Force of cochlear implant electrode insertion performed by a robotic insertion tool: comparison of traditional versus Advance Off-Stylet Techniques

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Group 15: Force Sensing Drill

Background Presentation

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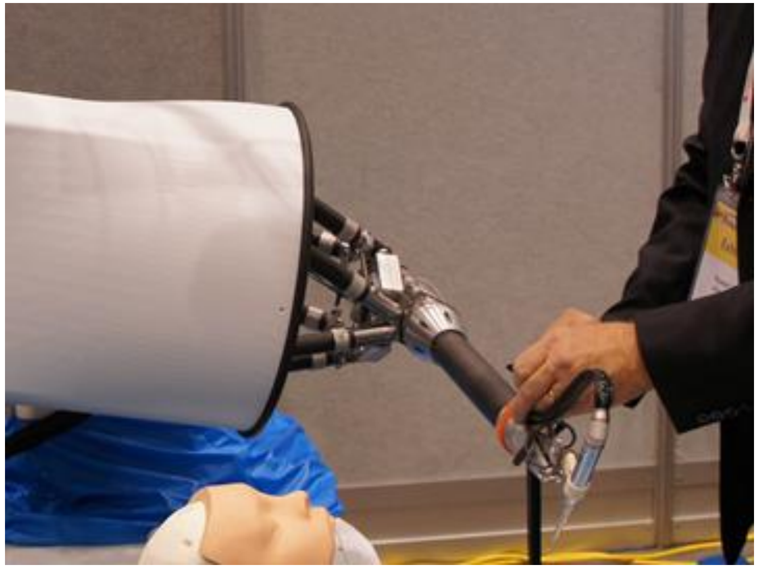
GALEN ROBOTICS

Overview

- **Galen Robot:** Hand-over-hand cooperatively controlled surgical robotic system used for head and neck microsurgery.
- For some applications it is useful to measure and control the **tool-to-tissue** forces as well.
- **Goal:** To sense these forces and integrate this data for better control of the Galen robot
- **Applications:**
  - Visualization of forces
  - Safety limits
  - Surgical skill evaluation
  - Unbiased comparison of surgical techniques



Paper Selected

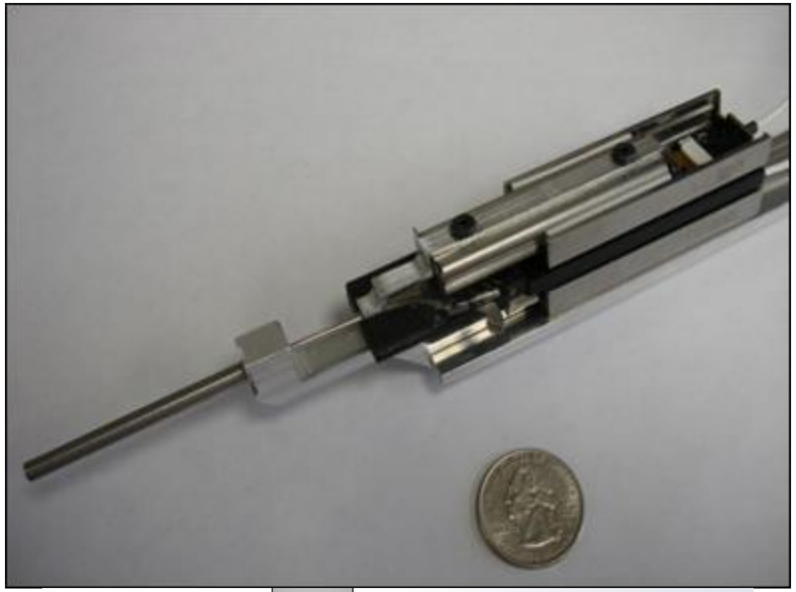
- Force of Cochlear Implant Electrode Insertion Performed by a Robotic Insertion Tool: comparison of Tradition versus Advanced Off-Stylet Technique

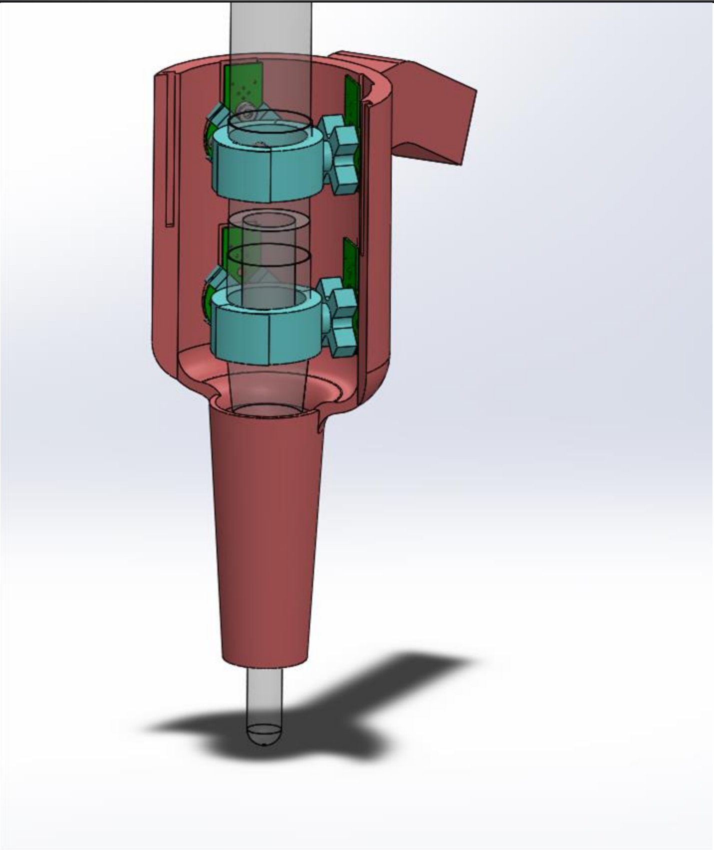
- Researchers from Vanderbilt University Medical Center and Department of Mechanical Engineering

Citation: Schurzig, Daniel et al. “Force of Cochlear Implant Electrode Insertion Performed by a Robotic Insertion Tool: Comparison of Traditional versus Advance Off-Stylet Techniques.” Otology & neurotology : official publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology 31.8 (2010): 1207–1210. PMC. Web. 26 Apr. 2018.

Paper Selected

- Currently, we use a force sensing sleeve to measure drill tip forces
  - Sleeve can be modified for different applications
- Paper shows it is beneficial for a cochlear insertion tool to have force sensing
- Also shows how force sensing provides an unbiased evaluation of surgical techniques
- Use Galen to provide an automated process for cochlear implant surgery





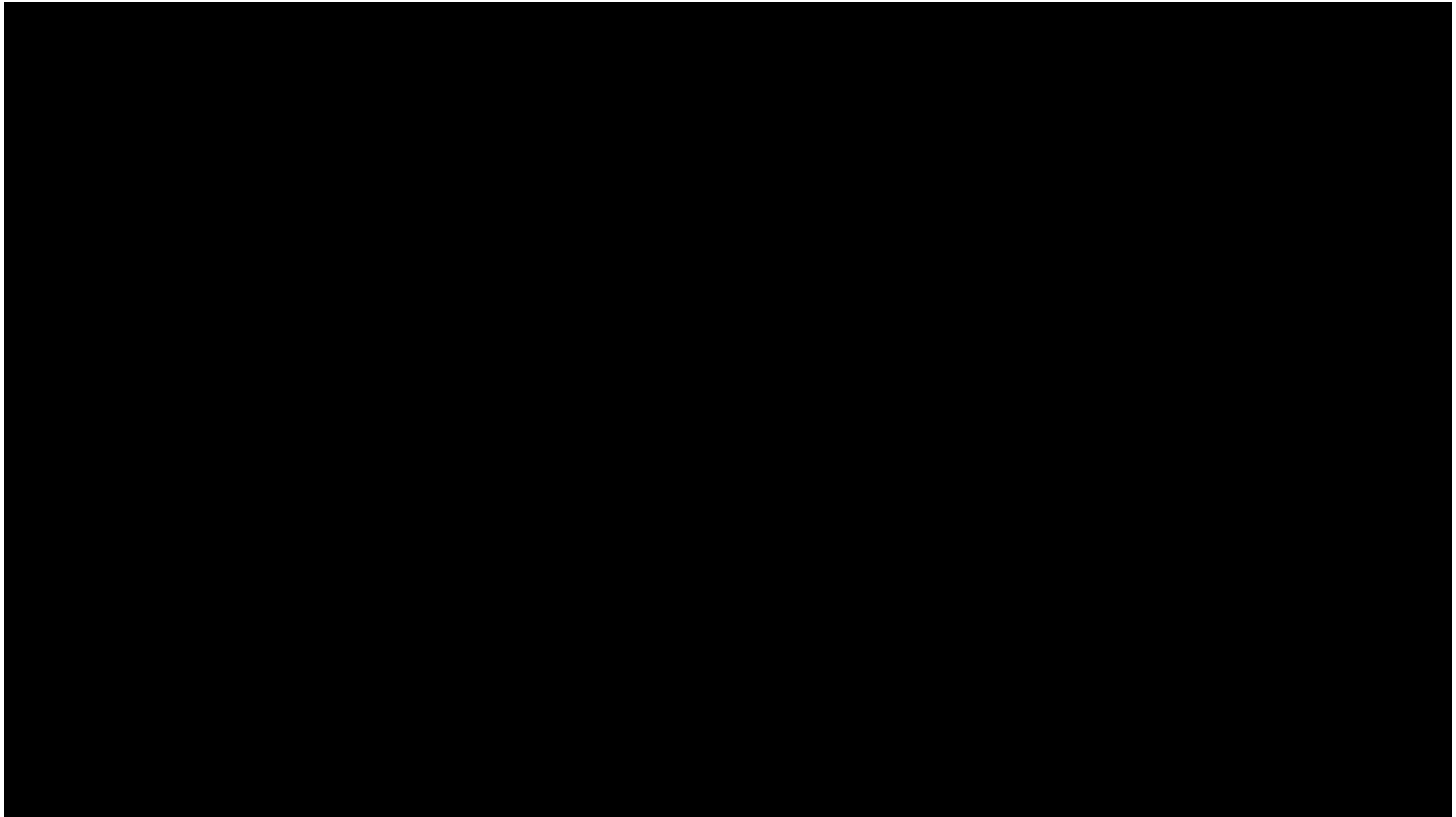
Problem Summary

- Due to the spiral structure of the cochlea, insertion of an electrode array into the cochlea causes intracochlear trauma which leads to hearing loss
- There are two different electrode array insertion methods: Advance Off-Stylet (AOS) method and the traditional method.
- **Goal:** Researchers wanted to quantify how AOS and traditional insertion methods lead affect the insertion force.
- **Challenges:**
    - High degree of variability between trials performed by human operators which leads to difficulties in quantifying the difference between the two insertion methods.
    - Rupture force of basilar membrane is between 0.029 to 0.039 N

Key Result

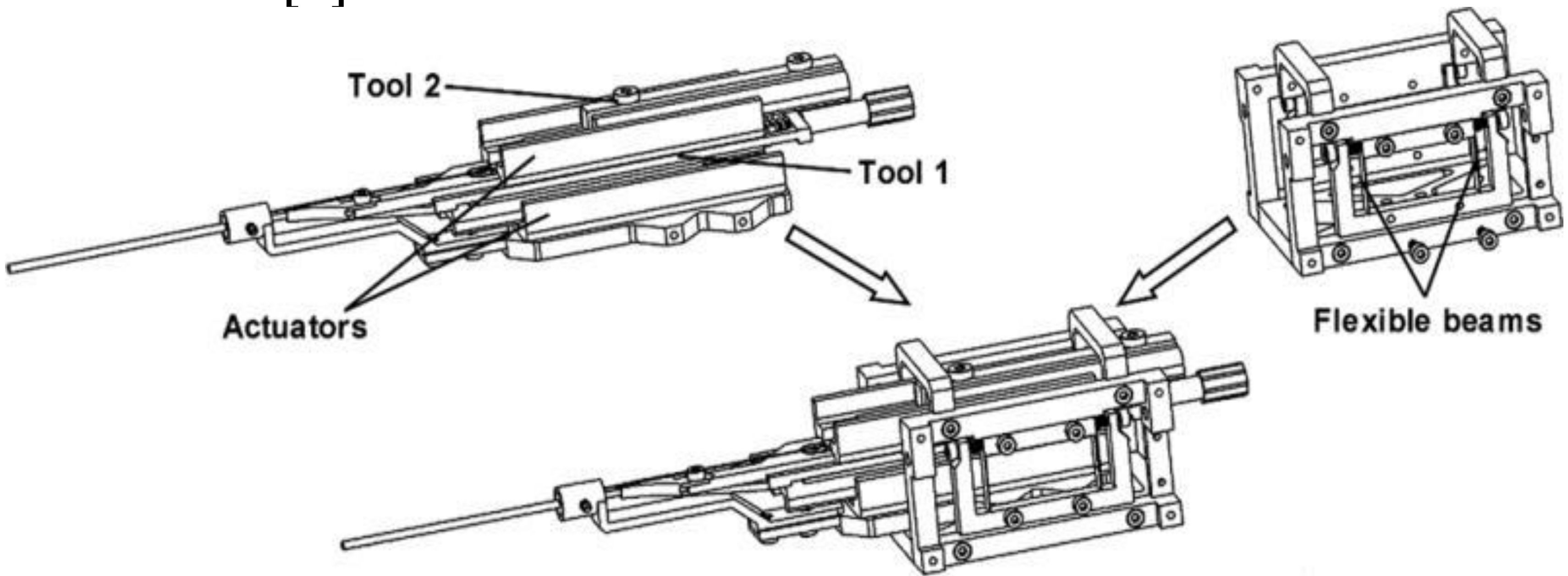
- The paper proved that cochlear implant electrode insertion via AOS is associated with lower average and maximum insertion forces compared to traditional insertion
- Three central contributions
    - Empirical support for the use of the AOS method over the traditional insertion method
    - Evidence that automated insertion can minimize forces and decrease variability over manual insertion
    - Proof that force sensing is beneficial in certain surgical procedures

Background: Two methods of Insertion



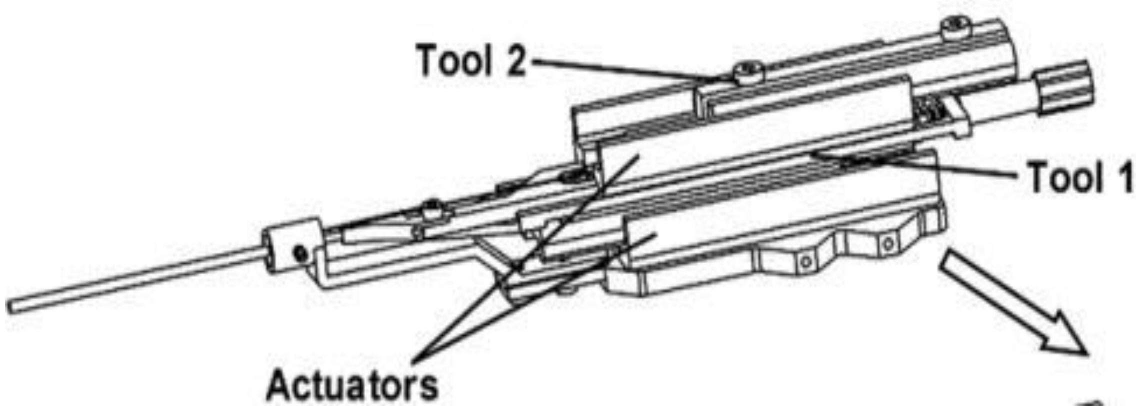
Technical Approach: Insertion tool

- **Challenge:** High degree of variability between trials performed by human operators
- Automated insertion technique was used
  - Maximizes repeatability and minimizes variability between trials
  - Cochlear implant electrode array insertion with robot devices is clinically feasible [2]



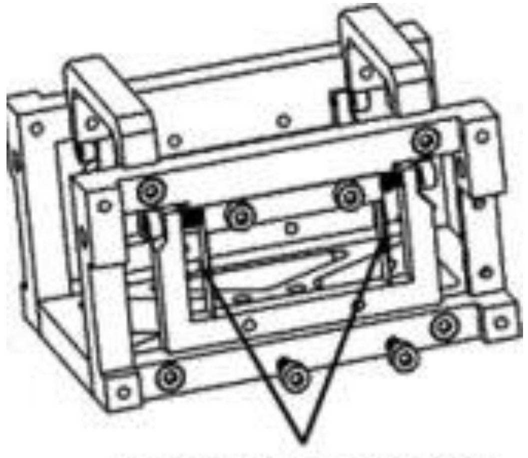
Insertion tool (cont)

- Two linear actuators (Model SL2060; SmarAct GmbH; Oldenburg, Germany) in which tools that grasp the electrodes are attached.
- One actuator and tool assembly grasp the electrode array through a modified surgical alligator forceps.
- The other hold the stylet through a stainless steel hooked wire
- The two-actuator system allow for both the AOS and traditional insertion methods.



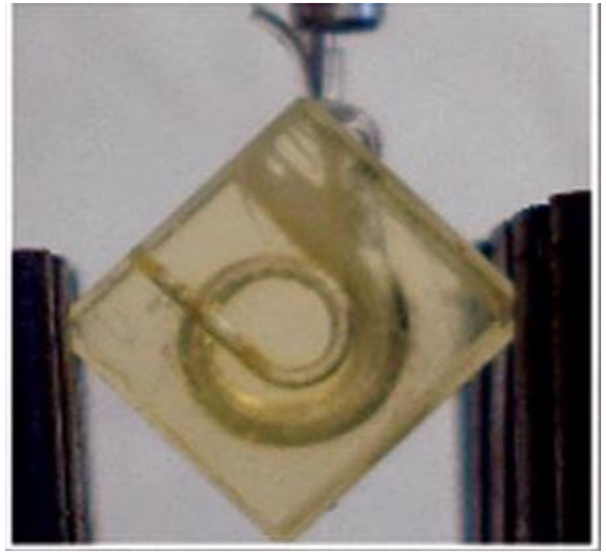
Force Sensing Unit

- A force sensing unit is coupled with the insertion tool
- 4 flexible aluminum beams to transform the force along the axis of insertion into deformation
  - Measured by 4 semiconductor strain gauges (Model SS-060-033-1000PB; Micron Instruments, Inc.; Simi Valley, CA)
- The electrical readout of strain guages is calibrated to quantify force of insertion
- 0.001 N force resolution



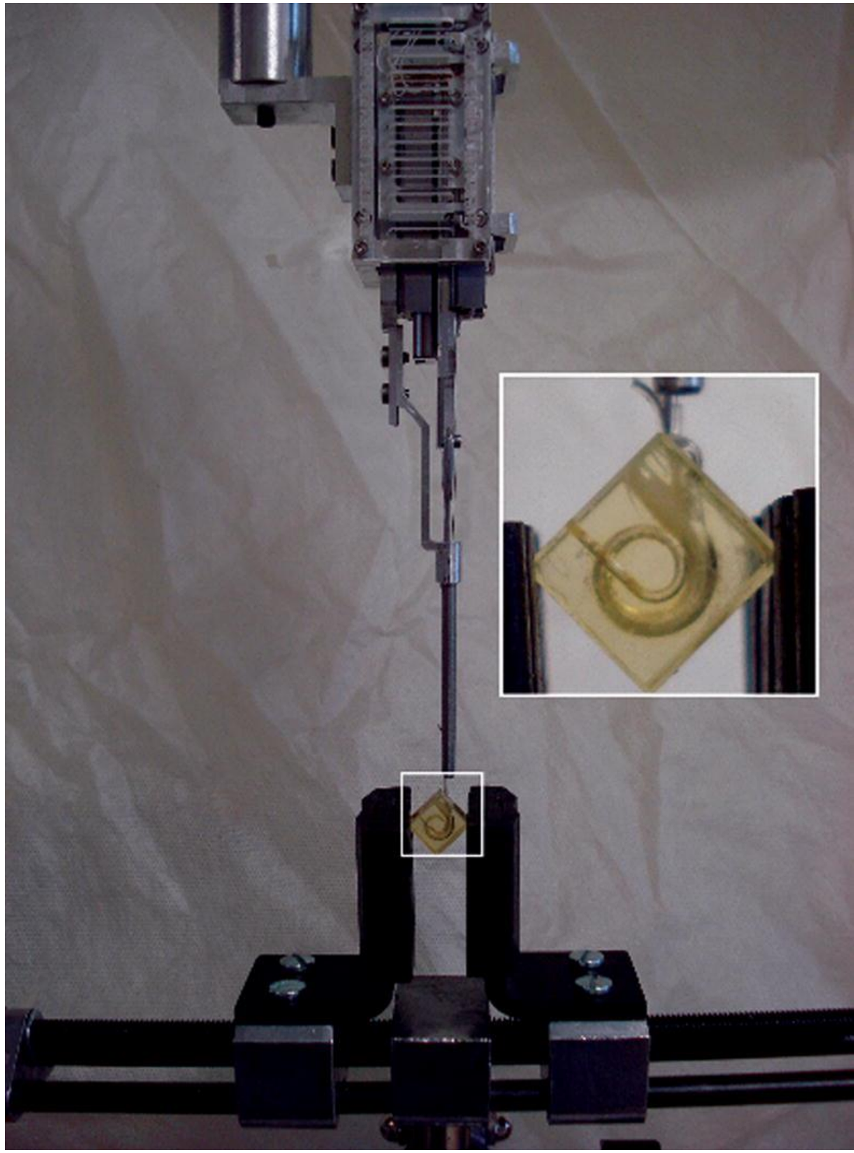
Phantom

- 3D model of the scala tympani component of the cochlea (Med-el Corporation; Innsbruck, Austria)
    - Anatomically correct
- Filled with soapy water to simulate intracochlear conditions



Experiment

- The insertion tool was loaded with a cochlear implant electrode
  - Positioned above the model
- Five insertions were done for both the AOS and the traditional insertion methods.
- During insertion, the force in the insertion direction was measured with respect to insertion depth in mm
  - Force from the contact between the electrode array and the scala tympani model



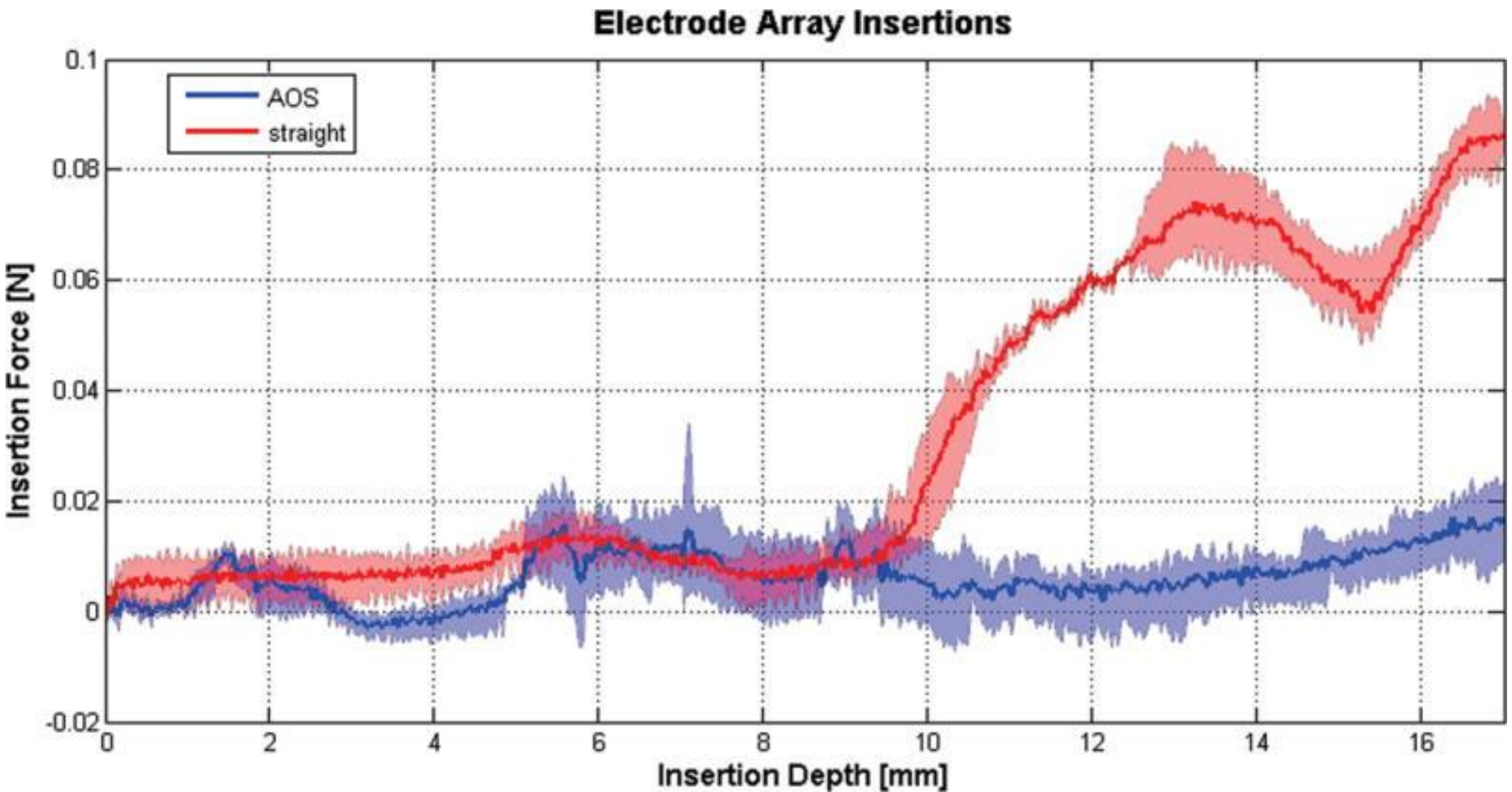
Results

- Force profiles for both insertion methods were analyzed by calculating average and peak insertions forces
  - Compared using confidence intervals

- In all cases, the electrode array was successfully inserted 17 mm deep into the scala tympani model.

Insertion Forces Plot

- Graph of insertion forces (N) with respect to insertion depth (mm)
- Solid lines represent the average forces for the two methods
- Shaded region show variability of forces

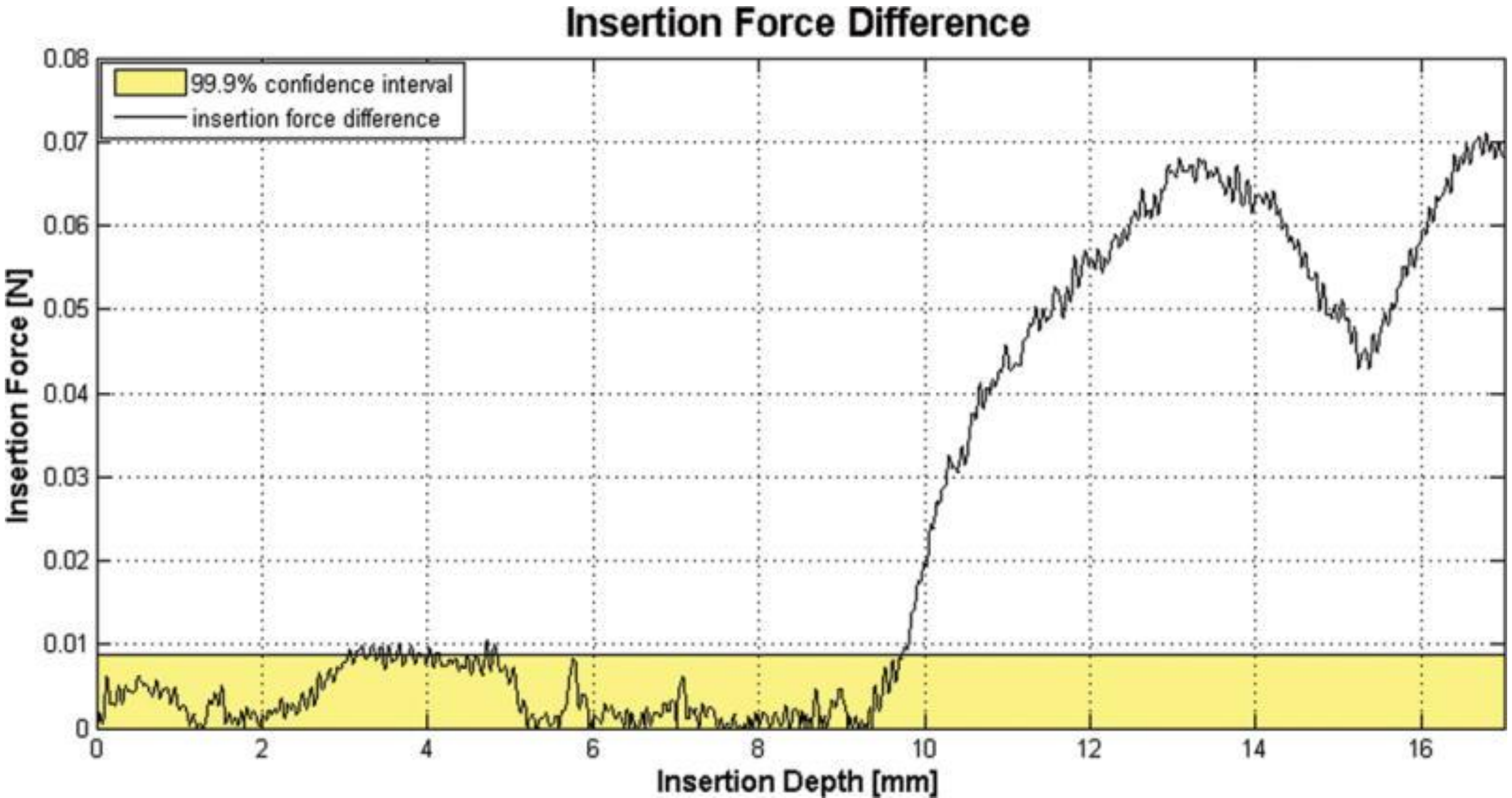


Results (cont)

- For the first 7 mm of insertion the average force for recorded:
  - 0.004 ± 0.006 N for the AOS
  - .008 ± .004 N for the traditional method
- Inside the spiral of the cochlea (7 mm to 17 mm insertion depth), the average force for recorded:
  - 0.008 ± 0.006 N for the AOS method
  - .046 ± .027 N for the traditional method
- Force maxima were 0.034 N for the AOS method and 0.093 N for the traditional insertion.

Insertion Force Difference

- Since both methods are the same for the first 7 mm of insertion, 99.9% confidence interval for the absolute value difference between the two techniques was calculated
- The graph shows that the difference between the two methods beyond 9.74 mm insertion depth is highly significant



Assessment

- Due to the lower force profile, it is proven that AOS should be the preferred method over the traditional method in electrode array insertion
- Provided evidence on how automated cochlear implant electrode insertion can minimize forces and decrease variability over manual insertion
- Proved that force sensing is beneficial in certain surgical procedures
    - AOS forces were below the rupture force of the basilar membrane while the traditional insertion force exceeded it [3]

Assessment

Pros

- Proved their hypothesis that AOS is the preferred method of electrode insertion
- Results were well quantified
  - Easy to see why their data led to their conclusion
- Did not explain too much
  - Provided most of the necessary background to understand the paper

Cons

- Grammar and typos
  - Basilar membrane not “member”
- Figure about the tool was slightly confusing
  - Could have elaborate more on how the insertion tool moves
- Did not include some necessary background
  - Stylet?
  - Electrode array?

Conclusion

- Proved that automated surgical techniques can lead to force minimization and decreased variability
  - Can eventually use the Galen for similar automation
- The force sensing integration with the cochlear implant electrode insertion tool proved that force sensing can be quite useful in surgical procedures
  - Particularly head and neck surgery, which the Galen focuses on, where there are anatomical structures that can easily be damaged
- Next Steps:
  - Provide force sensing for the drill
  - Adapt the force sensing sleeve for other applications

References

- Insertion tool picture: https://www.vanderbilt.edu/wp-content/uploads/sites/76/assets/index_files/image012.jpg

1. Schurzig, Daniel et al. "Force of Cochlear Implant Electrode Insertion Performed by a Robotic Insertion Tool: Comparison of Traditional versus Advance Off-Stylet Techniques." Otology & neurotology : official publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology 31.8 (2010): 1207–1210. PMC. Web. 26 Apr. 2018.
2. Hussong A, Rau TS, Majdani O, et al. An automated insertion tool for cochlear implants: another step towards atraumatic cochlear implant surgery. Int Journal of Comp Assist Rad And Surg. 2009;5(2):163–171.
3. Todd CA, Naghdy F, Svehla MJ. Force Application During Cochlear Implant Insertion: An Analysis for Improvement of Surgeon Technique. IEEE Transactions on Mechatronics. 2007;54:1247–1255.