Creation of a Single, Universal Performance Measure Using Multiple Imputation in a National Web-Based Cochlear Implant Database

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  - founder, Aii/HERMES (non-profit); Aii/HERMES grant (supported by Cochlear, Advanced Bionics)
Cochlear Implant Speech Perception Outcomes are Heterogenous

- >20 tests
- CNC, AZBio, HINT most common
- Incompatible!

¹Vila et. Al, 2016
Multiple Incompatible Outcomes Impair Research

- Can’t compare
  - Device design/technology
  - Surgical techniques
  - Populations

- Can’t pool data
  - Can’t combine sites
  - Lose n’s and statistical power
Problem: Multiple Incompatible Outcomes

AzBio → CNC
Not all comparable

All Comparable
Why Important?

- Big data
- HERMES
  - Prospective, national, web-based CI database, n=\textit{thousands}
  - 24 US academic medical centers and private practice
  - ❄ Multiple speech outcome measures
Solving the Problem

- **CNCw** chosen as the standard
- Subjects without CNC = **missing data**
- Need to **replace** missing CNC
- **Imputation** = intelligently replacing missing data
Imputation

- Mean
- Regression
- Extrapolation
- Substitution
- MICE:
  \textbf{M}ultivariate \textbf{I}mputation by \textbf{C}hained \textbf{E}quations
Methods

- HERMES
- n=157 with 1 year postoperative data
- Outcome measures diverse (CNCw, HINT, AZBio, etc.)
- Calculate missing CNCw via MICE
  - Accounts for other outcomes (including BKB-SIN, AzBio), age, sex, duration of hearing loss, recent use.
- Used larger, imputed dataset to analyze performance in older adults
How Does MICE Work?

17 Subjects with 10 CNCw Iterations

“Multivariate Imputation by Chained Equations” (MICE)

Available data:
- Azbio
- BKBsin
- CNCp
- CnCw
- Sex
- Age
- CI usage
- Duration of HL

N = 157
“Multivariate Imputation by Chained Equations” (MICE)

Has CNCw
N = 140

Missing CNCw
N = 17
“Multivariate Imputation by Chained Equations” (MICE)

Available data:
- Azbio
- BKBsin
- CNCp
- CNCw
- Sex
- Age
- CI usage
- Duration of HL

Missing CNCw

N = 157
"Multivariate Imputation by Chained Equations" (MICE)

Available data:
- Azbio
- BKBsin
- CNCp
- CNCw
- Sex
- Age
- CI usage
- Duration of HL

N = 157

Imputed CNCw

x10
Imputed Data-sets used for Analysis

Imp.1  Imp.2  Imp.3  Imp.4  Imp.5  Imp.6  Imp.7  Imp.8  Imp.9  Imp.10


b  b  b  b  b  b  b  b  b  b
- “MICE” maximizes sample size
  - Uniformity of outcome measures
- Larger sample sizes = stronger analysis

- Use a “Larger” database from “MICE” to answer clinical questions…
How does age affect Cochlear Implant Performance?
# Age and Cochlear Implant Performance

- 17 imputed patients ("MICE")
- All have CNCw as outcome measure

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>157</td>
</tr>
<tr>
<td>Age, mean ± s.d. (range)</td>
<td>66.7 ± 17.9 (19-93)</td>
</tr>
<tr>
<td>Duration of deafness, mean ± s.d. (range)</td>
<td>23.2 ± 15.9 (.5-90)</td>
</tr>
<tr>
<td>CI Usage (months), mean ± s.d. (range)</td>
<td>11.78 ± 3.33 (3-17)</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>79 (50.3%)</td>
</tr>
<tr>
<td>Side of CI, n (%)</td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>63 (40.1%)</td>
</tr>
<tr>
<td>Right</td>
<td>69 (43.0%)</td>
</tr>
<tr>
<td>Bilateral</td>
<td>25 (15.9%)</td>
</tr>
</tbody>
</table>
Univariable Analysis

Age was a weak predictor of worse CNCw score

\( b = -0.30; \) 95% CI = -0.51, -0.09; p<0.05)
Multivariable Analysis

• Controlled for
  • Sex
  • Duration of hearing loss
  • Device usage
  • Age

• Age was no longer a predictor of CNCw

\[(b = -0.33; 95\% \text{ CI} = -0.96, 0.30; p > 0.05)\]
Conclusions

- Using multiple imputation, CNCw values were calculated when other outcomes were available.

- confirmed that older age is a weak-to insignificant predictor of performance.
Discussion

- Multiple Imputation allows for the creation of a single, universal performance measure.

- Database will grow, and imputation will improve.
  - Pave the way for easier conversion between testing methods.
Thank You

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