Position of Auditory Brainstem Implant Electrode Influences Audiometric Outcomes and Side Effects

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Background
Auditory Brainstem Implant placement

- ABI’s are placed directly over the brainstem in proximity to the dorsal cochlear nucleus (DCN)

- Placement is “blind” and electrophysiology is utilized to confirm placement

- Audiometric outcomes vary widely among similar cohorts

- Electrodes are commonly inactivated due to side effects
Rationale
Artifact obscures electrode position in post-op CT

Nucleus Profile ABI 541 with flexible array (Cochlear) (NOT FDA APPROVED)

Standard Axial View: windmill streak artifact present

MPR View: Electrode positioning is impossible to determine
We hypothesize that:

1) Post-operative Computed Tomography (CT) can resolve electrode array position in 3D space.

2) CT determined ABI array positions correlate with audiometric data and side effects.
### Methods

**3D Reconstruction of Post-operative CT**

- 4 Pediatric (non-NF2) and 7 Adult ABI subjects (6 NF2, 1 non-NF2) from our institution
  - *(IRB approved protocols #340312, #441528, #444277).*

- True axial series were reformatted in Multiplanar Reconstruction (MPR) using the McRae line. DICOM files were imported into Osirix MD v.7.0.1 64-bit. Basion and electrode tip coordinates were marked in MPR

- CT series were then viewed in 3D Maximum Intensity Projection (MIP)
Methods
3D Maximum Intensity Projection

360° view of post-operative axial CT scan
• 3D maximum intensity projection (MIP) revealed electrode array position

• Linear and angular measurements between marked coordinates were made using standard posterior and lateral views

Methods
3D Reconstruction of Post-operative CT
Methods
A new classification system for electrode positions

TYPES I-IV
Based on Angle V from a lateral view

TYPE I
71-90°

TYPE II
20-70°

TYPE III
0-19°

TYPE IV
outside 0-90° or laterally tilted

TYPES A, B, C, D
Based on Angle T from a posterior view

TYPE A
71-90°

TYPE B
20-70°

TYPE C
0-19°

TYPE D
less than 0°
Post-activation data included:

- The number and distribution of active electrodes and side effects
- Psychophysical threshold (T) levels during perceptual testing
Results
A wide variety of angles were observed

- All arrays were normalized to the right side for comparison.
- The majority of electrodes have a range of angles between 0-90 degrees with respect to the horizontal.
Results
Subject Responses: T Values, disabled electrodes (X)

4 Pediatric Subjects
(2 revisions)

6 Adult Subjects
(All displayed as if R side)
3 Results
Some orientations may be more optimal than others

Combined Classification Types in Subjects with Audiometric Data

<table>
<thead>
<tr>
<th>Combined Classification</th>
<th>Mean number of active electrodes (n)</th>
<th>Mean number of side effects (n)</th>
<th>Mean T’s during ABI programming (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type IA (1, 1)</td>
<td>12 (2)</td>
<td>2.5 (2)</td>
<td>98.4 CL (2)</td>
</tr>
<tr>
<td>Type IB (0, 1)</td>
<td>14 (1)</td>
<td>3 (1)</td>
<td>135.29 CL (1)</td>
</tr>
<tr>
<td>Type IIA (0, 3)</td>
<td>14 (3)</td>
<td>0 (3)</td>
<td>99.62 CL (2)</td>
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<tr>
<td>Type IIB* (1, 1)</td>
<td>11.5 (2)</td>
<td>6 (1)</td>
<td>142.36 CL (1)</td>
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<tr>
<td>Type IIIA (1, 0)</td>
<td>8 (1)</td>
<td>5 (1)</td>
<td>92 CL (1)</td>
</tr>
<tr>
<td>Type IV (1, 0)</td>
<td>12 (1)</td>
<td>7 (1)</td>
<td>125.5 CL (1)</td>
</tr>
<tr>
<td>Type D (2, 0)</td>
<td>12 (2)</td>
<td>10.5 (2)</td>
<td>165.79 CL (2)</td>
</tr>
</tbody>
</table>

T = Threshold value for ABI programming map
* 2 additional adult subjects with IIB did not have audiometric data

TYPES A, B, C, D
Based on Angle T from a posterior view
Discussion / Conclusion
The potential for more optimum placement

- This study is the first to analyze post-operative ABI array orientation and correlate with audiometric data.
- A classification system was devised that characterizes electrode array position in the skull.
- ABI placement varies widely among patients and may explain the range of outcomes seen among similar cohorts.
- The use of imaging may potentially optimize array placement, improve auditory outcomes, and reduce side effects.
Discussion / Conclusion

ABI electrode array position can be resolved

- Limitations of our study include:
  - Inability to resolve neural structures with CT
  - Reliance on behavioral responses from young children and NF2 with comorbidities
  - Small sample size
  - Prospective studies on larger numbers of patients will determine the predictive value of ABI location on hearing outcomes and side effects.
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- Elliott D. Kozin, MD
- Mary E. Cunnane, MD
- Parth Shah, BA
3 Results
A wide variety of linear distances were observed

- Linear distances were difficult to normalize due to variable anatomy between subjects.
- A few adult and pediatric subjects had values beyond twice the standard error of the mean (dotted line).
- This subgroup was analyzed to identify potential differences in electrode distribution.

Position of Proximal ABI Electrode Array Tip For Pediatric and Adult Subjects