Estimating Conductive Hearing Loss from Wideband Acoustic Immittance Measurements

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INTRODUCTION

Wideband acoustic immittance (WAI) measurements have demonstrated clinical utility in the differential diagnosis of otitis media with effusion (OME). Our previous work has shown that wideband acoustic immittance is sensitive to the volume of effusion present in ears with OME (Merchant et al., 2021, Fig. 1). This is significant as our prior work also demonstrated that the volume of the effusion appears to drive, or at least play a significant role in, how much conductive hearing loss (CHL) a child has due to a given episode of OME (Al-Salmi et al., 2021, Fig. 2). Given this association, the goal of this work was to determine how well CHL could be estimated directly from WAI in ears with OME. The ability to estimate CHL objectively and non-invasively from an easy-to-measure acoustic measurement in ears with OME would have significant clinical value, as testing hearing behaviorally in the population that is most affected by OME (pediatrics) can be both time and resource intensive.

METHODS

34 ears from a previously published study on OME were included: 26 ears with OME (with varying effusion volumes) and 8 age-matched healthy normal control ears. Both WAI and air- and bone-conduction audiometric thresholds from each ear were recorded. First, average WAI absorbance across frequency (0.226-8 kHz) was compared to both four-frequency pure-tone average (4PTA, 0.5-4 kHz) and average air-bone gap (ABG, 0.5-4 kHz) in each ear. Average absorbance was strongly correlated with both 4PTA (r = -0.86) and ABG (r = -0.91), suggesting the potential for CHL to be predicted from absorbance measures.

PTA & ABG CORRELATIONS WITH WAI

Average WAI absorbance across frequency (0.226-8 kHz) was compared to both four-frequency pure-tone average (4PTA, 0.5-4 kHz) and average air-bone gap (ABG, 0.5-4 kHz) in each ear. The observation that the CHL2 estimates in the lower cluster (23/34) are consistently lower than PTA while the CHL2 estimates in the upper cluster (11/34) are larger than 4PTA by a factor of two suggests a scheme for improving the CHL estimate. For ears in the lower cluster, which we suppose detect pressure (PRES), CHL2 was added to CHL2. For ears in the upper cluster, which we suppose detect power (PWR), CHL2 will be divided by two (Fig. 6).

CONCLUSIONS

- WAI, combined with our model, can estimate behavioral audiometer thresholds (CHL) objectively and non-invasively within a clinically meaningful margin of error (less than the +/-5 dB test-retest reliability of behavioral audiometry).
- This is a significant finding given the challenges associated with behavioral audiometric testing in pediatric populations where OME is most common.
- The discovery of two distinct types of ears, pressure detectors and power detectors, warrants further investigation.

ACKNOWLEDGEMENTS AND REFERENCES

This work was supported by the NIH NIGMS under award number R21GM11903 and the NIDCD Disorders under award number R01DC063116.


WAI-BASED MODEL ESTIMATION OF CONDUCTIVE HEARING LOSS

Two different CHL estimation methods were used initially. The first approach (CHL1) models CHL as being due to incomplete sound absorption (i.e., reflection) at the tympanic membrane and is calculated as the average absorbance from 2-4 Hz converted to dB. The second approach (CHL2) models CHL as being due to a pressure drop across the ossicular chain, which is presumed to be in series with a cochlear load and is calculated as the middle-ear model damping component R2 divided by the cochlear load R1 = 2 x 10^7 (mks acoustic Ohm) converted to dB.

The correlation of CHL2 with 4PTA is 95% and the prediction error, quantified as the mean absolute difference, is 3.2 dB. Although the calculation of CHL2 is empirically motivated, its application requires prior knowledge of whether an ear belongs to the PRS or PWR cluster. A logistic regression approach could be used to predict which cluster an ear belongs to, and our data thus far support the feasibility of this. Additionally, subjects with OME and 4PTA measurements in both ears almost always had either two PRS ears or two PWR ears. The strong within-subject correlation of ear status (PWR or PRS) suggests that this feature may have a biological origin.