Objective Impedance Features of Cochlear Implants for the Evaluation of Hearing Preservation

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Introduction

Cochlear implantation is an effective treatment for severe to profound sensorineural hearing disorders. As the indications for cochlear implants (CIs) have broadened in recent years, a growing number of patients demonstrate natural residual hearing (RH). Studies have shown that such patients benefit from improved speech perception when their RH is preserved despite CI surgery. Today, however, about half of the CI patients lose their RH post-surgery. Electrical impedance measurements recorded by the CI contain information about the status of the cochlea, are widely available, can be performed within seconds and can potentially be used to monitor RH [1] [2]. This work explores the potential of impedance data as an objective biomarker for postoperative preservation of RH (HP).

Materials and Methods

Impedance and audiometric data of a cohort of 50 subjects were available for this work. The pure-tone-audiometric data was used as ground truth for the evaluations with impedance data. Through descriptive statistics and K-means clustering, we analyzed the data for significant differences in HP. Longitudinal impedance data with subcomponents based on anatomical grouped impedances were incorporated into a Linear Mixed Effects model to evaluate RH. Additionally, an impedance response model was developed. From this model, features were extracted, correlation analyses performed, and an Elastic Net Model employed to select features and predict HP and RH.

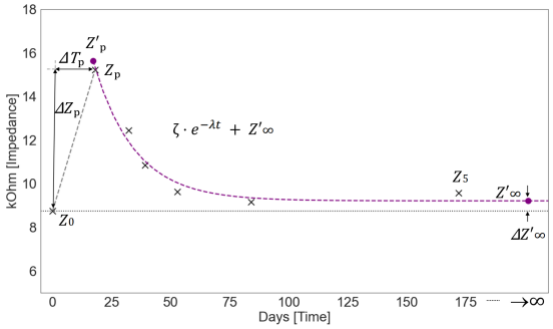

Fig. 1 Illustration of impedance response model (dashed lines) given impedance measurements (crosses). Impedance features are labelled within the figure.

Results

Differences in HP between high and low impedance groups were revealed in a prognostic setting ($p=0.006$). Our results aligned with findings from existing literature in that time and impedances are significantly associated with postoperative RH ($p<0.001$). Moreover, the corresponding impedance coefficients are in good agreement with the results of previous studies using different CIs (−2.98 $dB/k\Omega$, CI(95%) = [−4.28, −1.69] $dB/k\Omega$) [1]. The correlation analyses and the Elastic Net Model found the most promising features to predict absolute HP beyond three months: the preoperative hearing threshold, the impedance decay rate, peak impedance, impedance at month six, and the last impedance estimate (see Fig. 1).

Discussion

Proposals for extending the analysis involve the inclusion of additional impedance subcomponents, incorporation of time integrals of the impedance response and the extension of the audio frequency range. In accordance with previous literature, we hypothesized that there are relationships between immune response, HP and impedance dynamics in the early postoperative period [1].
More data and further investigations are required to support our results and extend the models. We see the potential to use the impedance features for early detection of postoperative RH loss and thus enable early corrective measures such as pharmacotherapy.

References

[1] S. Schraivogel, P. Aebischer, S. Weder, M. Caversaccio, and W. Wimmer, “Cochlear implant electrode impedance subcomponents as biomarker for residual hearing”
[2] N. J. Thompson et al., “Electrode Array Type and Its Impact on Impedance Fluctuations and Loss of Residual Hearing in Cochlear Implantation”

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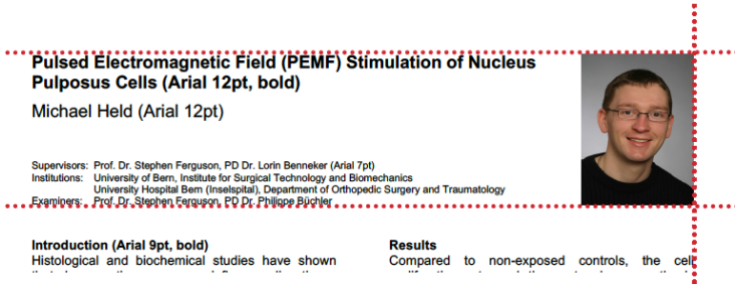

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