Detect, Predict, Prevent:
Using Statistical Modeling to Forecast and Monitor Ototoxic Hearing Loss

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Objectives

- This study aims to address the limitations of current methods for detecting and predicting ototoxic hearing loss resulting from cancer treatment by introducing an innovative model-driven approach to the audiogram.
- Specifically, the goal is to develop a flexible algorithm-based tool that generates patient-specific ranges of acceptable hearing variation for rapid identification of potential hearing damage and forecasting of future hearing loss.
- For a more complete background on previous efforts to model or predict ototoxic hearing loss, please see our review (DeBacker et al., 2023).

Methods

- Both the monitoring and forecasting models use a Gaussian Process. Foundational details of the modeling can be found in McMillan et al., 2024.
- The models were trained on 105 cisplatin patients from the VA Portland Health Care System
- The model includes patient **age**, measured **baseline hearing**, test **limits of the audiometer** used, expected **radiation to the cochlea**, and expected **cisplatin dose and schedule**
- A validation sample of 85 chemotherapy patients is currently being tested

References

McMillan, G.P., DeBacker, J.R., Hungerford, M., & Konrad-Martin, D. (2024). Serial Monitoring of the Audiogram in Hearing Conservation using Gaussian Processes. *Frontiers in Audiology & Otology.* https://doi.org/10.3389/fauot.2024.1389116

DeBacker, J.R., McMillan, G.P., Martchenke, N., Lacey, C.M., Stuehm, H.R., Hungerford, M.E., & Konrad-Martin, D. (2023). Ototoxicity prognostic models in adult and pediatric cancer patients: a rapid review. *Journal of Cancer Survivorship.* https://doi.org/10.1007/s11764-022-01315-8

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WCA World Congress of Audiology

Monitoring

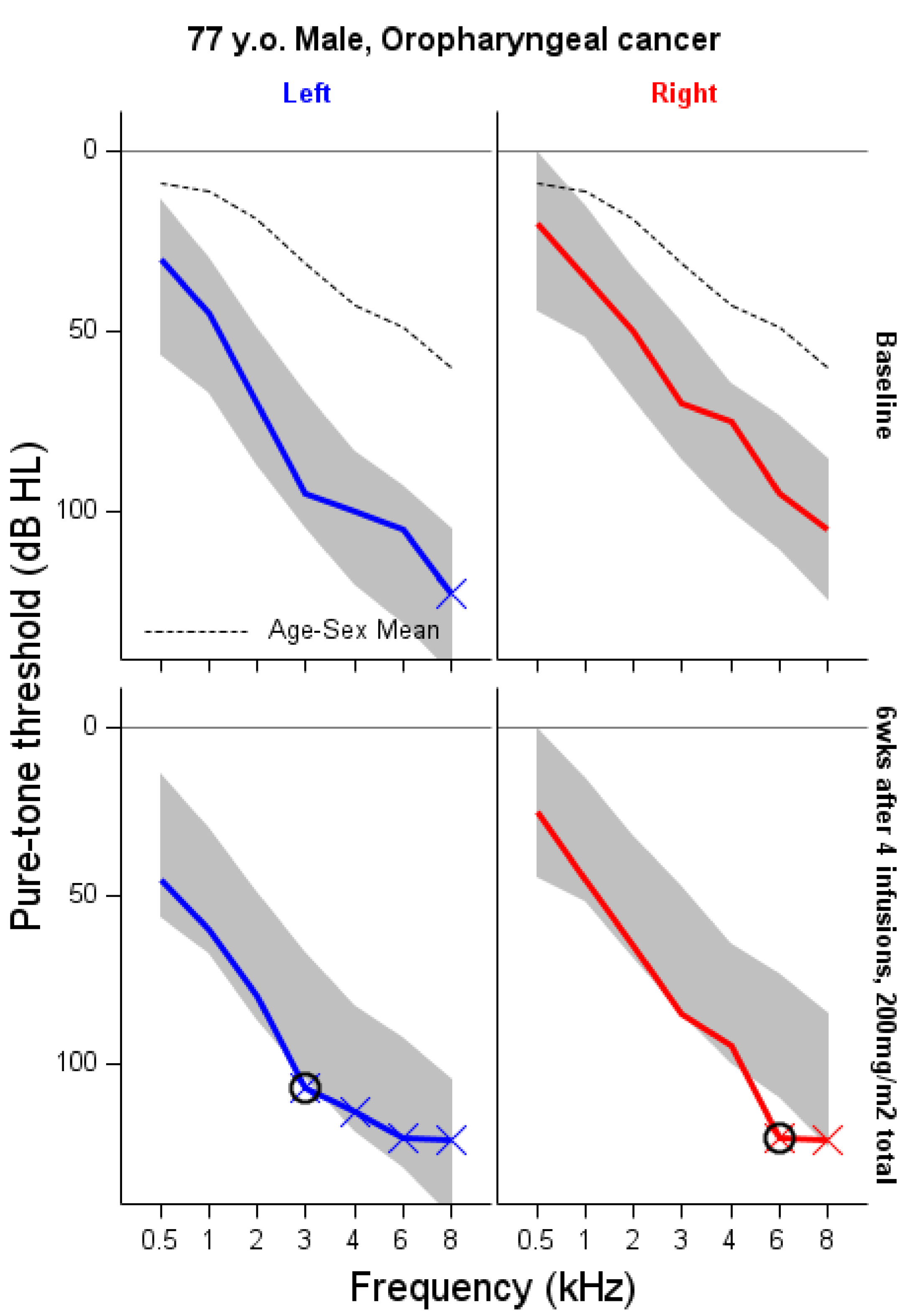

Figure 1. Current paradigms for monitoring patient hearing loss during treatment rely on collecting a baseline audiogram and then using specific criteria to identify significant changes. As depicted here, we use a deep learning model to identify expected amounts of hearing variation and then flag any thresholds that fall outside of that window at a follow-up visit. In this figure, measured thresholds are indicated by the solid lines with the baseline in the first row and the follow up in the second row. Frequency-specific margins of test variability are depicted in gray. Non-responses are indicated by an X and circles indicate changes that fall outside of the expected margin.

Forecasting

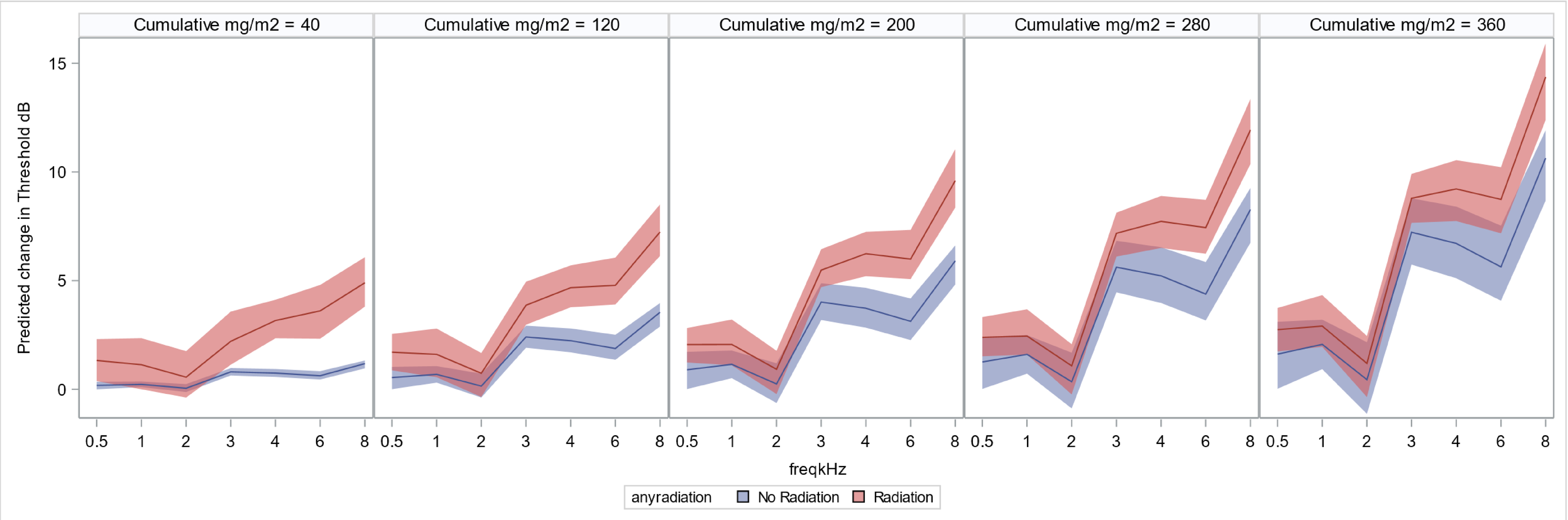

Figure 2. Each panel shows the expected change in pure tone threshold for an average patient at increasing (left to right) cumulative doses of cisplatin. The x-axis shows the audiometric test frequency, and the y-axis is the expected change in pure tone threshold. Expectations for cisplatin exposure alone are shown in blue, while cisplatin with concurrent radiation to the cochlea is depicted in red. As indicated here, radiation and increasing cumulative cisplatin exposure above 40 mg/m2 significantly increase expected hearing loss.

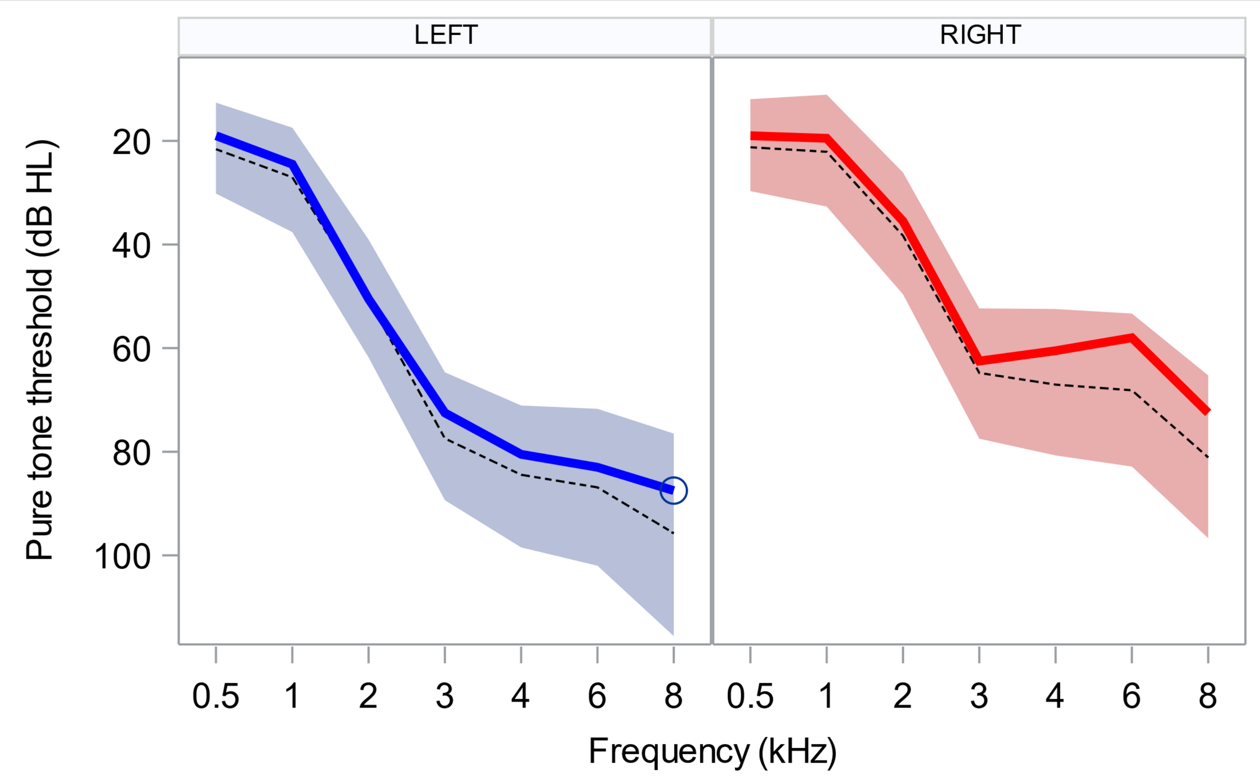

Figure 3. This figure depicts the ototoxicity forecast for a 70 year old male with oropharyngeal cancer and concurrent radiation after 240 mg/m2 cumulative exposure. The solid blue/red lines are the baseline audiogram measured prior to chemoradiation. The dashed line and shaded area is the prediction region for this subject after the prescribed chemoradiation. Circle indicates no response threshold at baseline. The model-based approach forecasts a 60% chance of an ASHA shift at follow-up and a 2% chance of a CTCAE Grade 2 outcome.

Discussion

This study demonstrates the feasibility and effectiveness of utilizing AI-driven algorithms for the detection and prediction of ototoxic hearing loss in cancer treatment and other serial monitoring contexts. The development of a flexible tool capable of generating patient-specific ranges of acceptable hearing variation marks a significant advancement in auditory monitoring. By leveraging AI technology, healthcare providers can proactively manage and prevent hearing impairments, thereby improving patient outcomes and quality of life.

Future Directions of this work will expand the model to include extended high frequencies above 8 kHz and model additional auditory outcomes including speech in noise testing and tympanometry. Additionally, the serial monitoring modeling has implications outside the realm of audiology and so our group hopes to expand this work to other non-auditory domains including glucose and blood pressure monitoring.