AMERICAN OTOLOGICAL SOCIETY

Renee M. Banakis Hartl, MD, AuD

Assistant Professor, Otology and Neurotology

University of Michigan

"Cochlear Implant Insertion Trauma: Intracochlear Pressure Measurements and Anatomic Changes on Cadaveric Specimen"

FELLOWSHIP GRANT 2020

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Banakis Hartl RM, Greene NT. *Measurement and Mitigation of Intracochlear Pressure Transients During Cochlear Implant Electrode Insertion*. *Otol Neurotol*. 2022 Feb 1;43(2):174-182. doi: 10.1097/MAO.0000000000003401. PMID: 34753876.

Boscoe EF, **Banakis Hartl RM**, Gubbels SP, Greene NT. *Effects of Varying Laser Parameters During Laser Stapedotomy on Intracochlear Pressures*. *Otolaryngol Head Neck Surg*. 2023 Mar;168(3):462-468. doi: 10.1177/01945998221104658. Epub 2023 Jan 19. PMID: 35671134; PMCID: PMC10097413.

Chabuz CA, **Banakis Hartl RM**, Rodriguez K, Gonzalez J, Cass SP, Greene NT. *Characterization of Tip Fold-Over Using Fluoroscopy and Intracochlear Pressure in Cadaver Specimens*. *Laryngoscope*. 2024 Dec 24. doi: 10.1002/lary.31977. Epub ahead of print. PMID: 39719824.

RESEARCH SUMMARY:

With increasing focus on hearing preservation during cochlear implant surgery, atraumatic electrode insertion is of the utmost importance. It has been established previously that large pressure spikes can be generated in the cochlea during the electrode insertion. Estimates of equivalent ear canal pressure suggest these peak pressures may be of sufficient intensity to cause trauma similar to that of an acoustic blast injury and may be one source for postoperative loss of residual hearing. Here, we investigated insertion trauma as a mechanism for postoperative loss of residual hearing. The overall objective of this research was to characterize changes in the intracochlear environment resulting from implant insertion in order to better understand the mechanism of loss of residual hearing. To accomplish this objective, we characterized changes in intracochlear pressures during cochlear implant insertions in a human cadaveric model, investigating the influence of multiple factors, including electrode geometry, the presence of a sheath or stylet, insertion speed, and post-insertional electrode manipulations. Simultaneous fluoroscopy measurements were made to correlate the location of the electrode with measured pressure changes.

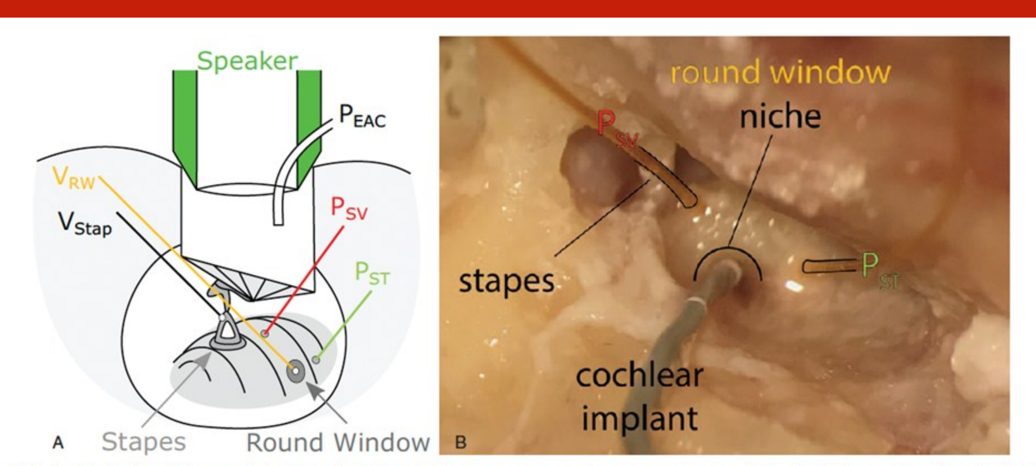

FIG. 1. Illustration of the surgical approach to the middle ear, pressure probe placement, acoustical stimulation, and cochlear implant insertion approach. Pressure probes were inserted into the scala vestibuli (P_{SV}) and scala tympani (P_{ST}) through small cochleostomies adjacent to the stapes footplate and round window, respectively. Cochleostomies were sealed with alginate dental impression material. Cochlear implants were inserted, under water, through the round window membrane.

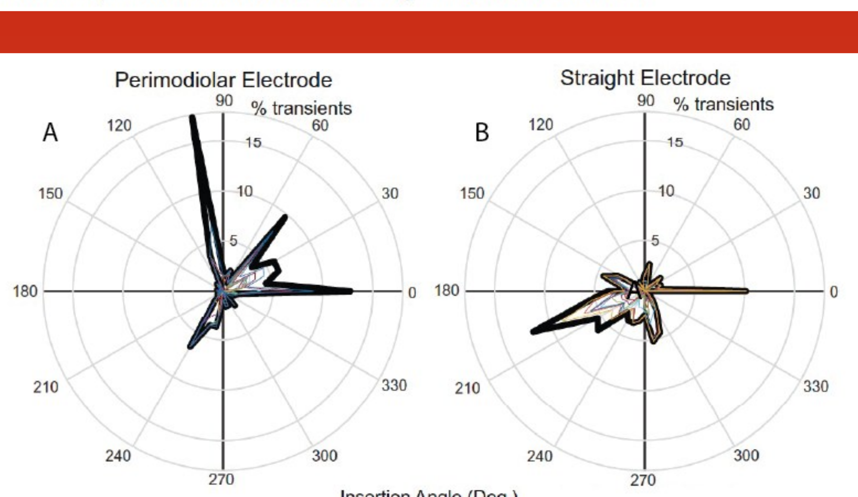

FIG. 5. The patterns of transient generation were quantified by calculating the percentage of transients occurring at each insertion angle (in 10 degrees increments), for both the perimodiolar (*A*) and straight (*B*) electrodes. The overall percentage of transients occurring at each angle is illustrated with a heavy black line, the percentage of transients occurring in each insertion, at each angle, are shown with colored lines, for both electrodes. Note, the percentages are cumulative, thus the difference between adjacent colored lines indicates the % within each insertion.

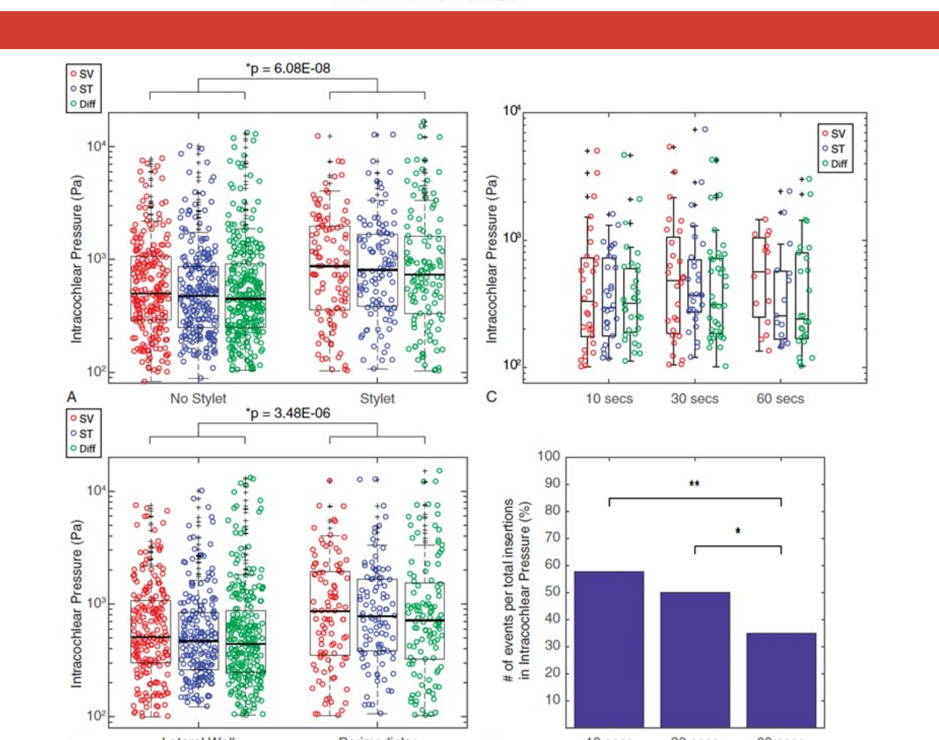

FIG. 3. Summary of peak pressure levels observed in all specimens during all electrode insertions by electrode characteristics and analyses of insertion duration. Unfiltered peak intracochlear pressure measurements are shown by electrode characteristics (straight or precurved in Panel A, styleted or non-styleted in Panel B). Panel C shows a summary of peak pressure levels observed in all specimens during all electrode insertions by insertion duration. Box plots represent the median ±25% of the range of pressures observed, whiskers show the full range of the estimated distribution, and +'s mark outliers. Panel D shows the percent of insertions with a significant pressure event by insertion duration. Chi-squared analysis with Bonferroni correction revealed a significant pattern of fewer exposures with longer insertions. Significant differences between groups are indicated with asterisks (* $p < 0.05$, ** $p < 0.01$).

OUTCOMES:

- Implant insertion and post-insertion manipulations produced high-intensity pressure transients with all electrodes tested, with some exceeding 170 dB peak SPL.
- Average peak pressures were significantly lower for lateral wall, non-stylet electrodes ($p << 0.001$). There was no correlation between electrode length, diameter, or volume and transient intracochlear pressure amplitudes.
- The likelihood of generating transients was lowest with the slowest insertions ($p << 0.001$) of at least 60 seconds.
- Post-insertional manipulations, including removal, can generate significantly higher peak pressure than insertions ($p < 0.0003$).
- Pressure transients appear to be generated when the leading electrode directly contacts intracochlear structures (particularly the medial or lateral walls).
- There appear to be 3 morphologically distinct patterns of electrode tip fold-over: anterior-posterior, medial-lateral, and s-shaped. Elevated pressure transients were noted before and during the tip fold-over event related to electrode twisting.

FURTHER FUNDING HAS ENABLED US TO:

- The collaborative team (led by Dr. Nathaniel Greene at the University of Colorado) has submitted for NIH funding to continue investigation into the mechanisms underlying and implications of observed intracochlear pressure changes, including development of an animal model and an outcomes-based clinical protocol.
- The primary investigator has expanded research to focus on psychoacoustical outcomes for cochlear implant recipients, particularly with regards to single-sided deafness and binaural hearing tasks. A recently renovated anechoic chamber at the University of Michigan has facilitated the development of a novel combined speech-in-noise and localization task during which subjects head movement is tracked with the goal of evaluating the effects of cochlear implant use on ecologically valid speech localization performance and examine the resulting behavioral adaptations . This effort is also funded by the American Otological Society.

LAY SUMMARY:

While there does not appear to be a particular cochlear implant electrode geometry or size that correlates with higher peak intracochlear pressures, the insertion conditions that are associated with fewer pressure transients include the adoption of non-styleted electrodes and slow insertion speeds. Data presented here also demonstrate that higher changes in peak intracochlear pressures can be generated by post-insertional manipulations, including manipulation and withdrawal of electrodes. Avoiding such manipulations may further mitigate cochlear trauma generated during surgery.