Abstract

Title: Using middle-ear reflectance and audiometry to diagnose conductive hearing loss

Presenters: Prof Jont Allen, Dr Patricia Jeng, Mr Joshua Hajicek; Mimosa Acoustics, Inc.

Middle-ear reflectance with audiometry can shed light on the difficult differential diagnosis for conductive hearing loss with an intact tympanic membrane and aerated middle ear, discriminating between ossicular fixation, ossicular discontinuity, and semi-circular canal dehiscence (Nakajima et al, 2012). Sensitivity and specificity were on par with a laboratory method using umbo velocity with audiometry. The reflectance measurement takes only seconds to make and is non-invasive. It allows for pre-surgical diagnosis of conductive hearing loss, which is a win for both clinician and patient. We will discuss the underlying physiology and physics behind these pathologies (to the extent we can) and discuss why the combination of audiometry and reflectance allows this differential diagnosis.

Outcome results:

1. Interpret audiometry and reflectance test results for ears with conductive hearing loss and an intact tympanic membrane and aerated middle ear.
2. For the three pathologies, describe the expected middle-ear reflectance pattern.
Reflections from the round window

Using middle-ear reflectance and audiometry to diagnose conductive hearing loss

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Pat S Jeng
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What is Impedance?

What do you think of when I say:
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Clinical impedance measurement:
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- Tympanometry?
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- Acoustic impedance:
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  \[ \text{Reflectance}(\text{freq}) \leftrightarrow \text{Acoustic Impedance}(\text{freq}) \]
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  - Tymps measured at a few freqs: e.g., 0.226, 1 kHz
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  - Reflectance?
  - Reflectance(freq) ↔ Acoustic Impedance(freq)
  - Tymps measured at a few freqs: e.g., 0.226, 1 kHz

- **Mimosa’s Wideband Power Reflectance:**
  - Truly multifrequency: 0.2–6.0 kHz
**What is Wideband Power Reflectance?**

Reflectance is defined as the ratio of the reflected to incident ear canal acoustic power.
What is Wideband Power Reflectance?

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- Wideband reflectance and impedance are closely related concepts.
What is *Wideband Power Reflectance*?

- Reflectance is defined as the ratio of the reflected to incident ear canal acoustic power.
- Wideband reflectance and impedance are closely related concepts.
- Reflectance and impedance are functions of frequency, typically from 200–6000 Hz.
Mimosa Acoustics’ Otostat™

Acoustic Reflectance ⇔ ME diagnostics
## Tympanometry vs. Reflectance

<table>
<thead>
<tr>
<th>Can Measure or Diagnose</th>
<th>Tymp</th>
<th>Reflect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Otitis Media with Effusion</td>
<td>Yes?</td>
<td>Yes</td>
</tr>
<tr>
<td>Ossicular discontinuity</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Otosclerosis (stapes fixation)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>TM Perforations</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Hypermobile TM</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Dehiscence</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Acoustic reflex</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Bacterial biofilm</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Canal Volume</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>ME volume</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>ME Static pressure</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Recent Literature

- Technique: Allen 86; Siegel 90; Keefe 93; Withnell 09;

- Results:
  - Temporal bones: Voss 01; Voss et al. 12
  - Newborns: Keefe & Norton 00; Hunter 10
  - Adults:
    - Normals: Voss & Allen; Scheperle; Shahnaz
    - Pathology: Feeney 04; Allen 05; Margolis 10; Nakajima et al. 2012

- Nakajima et al (2012) – Results on Ossicular:
  - Discontinuity (N=6)
  - Fixation (N=14)
  - Dehiscence (N=11)
Ossicular Discontinuity

- N=6 ears with *Stapes Discontinuity*
- Left: *lower* stiffness $\equiv$ Reflectance $[|\Gamma(f)|^2]$ *resonance*!
- Right: *Absorbance* ($\equiv 1 - |\Gamma(f)|^2$ dB) has higher slope
  - Slope 6-12 dB/oct (vs. normal $\approx 3$ dB/oct)
- Lower stiffness + free mass $\Rightarrow$ *resonance* $\approx 0.5$-0.8 kHz
- A few ears different (multiple pathologies?)
Five representative (of 11) with Stapes Fixation

- Left: Four of five show a small increase in stiffness
- Right: Absorbance data show this most clearly
- Not shown: Umbo Velocity is decreased (≈ 10 dB)
- What going on? Stiffness increase due to fixed stapes
- One ear (of 11) very different (discontinuity?)
Superior Canal Dehiscence & cholesteatoma
Six ears (of 11) with Dehiscence
- Left: Reflectance
- Right: Absorbance
- Clear resonance around 1 kHz
- Not shown: Air bone gap is modest (<10 dB)
- What's going on? The jury is still out
Diagnostic Evaluation

Dehiscences
Ossicular Discontinuity
Stapes Fixation

- Separation via Absorbance and Air-bone conduction
- Note: All 31 ears have healthy TM & aerated ME
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- Technique: Allen 86; Siegel 90; Keefe 93; Withnell 09;
- Results:
  - Temporal bones: Voss 01; Voss et al. 11
  - Children: Keefe & Norton 03?; Hunter 08
  - Adults
    - Normals: Voss & Allen; Scheperle; Shahnaz
    - Pathology: Feeney 04; Allen 05; Margolis 10; Nakajima et al. 2012
- Voss, Merchant & Horton (2011)
  - Middle ear pressure (N=8)
ME pressure and Power Reflectance

Positive & Negative pressure (50 dPa steps)

What's going on?
- ME pressure dramatically changes TM stiffness
- Easily observed in the Power Reflectance
- +Pres Stretches vs. -Pres compresses joints
Correlation with DPOAE test results

- Excellent False-positive DPOAE detection
  Hunter et al., 2009; Sanford et al., 2009
- DPOAE Normative regions for newborns
  Hunter et al., 2010
Conclusions

- Reflectance is rich in information
- It seems to be able to quantify many pathologies
- Well documented in the scientific literature
- Many new results in the last year (more on the way)
Thanks for your attention

http://mimosaacoustics.com/
References


