Robotic Bone Drilling Assessment

Seminar Review:
Study Design and Phantom Design

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**Mastoidectomy:** Surgery that involves the removal of a portion of the mastoid bone

Images from *First Clinical Evaluation of the Navigated Controlled Drill at the Lateral Skull Base* (Hofer et al.)
Project Overview

Design and conduct experiments to evaluate the performance of the Galen System in the bone drilling procedure.

Design studies → Prepare phantoms → Conduct studies → Analyze results
The Navigation-Controlled Drill in temporal bone surgery: A feasibility study
Gero Strauss, MD; Kirill Koulechov, PhD; Mathias Hofer, MD; Elmar Dittrich; Ronny Grunert; Hendrick Moeckel; Eva Muller; Werner Korb, PhD; Christos Trantakis, MD; Thomas Schulz, MD; Juergen Meixensberger, MD, PhD; Andreas Dietz, MD, PhD; Tim Lueth, PhD

ElePhant - An anatomical Electronic Phantom as simulation-system for otologic surgery

The influence of various registration procedures upon surgical accuracy during navigated controlled petrous bone surgery
Hofer M, Dittrich E, Baumberger C, Strauss M, Dietz A, Lüth T, Strauss G.
Device Evaluated

Navigation-controlled (NC) drill

- Preoperative determination of workspace in CT record
- Drill switches off automatically once borders of workspace are reached

Image from *The influence of various registration procedures upon surgical accuracy during navigated controlled petrous bone surgery* (Hofer et al.)
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ElePhant (Electronic Phantom)

- Based on CT data record
- 3D printed with 3D printer Z\textsuperscript{TM}510
- Material: plaster infiltrated with polyurethane and acetone

Image from \textit{ElePhant - An anatomical Electronic Phantom as simulation-system for otologic surgery} (Grunert et al.)
ElePhant (Electronic Phantom)

- Metal cable: sigmoid sinus, horizontal semicircular canal
  - Alloy (lead, bismuth, tin)
  - Tip of structures connected with analogue output (0.5V) and input channel of data acquisition card
  - Drill connected with ground of DAQ-card
- Optical fiber: facial nerve
  - LED provides light through fiber optic a photodiode at the other end detects the light intensity
  - Photodiode is connected with an input channel of the DAQ-card
## Test Subjects

<table>
<thead>
<tr>
<th>Group</th>
<th>Number</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgeons inexperienced in otologic surgery</td>
<td>5</td>
<td>With Navigated Control</td>
</tr>
<tr>
<td>Surgeons experienced in otologic surgery</td>
<td>5</td>
<td>Without Navigated Control (could view navigation information)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>With Navigated Control</td>
</tr>
</tbody>
</table>
## Evaluation Criteria

<table>
<thead>
<tr>
<th>Evaluation Criteria</th>
<th>Procedure for Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>Record time</td>
</tr>
<tr>
<td>Deviation from planned volume</td>
<td>3D reconstruction using CT data, compare with predetermined workspace</td>
</tr>
<tr>
<td>Number of injuries to high-risk structures</td>
<td>Record counts</td>
</tr>
<tr>
<td>Extent of injury to facial nerve</td>
<td>Light intensity of fiber-optic detector</td>
</tr>
<tr>
<td>Minimal distance to high-risk structures</td>
<td>Evaluation of CT images</td>
</tr>
</tbody>
</table>
## Summary of Results

<table>
<thead>
<tr>
<th>Group</th>
<th>Time</th>
<th>Speed of resection</th>
<th>Deviation to planned volume</th>
<th>Number of injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experienced w/o NC</td>
<td>715 s</td>
<td>9.62 mm³/s</td>
<td>-39.9%</td>
<td>1 facial nerve injury</td>
</tr>
<tr>
<td>Experienced + NC</td>
<td>817 s</td>
<td>10.08 mm³/s</td>
<td>-34%</td>
<td>0</td>
</tr>
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Phantom

Color-coded model

- Model based on CT data record
- Printed with Spectrum Z510
- Color-coded damage identification of facial nerve

Image from The influence of various registration procedures upon surgical accuracy during navigated controlled petrous bone surgery (Hofer et al.)
Phantom

Color-coding of facial nerve
Phantom

Target workspace comes in direct contact with the border of the nerve
Test subjects

- 10 medical students without surgical experience
- Instructions
  - Drill out cavity until drill comes to a stop
  - Subjects not informed of location and significance of facial nerve
  - Subjects not informed of significance of color-coding
Evaluation Criteria

- Record deviation of drill from facial nerve
  - Evaluated by 5 jurors
  - Models examined with three- to seven-fold magnification under microscope

<table>
<thead>
<tr>
<th>Outside facial nerve</th>
<th>Within facial nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;1.5 mm</td>
<td>Yellow 0 to -0.5 mm</td>
</tr>
<tr>
<td>1.5 to 1 mm</td>
<td>Blue -0.5 to -1.5 mm</td>
</tr>
<tr>
<td>1 to 0.5 mm</td>
<td>Yellow 0 to -0.5 mm</td>
</tr>
<tr>
<td>0.5 to 0 mm</td>
<td>Blue -0.5 to -1.5 mm</td>
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