Feasibility of Pediatric Robotic Cochlear Implantation

A Phantom Study

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Robotic Cochlear Implantation

Planning

Robotic middle ear access

Electrode array insertion

Robotic inner ear access

Weber et al. Science Robotics, 2017
Rationale

> CI in children is established
> Atraumatic and minimal invasiveness
> Robotic CI is developing
> RCI in children is of interest
Investigation of:

1. Anatomic growth
   a) Skull thickness study
   b) Cochlear angles evaluation

2. Robotic middle/inner ear access
   a) Feasibility of planning computer assisted planning
   b) Feasibility of robotic drilling
   c) Feasibility of insertion
Anatomical changes during growth

Anatomical changes during growth
Anatomical changes during growth

Round window angle- 2yo

Cochlear angle
Material & Methods

1. Segmentation and planning trajectory
2. Assessment of cochlea parameters and middle ear measurements
3. Creation of 3D printed phantom
4. Robotic Middle Ear access
5. Robotic Inner Ear access
6. Electrode Insertion
1. Segmentation & Planning Trajectory
Segmentation and Planning Outcome
2. Assessment of cochlea parameters and middle ear measurements

<table>
<thead>
<tr>
<th>Safety Margins</th>
<th>Cochlea Parameters</th>
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<tbody>
<tr>
<td>Stapes</td>
<td>Diameter</td>
</tr>
<tr>
<td>Incus and Malleus</td>
<td>Height</td>
</tr>
<tr>
<td>External Auditory Canal</td>
<td>Width</td>
</tr>
<tr>
<td>Facial Nerve</td>
<td>CDL (900°)</td>
</tr>
<tr>
<td>Chorda Tympani</td>
<td>8.4 mm</td>
</tr>
<tr>
<td></td>
<td>3.2 mm</td>
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<td></td>
<td>7.0 mm</td>
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<td>30.7 mm</td>
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- Stapes: 1.52 mm
- Incus and Malleus: 1.66 mm
- External Auditory Canal: 2.21 mm
- Facial Nerve: 0.51 mm
- Chorda Tympani: 0.32 mm
3. Skull thickness evaluation
4. Creation of 3D printed phantom
5. Head support and fixation
4. Robotic Middle and Inner Ear Access
Results
Nerve distances from the drill bit with age (n=17)
Cochlear changes with age (n=17)

Difficult for manual insertion

- **Round Window Angle**
- **Cochlear Angle**

**Axes:**
- **Y-axis:** Angles in degrees
- **X-axis:** Age in Months
Skull Thickness evaluation (n=20)

Group 1, n=3 (8-10 m)
Group 2, n=6 (13-14 m)
Group 3, n=7 (24-25 m)
Group 4, n=4 (48-49 m)
Drilling and Insertion (n=8)

Id: 12R
Age (months): 10

Anatomy
Cochlear duct length (mm) 32.8

Otoplan
Distance to FN (mm) 0.36
Distance to ChT (mm) 0.30
In-plane angle (°) 14.2
Out-plane angle (°) 28.9

Postoperative
Contacts inserted 12/12
Accuracy at Target (mm) 0.14
Insertion depth (°) 482
Accuracy Measurements

No damage to the Facial Nerve in all 8 cases

Accuracy at FN
0.06 ± 0.04 mm

Accuracy at Target
0.15 ± 0.03 mm
Conclusion

> Facial recess: sufficient space to relevant anatomy for planning and drilling;
> Impact of cochlear angle in planning the trajectory;
> Cranial growth process didn’t affect the planning of a safe trajectory;
> To develop and validate the proposed procedure for use in children, next stage optimization of the current workflow and adaptation of the surgical material to pediatric population is necessary.
Thank you!

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