Cochlear implants: new developments and considerations for Chinese speakers

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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
PROVEN OUTCOMES

Slim half-band electrode

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

Hearing Threshold Change (dBHL)

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
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></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>
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<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>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>
</tr>
<tr>
<td>Peng et al., 2004</td>
<td>30</td>
<td>9;3</td>
<td>3;7</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>
</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>
<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>
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<th>Mean age at implantation (yr)</th>
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<th>Outcomes</th>
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<td>8.3</td>
<td>&lt;0.5 to 2</td>
<td>~40%</td>
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<tr>
<td>533</td>
<td>1 to &gt;17</td>
<td>No information</td>
<td>44%</td>
</tr>
<tr>
<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
  – IV: Word recognition scores
  – IV: Age at implantation (Age)
  – IV: Duration of implant use (Time)
## Results – Linear regression

<table>
<thead>
<tr>
<th>Variables</th>
<th>Word recognition</th>
<th>Tone Production</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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<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>
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<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>
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<td>&gt;=10</td>
<td>4.41</td>
<td>0.24</td>
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# Linear regression – Word Recognition

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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
Word Recognition
Word Recognition

![Graph showing word recognition improvement over time]

Pre-op, 1 yr, 2 yr, 3 yr, 4 yr, 5 yr

- 7
- 8
- 9
- >=10
Word Recognition

![Graph showing word recognition over time with pre-op, 1 yr, 2 yr, 3 yr, 4 yr, and 5 yr as x-axis and percentage as y-axis. Lines represent different criteria: 7, 8, 9, and ≥10.]
Word Recognition

The graph shows the performance of word recognition over time post-operation. The x-axis represents the time periods: pre-op, 1 yr, 2 yr, 3 yr, 4 yr, and 5 yr. The y-axis represents the percentage of word recognition, ranging from 0 to 100.

Four lines represent different groups or conditions, indicated by different colors and markers:
- Line 7: Cyan squares
- Line 8: Blue circles
- Line 9: Red triangles
- Line >=10: Black diamonds

The graph indicates variations in word recognition across different time points and conditions.
## Linear regression – Tone production

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<tr>
<td>&lt;2</td>
<td>2.50</td>
<td>0.42</td>
</tr>
<tr>
<td>2</td>
<td>7.38</td>
<td>0.02</td>
</tr>
<tr>
<td>3</td>
<td>9.05</td>
<td>0.00</td>
</tr>
<tr>
<td>4</td>
<td>3.50</td>
<td>0.25</td>
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<tr>
<td>9</td>
<td>-0.14</td>
<td>0.93</td>
</tr>
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<td>&gt;=10</td>
<td>2.76</td>
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<td>2.76</td>
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</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 duration (yrs)</th>
<th>Word recognition duration (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;2</td>
<td>😊😊😊</td>
<td>😊😊😊</td>
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<td>😊😊😊</td>
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<td>😊</td>
<td>😊</td>
</tr>
</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
CUHK Jockey Club Minimally Invasive Surgical Skills Centre

Department of Otorhinolaryngology, Head and Neck Surgery