Robot-Assisted Percutaneous Cochlear Implantation

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Overview of Cochlear Implantation

- Cochlear Implants restore hearing in cases of severe hearing loss
- Direct stimulation of the auditory nerve bypassing outer and middle ear structures
Goal: Minimally Invasive Access

- Surgery time decreased by up to 71%
- Bone removal decreased by 99.5%
- Make Cochlear Implantation “LASIK for the ear”
Percutaneous Cochlear Implantation

- Place bone-implanted fiducial markers

- CT scan

- Identify anatomy and plan drill path

- Manufacture customized Microstereotactic frame

- Mount frame onto fiducial markers

- Currently: Clinical validation
Percutaneous Cochlear Implantation

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(Video)
2x speed
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(Video) 8x speed
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Great – We Can Get There, But Did We Forget About Inserting the Electrode?
More Motivation for a Robotic Solution

- Implant has to be placed in the right chamber of the cochlea
- Inner ear membranes can easily be damaged
- Reliability of robotic devices for optimal electrode placement
- More patient safety with force sensing feedback

Pictures from Dr. Gary Wright, UTSW
Robotic Insertion Tool

- Tool dimensions: 200mm x 50mm x 40mm
- Tool weight: 195g
- Designed for implementation in PCI
- Integrated Force Sensor
Insertion Mechanism

- Tube (1) to guide array during insertion and protect patient’s anatomy
- One mechanism to deploy electrode (4, 5)
- Second mechanism to generate relative stylet movements
Insertion Mechanism

- Modified surgical forceps (1) to grip electrode array
- Set screw on back (5) to open/close mechanism
• Housing with flexible structure (2)
• Semiconductor strain gauges (1) are attached to this structure measure deflection
Experiments

- Test insertions into 3D cochlea model to check failure detection
- Measurement range: 60mN
- Measurement accuracy: 3mN
A Manual Insertion Tool Alternative
Cadaver Study

Pushing this knob inserts the electrode into the cochlea.
Can We Improve This?
Tool Platform
Adjustable Legs
Prepositioning Frame
Temporal Bone
Design Using Clinical Trajectories
Method of Attaching Robot to Skull

Guide for anchoring screw

Robot attachment sphere/fiducial marker

(A)

(B)
Actuators and Leg Mechanism

- Screw
- Power cable
- Motor housing

[Image of a mechanical assembly with labels for screw, power cable, and motor housing]
TABLE I

TARGET REGISTRATION ERROR (TRE) AND TARGET LOCALIZATION ERROR (TLE) AT THE COCHLEAR TARGET FOR THE FREE-SPACE ACCURACY EXPERIMENT

<table>
<thead>
<tr>
<th></th>
<th>Mean [mm]</th>
<th>Standard Deviation [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured TRE</td>
<td>0.21</td>
<td>0.07</td>
</tr>
<tr>
<td>TRE due to fiducials</td>
<td>0.02</td>
<td>0.0004</td>
</tr>
<tr>
<td>TLE</td>
<td>0.04</td>
<td>—</td>
</tr>
<tr>
<td>TRE due to AIM Frame</td>
<td>0.20</td>
<td>0.07</td>
</tr>
</tbody>
</table>
(Video)
Accuracy:  Phantom (n=30): $0.20 \pm 0.07\text{mm}$  Cadaver (n=1): 0.38mm