Cochlear implants: new developments and considerations for Chinese speakers

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Institute of Human Communicative Research and Department of Otorhinolaryngology, Head and Neck Surgery
Financial disclosure

• Currently receiving research grants as PI from
  – Medel on VSB/ BB studies
  – Advanced Bionics on CI studies
• As Co-I in
  – Research projects associated with Signal processing with Cochlear Ltd
• CI surgeon performing devices from Medel/ Advanced Bionics and Cochlear Ltd
New Development

- Atraumatic insertion, allowing preservation of residual hearing
- Single-sided deafness/ Tinnitus management
- Bilateral cochlear implant
New Electrode Design

- Cochlear Nucleus CI 422
- Medel Soft series
  - Flex soft 31 versus 28
- Advanced Bionics HiFocus V
• Active electrode spread: 5.0 mm
• Proximal blue marker to distal tip of array: 18.5 mm
• Total array length, distal tip to jog: 23.7 mm
• Diameter distal tip: 0.5 mm
• Diameter proximal base at blue marker: 0.7 mm
• Cochleostomy size: 0.8 mm
• Lead length fantail to neck/jog of array: 84 mm
Roland, Oct. 2010, 8027 Left Mid Scala Electrode Advanced Bionics
Slim half-band electrode

PROVEN OUTCOMES

**CI422 Speech Performance (Quiet)**
Word Recognition (% Correct)

- Group Mean
- Pre-operative
- Best aided condition

N=19, 6 month post-operative data

*** p<0.001 paired-t

*CAG5198 Clinical Evaluation of the CI422 electrode array.*
*Courtesy of Professor H. Skarzynski.*

**CI422 Speech Performance (Noise)**
Word Recognition (% Correct)

- Group Mean
- Pre-operative
- Best aided condition

N=19, SNR=10dB, 6 month post-operative data

*** p<0.001 paired-t

*CAG5198 Clinical Evaluation of the CI422 electrode array.*
*Courtesy of Professor H. Skarzynski.*

**CI422 Hearing Preservation**

- Pre-operative threshold
- Post-operative threshold
- Median change

N=19, 6 month post-operative data

*CAG5198 Clinical Evaluation of the CI422 electrode array.*
*Courtesy of Professor H. Skarzynski.*
Bilateral Cochlea Implant

- Bilateral Simultaneous or Sequential Cochlear Implant

Binaural cochlear implantation: Comparison of 3m/house and nucleus 22 devices with evidence of sensory integration††
Balkany et al 1988

Binaural Cochlear Implants Placed during the Same Operation
Gantz et al 2002
Evidence based review

Bilateral Cochlear Implantation: An Evidence-Based Medicine Evaluation

John Murphy, MBBS, MRCS; Gerard O'Donoghue, MCh, FRCS
Bilateral surgeries- How I do it?

• Simultaneous surgeries not much difference from unilateral
• The differences:
  
  Drape the whole head
  Test the first side before starting the second side
  No monopolar diathermy on the second side
  (also true for sequential CI)
Question: sequential when to do

- US multicenter study Roberts 2007
- 3 age groups 3-5/5-8/>8
- Young children achieved better in speech perception in second ear
- Second ear not as good as the first side for age >5

Recommendation: sequential better to do before age of 5
Conclusion

• Bilateral cochlear implant offers additional advantage to unilateral implant in terms of speech understanding and directional hearing
• Simultaneous implant is preferred
• Surgery does not carry a higher risk
Question: Children younger than 12 months
(James and Papsin)
The Six Cantonese Tones

- Design of materials and test
- Tests of Word and Tone recognition
Outline

• Outcomes on Mandarin
  – Literature review
  – Tones/ word recognition and others

• Outcomes on Cantonese
  – 5 year data on Prince of Wales Hospital
  – Tone production / word recognition
# Outcomes on Mandarin Tone Perception

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>Mean age at implantation (yr)</th>
<th>Mean duration of implant use (yr)</th>
<th>Mean percentage correct</th>
<th>Chance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wu &amp; Yang, 2003</td>
<td>16</td>
<td>5.8</td>
<td>1</td>
<td>73.1</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>79.2</td>
<td></td>
</tr>
<tr>
<td>Peng et al., 2004</td>
<td>30</td>
<td>9;3</td>
<td>3;7</td>
<td>72.9</td>
<td>50%</td>
</tr>
<tr>
<td>Cao et al., 2004</td>
<td>53</td>
<td>1 to &gt;17</td>
<td>No information</td>
<td>69</td>
<td>?</td>
</tr>
<tr>
<td>Huang et al., 2005</td>
<td>26</td>
<td>3.5</td>
<td>1.2 to 3.5</td>
<td>54.8</td>
<td>25%</td>
</tr>
<tr>
<td>Wang et al., 2007</td>
<td>29</td>
<td>Young gp: 2.2 Old gp: 6.5</td>
<td>Young gp: 4.5 Old gp: 4.1</td>
<td>72.1</td>
<td>33.3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>57.3</td>
<td></td>
</tr>
</tbody>
</table>
## Outcomes on Mandarin Tone Production

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>Mean age at implantation (yr)</th>
<th>Mean duration of implant use (yr)</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xu et al., 2004</td>
<td>4</td>
<td>4 to 9</td>
<td>1 to 5</td>
<td>Acoustic analysis: Tones produced tended to be flat; Tone intelligibility: 0.25 to 8.5 out of a 10-pt rating scale</td>
</tr>
<tr>
<td>Peng et al., 2004</td>
<td>30</td>
<td>9;3</td>
<td>3;7</td>
<td>53% correct</td>
</tr>
<tr>
<td>Han et al., 2007</td>
<td>14</td>
<td>1.16 to 7.09</td>
<td>0.3 to 2.6</td>
<td>48.4% correct</td>
</tr>
</tbody>
</table>
## Outcomes on Mandarin Open-set Word Recognition

<table>
<thead>
<tr>
<th>Source</th>
<th>N</th>
<th>Mean age at implantation (yr)</th>
<th>Mean duration of implant use (yr)</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cao et al., 2000</td>
<td>25</td>
<td>8.3</td>
<td>&lt;0.5 to 2</td>
<td>~40%</td>
</tr>
<tr>
<td>Cao et al., 2004</td>
<td>533</td>
<td>1 to &gt;17</td>
<td>No information</td>
<td>44%</td>
</tr>
</tbody>
</table>
Outcomes on Mandarin Open-set Word Recognition

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean age at implantation (yr)</th>
<th>Mean duration of implant use (yr)</th>
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<td>No information</td>
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<tr>
<td>Wang et al., 2007</td>
<td>29</td>
<td>Young gp: 2.2 Old gp: 6.5</td>
<td>Young gp: 4.5 Old gp: 4.1</td>
<td>Young gp: 80% Old gp: 60.4%</td>
</tr>
</tbody>
</table>
Long term outcomes on Cantonese

- Speech outcomes
  - Open-set word recognition
  - Cantonese tone production

- To examine the effect of
  - implant experience
  - age at implantation
Subjects

- 45 prelingually deaf children
- 20 females and 25 males
- Using CI for 5 year
- Implanted at age from 1;04 to 14;09 (mean = 5;05)
Study design

- Open-set word recognition
- Tone production
- Expressed as percentage correct
- Tested at 6 time intervals from pre-operation to five-year post-surgery
Data Analyses

• Linear regression
  – DV: Tone production scores
    Word recognition scores
  – IV: Age at implantation (Age)
    Duration of implant use (Time)
## Results – Linear regression

<table>
<thead>
<tr>
<th>Variables</th>
<th>Word recognition P-value</th>
<th>Tone Production p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Age at implantation</td>
<td>0.807</td>
<td>0.027</td>
</tr>
<tr>
<td>Interaction</td>
<td>0.003</td>
<td>0.044</td>
</tr>
</tbody>
</table>
Data Analyses

• Linear regression, age by age
• Implanted at <2, 2, 3, 4, 5, 6, 7, 8, 9, >=10
  – DV: Tone production scores
  – IV: Word recognition scores
  – IV: Duration of implant use (Time)
Linear regression – age by age

- Parameter estimates
  - The estimated increase on tone production/word recognition scores in relation to one unit increase in time
  - Example
    - \(-3.5 = 3.5\) score decrease with 1 more year of implant use
    - \(6.5 = 6.5\) scores increase with 1 more year of implant use
## Linear regression – Word Recognition

<table>
<thead>
<tr>
<th>Age</th>
<th>Parameter estimate</th>
<th>p-value</th>
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<tbody>
<tr>
<td>&lt;2</td>
<td>14.59</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>14.70</td>
<td>0.00</td>
</tr>
<tr>
<td>3</td>
<td>7.51</td>
<td>0.11</td>
</tr>
<tr>
<td>4</td>
<td>7.99</td>
<td>0.03</td>
</tr>
<tr>
<td>5</td>
<td>6.37</td>
<td>0.39</td>
</tr>
<tr>
<td>6</td>
<td>9.74</td>
<td>0.00</td>
</tr>
<tr>
<td>7</td>
<td>10.51</td>
<td>0.03</td>
</tr>
<tr>
<td>8</td>
<td>2.64</td>
<td>0.15</td>
</tr>
<tr>
<td>9</td>
<td>-4.48</td>
<td>0.38</td>
</tr>
<tr>
<td>&gt;=10</td>
<td>4.41</td>
<td>0.24</td>
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Discussion

- Different magnitude of improvement for children implanted at various ages
Implanted before 8 years old

- Coefficient estimates =
  - <2: 14.59
  - 2;00 – 2;11: 14.70
  - 3;00 – 3;11: 7.51
  - 4;00 – 4;11: 7.99
  - 5;00 – 5;11: 6.37
  - 6;00 – 6;11: 9.74
  - 7;00 – 7;11 10.51
Implanted at or above 8 years old

- Coefficient estimates =
  - 8:00 – 8:11: 2.64
  - 9:00 – 9:11: -4.48
  - >=10:00: 4.41

- P-values all >0.05
Word Recognition

Graph showing the improvement in word recognition over time in patients post-operation.
Word Recognition

![Graph showing word recognition over time](graph.png)
Word Recognition

![Graph showing word recognition over time](graph.png)

- pre-op
- 1 yr
- 2 yr
- 3 yr
- 4 yr
- 5 yr

Colors and legends:
- 7
- 8
- 9
- ≥10
Word Recognition

[Graph showing trends in word recognition over time, with lines representing different groups and years.]
Word Recognition

[Graph showing word recognition rates over time with different colored lines representing different categories: pre-op, 1 yr, 2 yr, 3 yr, 4 yr, 5 yr.]

Legend:
- Blue: 7
- Red: 8
- Orange: 9
- Black: >=10
## Linear regression – Tone production

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<tbody>
<tr>
<td>&lt;2</td>
<td>2.50</td>
<td>0.42</td>
</tr>
<tr>
<td>2</td>
<td>7.38</td>
<td><strong>0.02</strong></td>
</tr>
<tr>
<td>3</td>
<td>9.05</td>
<td><strong>0.00</strong></td>
</tr>
<tr>
<td>4</td>
<td>3.50</td>
<td>0.25</td>
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</tr>
<tr>
<td>9</td>
<td>-0.14</td>
<td>0.93</td>
</tr>
<tr>
<td>&gt;=10</td>
<td>2.76</td>
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## Linear regression – Tone production

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<td>2.76</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Linear regression – age by age

- Up to 75% accuracy within one year of implant use
- Maintained throughout 5 years
Implanted at 2 to 3;11 years old

- Relatively lower scores in the first year
- Steadily improved
Implanted at > 4 years old

- Coefficient estimates ranged from -0.14 to 4.78
- Extent of improvement dropped markedly
Linear regression – age by age
Linear regression – age by age
Linear regression – age by age
Conclusion

• Children implanted at various ages showed improvements both in word recognition and tone production over time
• Children implanted younger than 4 achieved the highest scores over time
• The magnitude of improvement becomes smaller with increasing age of implantation
Conclusion

• Critical implanted age for word recognition
  – Below aged 7
    • Achieved >70% after 2 yrs
  – Aged 7 or above
    • Achieved 12-58% after 5 yrs
Summary

• Critical implanted age for acquiring tone
  – Before two
    • achieved 76% accuracy after 1 year
  – From 2 to 3;11
    • achieved >72% accuracy after 3 years
  – Older than 4
    • only achieved 44-69% after 5 years
<table>
<thead>
<tr>
<th>Age of implantation</th>
<th>Tone production</th>
<th>CI duration (yrs)</th>
<th>Word recognition</th>
<th>CI duration (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2</td>
<td>☻ ☻ ☻ ☻</td>
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<td>☻ ☻ ☻ ☻ ☻ ☻ ☻ ☻</td>
<td>2</td>
</tr>
<tr>
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<td>☻ ☻ ☻ ☻</td>
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<td>5</td>
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<tr>
<td>9</td>
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<td>5</td>
<td>☻ ☻ ☻ ☻ ☻ ☻ ☻ ☻</td>
<td>5</td>
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<td>≥10</td>
<td>☻ ☻ ☻ ☻ ☻</td>
<td>5</td>
<td>☻ ☻ ☻ ☻ ☻ ☻ ☻ ☻</td>
<td>5</td>
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</tbody>
</table>
What next?

• A low-cost device?
  • Durability, safety and efficacy/ Company survival
• A custom device?
  • Beating existing device
  • Awaiting innovation
• Future device
  • hardware: small, durable, flexible, custom designed electrodes, waterproof, noise reduction, total implantability