1.5$ years unilateral cochlear implant use
Bilateral input goes to dominant hemisphere after 2+ years unilateral stimulation

Lateralization of Cortical Responses by Stimulus Side

Participant Group

Left/CI-2 Stim

Bilateral

Right/CI-1 Stim

Dipole in each hemisphere
Abnormal auditory development with unilateral implant use

- Dominance of contralateral auditory cortex
  - Lack of inhibitory binaural processing during development

Sequential bilateral CI

1st CI
Abnormal auditory development with unilateral implant use

- Dominance of contralateral auditory cortex

- Ipsilateral cortex?
Perception of binaural cues restored by simultaneous bilateral implantation

Salloum et al., *Ear and Hearing*, 2010
Perception of binaural cues restored by simultaneous bilateral implantation

Normal Hearing (n=9)                      Sequential bilateral cochlear implant (n=19)                      Simultaneous bilateral cochlear implant (n=8)

Proportion of responses

Inter-aural Timing Differences (us)

Salloum et al., *Ear and Hearing*, 2010
Perception of binaural cues restored by simultaneous bilateral implantation

Left Responses
Right Responses

Normal Hearing
Simultaneous Bilateral CI

Inter-aural/implant Level Difference (dB/CU)

Response Rate

Inter-aural/implant Timing Difference

Response Rate
Non-auditory benefits of simultaneous implantation

- Hospital cost-savings
  - 35% over sequential procedures
- Similar length of stay as unilateral procedures (~ 1 day)
- No increased complications (Ramsden, et al., 2009)
- Increased parental satisfaction compared with 2 surgeries in short period.
- One course of programming and therapy
Summary and Conclusions

- There is a sensitive developmental period for bilateral auditory input

Simultaneous bilateral cochlear implantation
- Allows symmetric development of auditory brainstem and cortex
- Protects the brain from abnormal reorganization
- Promotes binaural hearing
- Provides significant cost savings over sequential procedures

Sequential bilateral cochlear implantation
- Does not reverse effects of unilateral stimulation
  - Abnormal asymmetry of brainstem and cortical activity
  - Abnormal binaural processing
Simultaneous bilateral cochlear implantation offers a cost-effective way to promote symmetric development and function along the bilateral auditory pathways and to establish binaural hearing for children who are deaf.
Thank you to all of our participants