What’s the Evidence for Wideband Reflectance?
Elementary, my dear Watson

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Topics

• Wideband Immittance Facts
• Wideband Tympanometry Evidence
• Adult Applications
• Pediatric Applications
• Cases

Sherlock Holmes was originally to be named “Sherrinford Holmes”
Lidén (1969) Original a,b,c,d Typing

Tympanograms in cases with
(a) Stapes fixation with otherwise normal middle ear.
(b) Adhesive otitis with stapes fixation.
(c) Disruption of the ossicular chain.
(d) Negative pressure in the middle ear.

Sir Arthur Conan Doyle never actually portrayed Holmes as wearing the iconic deerstalker cap and cape.
Facts on Traditional Immittance

- Lidén, Bjorkman, and Peterson (1972): Preferred immittance probe frequency is 800 Hz.

- Alberti and Jerger (1974) studied uncalibrated “compliance unit” systems at 220 and 800 Hz in various pathologies.

- Alberti and Jerger noted W-shaped patterns at 800 Hz were not specific to pathology;
Facts on Traditional Immittance

- But.....220-Hz tympanograms were insensitive to significant pathology such as otosclerosis, malleus fixation, severe scarring, and atrophy.
- 226 Hz tympanometry later shown to be insensitive to ME fluid in newborns

- *It is a capital mistake to theorize before one has data.* *Insensibly one begins to twist facts to suit theories, instead of theories to suit facts*

  — Sherlock Holmes
Also circa 1969...
So Why 226-Hz Probe Only??

- Calibration
- Simplicity
- Convenience
- Tradition
- “Good enough”
- Lack of evidence
The Middle Ear Filter

SPL-HL
OME
Severe OME
Roots of Wideband Immittance Measures

- Wideband immittance research systems developed by Allen (1986) and Keefe, Bulen, Arehart, & Burns (1993).
- Application in clinical assessment of the middle ear has occurred in the past 2 decades.
- Frequency ranges can be accurately tested up to 8 kHz due to improved calibration and reflectance technique (Keefe et al., 1993).
Sherlock has an information system “HOLMES 2” (Home Office Major Enquiry System) named after him, which is used by the UK Police force.
Wideband Absorbance Measurement

Absorbance = 1 - ER
Wideband Tympanometry Research System (Keefe et al.)
Produced by Interacoustics, Inc.

http://www.interacoustics.com/News_and_events/Newsmain.asp
Wideband Absorbance is Sensitive to Many Disorders:

- Middle ear effusion
- Ossicular disarticulation
- Eardrum perforation
- Ossicular fixation
- Eardrum atrophy
- Tympanosclerosis
- Conductive hearing loss
- Structural ossicular abnormalities
- Superior canal dehiscence
- Increased intracranial pressure
Wideband Tympanometry Research
Keefe & Simmons experimental system (2003)

Averaged Normals  Average Conductive HL
Wideband Absorbance for Detection of Conductive Hearing Loss
Keefe et al., 2012
Absorbance

3D Wideband Tympanogram

“Tympanometry”
The Wideband Tympanogram

3-D

2-D
Wideband Tympanometry

2-D Tympanogram “Slices”
Wideband Reflectance Reliability
Vander Werff, 2007

Obtained on Mimosa Hear-ID system
Effects of OME, middle ear pressure and PE tube
Sanford et al., JAAA 2014

Obtained on Interacoustics Experimental Wideband system
Ambient Absorbance in Children with Middle Ear Conditions
Hunter et al, 2008

Obtained on Mimosa Hear-ID system

Normal
Abnormal (OME)
Negative Pressure
Relation Between Pathology, ABG and Absorbance
Nakajima et al., 2013
Sherlock was inspired by Arthur Conan Doyle’s college professor, Dr. Joseph Bell, who was able to diagnose his patients with just a look.
Adult Case: Otosclerosis

Courtesy of Navid Shahnaz, Ph.D.
Newborn Conductive Hearing Loss

- Infants failing NHS due to conductive hearing loss are at high risk for persistent or fluctuant hearing loss.
- Average hearing for infants with CHL approximately 30 dB with range of 15-45 dB. (Maxon et al., 1993).
Newborn Transient Middle Ear Conditions

• In newborns, the middle-ear space may contain residual amniotic fluid, mesenchyme or meconium (Northrup et al., 1986; Jaisinghani et al. 1999; Miura et al. 2008).

• Similar physical effects to otitis media.

• These conditions affect both OAEs and AABR.
Difficulty of Identifying MEE with Conventional Tympanometry

- 226-Hz tympanogram usually normal or notched in confirmed MEE under 4 months of age
- Paradise et al., (1976) first observed this problem and attributed it to simple ear canal wall movement
Tympanometry in infants with middle ear effusion identified using CT scans.

Male with left ear filled with fluid as identified by CT (see yellow arrow).
Tympanometry in infant with left middle ear
Wideband Reflectance Normal and Abnormal Regions for Newborns – Hunter et al., 2010.

Obtained on Mimosa Hear-ID system
Wideband reflectance improves with OAE improvement

Hunter et al., 2010

Obtained on Mimosa Hear-ID system
Test performance for wideband reflectance compared to tympanometry
Hunter et al., 2010

Pass = 352 Refer = 141
Normal Newborn Case
Wideband Tympanometry & Group Delay

0.7-1.4 kHz band tympanogram
Peak: 0.88  TPP: -300

1.4-2.8 kHz band tympanogram
TWn: 0  TWp: 325

Absorbance vs. Frequency
Ambient
TPP
Ppt
Pnt
Normal Newborn Case
Wideband Acoustic Reflex Threshold to Clicks

Threshold =
60 SPL
Measured at +22 daPa
Newborn Conductive Case
Wideband Tympanometry & Group Delay
Newborn Conductive HL Case

Wideband Acoustic Reflex Threshold

Threshold = No Response
Measured at -300 daPa
Development of Ambient Absorbance in Normal Ears
Hunter, Keefe, Feeney AAS 2012

Obtained on Interacoustics Experimental Wideband system
Development of Wideband Absorbance & OAE/ABR Screening Status
Hunter, Keefe, Feeney AAS 2012

Obtained on Interacoustics Experimental Wideband system
Baby Leah

- Female, full-term, born by C-section
- Referred on OAE and AABR newborn screen in both ears
- Seen for follow-up, Mom is unconcerned, was told its “just fluid due to c-section”.
Baby Leah

- Repeat OAEs are absent in both ears
- ABR shows thresholds of 60 dBnHL in both ears for clicks, 1 and 4 kHz tonebursts
- Bone conduction thresholds are absent except for stimulus artifact
- Wideband immittance normal in both ears
- **Diagnosis = SNHL**
- Difficult counseling session, shock and denial
Baby Jacob

• Referred on newborn screen in both ears
• Seen for follow-up, referred on DPOAEs for both ears
• Toneburst ABR showed mild hearing loss in RE
• Mom is concerned, what do we know?
Jacob 3D Tympanograms
Jacob Absorbance
## Wideband Test Combinations for Diagnostic Interpretation

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>WB Tymp</th>
<th>WB Reflex</th>
<th>OAE</th>
<th>Audio/ABR</th>
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<tbody>
<tr>
<td>Normal</td>
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<td>Normal</td>
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<tr>
<td>Conductive</td>
<td>Flattened</td>
<td>Elevated/Absent</td>
<td>Absent</td>
<td>Elevated air threshold, normal bone</td>
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<tr>
<td>Cochlear</td>
<td>Normal</td>
<td>Normal/Elevated</td>
<td>Absent</td>
<td>Elevated air, elevated bone</td>
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<tr>
<td>Neural</td>
<td>Normal</td>
<td>Absent</td>
<td>Normal</td>
<td>Absent or markedly abnormal</td>
</tr>
</tbody>
</table>
CURRENT AND FUTURE WIDEBAND ABSORBANCE “APPS”

- Detection of OME and conductive hearing loss
- Newborn hearing screening and diagnosis
- Wideband acoustic reflex test
- Combined WBT, WBART, OAE test battery
- Adjusting OAE using pressure
Take Home Messages

- It's time to move beyond the ABCs of immittance
- Wideband tympanometry uses a familiar probe and measurement system
- The stimulus and recording is wideband
- Signal averaging and normative data are powerful techniques
- Test-retest reliability is high
- Available clinical studies show better test performance than single frequency tympanometry

“If in one hundred years I am known only as the man who invented Sherlock Holmes, then I will have considered my life a failure"
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Questions and Discussion