Making the Most of Middle Ear Measurements

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Making the Most of Middle Ear Measurements

- A Long Tradition with Admittance Measurement
- Evidence-Based Practice Includes Admittance Measurement
- Important Terminology
- Multi-Frequency Tympanometry
- Applications of Acoustic Reflexes in Infants and Young Children

James Jerger
Classic Impedance Studies in Early 1970s at Methodist Hospital
And Baylor College of Medicine in Houston Texas, USA
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Classic Impedance Studies in Early 1970s at Methodist Hospital
And Baylor College of Medicine in Houston Texas, USA

James Jerger Generates Research Evidence
In Support of Admittance Measurements


Acoustic Impittance Measurement:
My First Clinical Activity at Baylor College of Medicine (Houston Texas)

With Larry Mauldin (circa 1975)
<table>
<thead>
<tr>
<th>Early Publications on Impedance/Immittance Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Hall JW III and Weaver T. Impedance audiometry in a young population: The effects of age, sex and minor tympanogram abnormality. <em>J Otolaryngology (Toronto)</em> 8: 210-222, 1979</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Acoustic Reflex Amplitude in Auditory Dysfunction Dissertation: James W. Hall III, 1979</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Published Articles Based on PhD Dissertation</th>
</tr>
</thead>
</table>
Additional Published Articles on Impedance/Immittance Measures


A New Acoustic Reflex Pattern

**A New Acoustic Reflex Pattern**

**Susan Jerger, MD, James Jerger, PhD, James Hall, MD**

A new crossed-examined acoustic reflex pattern has been observed in four patients with retrocochlear diseases. This new reflex pattern is characterized by a unique "screwing" configuration. Reflexes were bilateral, with weakness in the non-audible ear constant. A reflex was not observed in two of these patients; a variation of this new pattern was noted in one patient. This new reflex pattern may be a reliable addition to threshold measures in some patients.

(Book Chapters and Monographs on Impedance/Immittance Measures)


**Additional Published Articles on Impedance/Immittance Measures**


**Acoustic Immittance Measurement:**

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Book Chapters and Monographs on Impedance/Immittance Measures (2)


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Best Practice is Evidence-Based Practice (EBP)

- Evidence-based practice is “the integration of best research evidence with clinical expertise and patient values” (Sackett et al, Evidence-Based Medicine: How to practice and teach EBM. London: Churchill, 2000, p. 1)
- EBP is a five step process
  - Focused clinical question
  - Evidence is sought to answer the question
  - Clinician evaluates the quality of evidence
  - Clinician must integrate the evidence with the patient’s clinical findings and preferred outcome to develop intervention plan
  - Document outcome and identify ways to improve it
### Evidence-Based Practice: Categories of Research Evidence (ASHA, 2004)

- **1a**: Well-designed meta-analysis of randomized controlled trials
- **1b**: Well-designed randomized controlled trials
- **2a**: Well-designed controlled studies without randomization
- **2b**: Well-designed quasi-experimental studies
- **3**: Well-designed non-experimental studies, i.e., correlational and case studies
- **4**: Expert committee reports, consensus conferences and clinical experience

### Evidence-Based Practice is Standard of Care: Definition of Standard of Care (SOC)

- Is consistent with local, regional or national clinical practice
- Follows peer-reviewed guidelines or recommendations on clinical practice approved by national
  - Multi-disciplinary professional committees or panels
  - Professional organizations,
- Is consistent with statements of
  - Scope of Practice
  - Code of Ethics
- Is in compliance with national health care guidelines for clinical practice and services

### Year 2007 Joint Committee on Infant Hearing (JCIH): Protocol for Evaluation for Hearing Loss In Infants from Birth to 6 months

- Child and family history
- Evaluation of risk factors for congenital hearing loss
- Parental report of infant’s responses to sound
- Clinical observation of infant’s auditory behavior
- Audiological assessment
  - Auditory brainstem response (ABR)
  - Otoacoustic emissions (distortion product or transient OAEs)
  - Tympanometry with 1000 Hz probe tone
  - Supplemental procedures, e.g.,
    - Electrocochleography (ECochG)
    - Auditory steady state response (ASSR)
    - Acoustic reflex measurement (for 1000 Hz probe tone)
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Making the Most of Middle Ear Measurements

**Definitions**

- Imittance = impedance + admittance
- Impedance ($Z_a$) = opposition to acoustic energy flow through middle ear system (in acoustic ohms)
- Admittance ($Y_a$) = ease of acoustic energy flow through middle ear system (in acoustic mmhos); reciprocal of $Z_a$

## Theory of Admittance Measurement.

### Relations Among Impedance Components

- $Z_a = \sqrt{R_a^2 + X_a^2}$, where $X_a = 2\pi f M (-k/2\pi f)$

  - $R_a$ = acoustic resistance, i.e., impedance due to friction
  - $X_a$ = acoustic reactance, i.e., impedance due to mass and stiffness (or compliance) components
Theory of Admittance Measurement:  
*Relations Among Admittance Components*

- \[ Y_a = \sqrt{G_a^2 + B_a^2} \], where
  - \( Y \) phase angle = \( \arctan \left( \frac{B_a}{G_a} \right) \)
  - \( G_a \) = acoustic conductance (admittance due to friction)
  - \( B_a \) = acoustic susceptance, i.e., admittance due to mass and stiffness (or compliance) components

**Making the Most of Middle Ear Measurements**

*Definitions*

- Acoustic impedance: The opposition of the flow of sound through a surface (the middle ear system). Acoustic impedance has three components:
  - Resistance
  - Positive reactance
  - Negative reactance
- Acoustic admittance: The reciprocal of acoustic impedance. The three components of admittance are:
  - Conductance (G)
  - Positive susceptance (B)
  - Negative susceptance (B)

**Definitions (2)**

- Acoustic compliance: The ratio of volume displacement to acoustic pressure at a surface (through the middle ear system). Acoustic compliance is:
  - The property of an ideal acoustic element whose movement in response to sound is determined solely by its elastic (spring-like) properties.
  - At low frequencies the middle ear functions for practical purposes as pure compliance.
  - In tympanometry (at 226 Hz) the compliance presented to the probe is the sum of the middle ear compliance and the air in the ear canal.
### Definitions (3)
- **Middle ear compliance or admittance:** The difference between peak compliance/admittance and compliance/admittance measured at a pressure sufficient to eliminate the influence of the middle ear system.
  - Also known as peak compensated Static acoustic admittance (200 Ytm)
  - The reference pressure is normally a positive pressure of 200 daPa.
  - At this pressure the indicated compliance or admittance is that of the air-filled space within the ear canal between the tip of the probe and the tympanic membrane.

### Definitions (4)
- **Equivalent volume:**
  - The volume of an air-filled cavity having the same acoustic admittance (or impedance or compliance) as that of the component or system which it represents.
  - Ear canal volume is not measured directly but inferred from the measurement of admittance.
- **Middle ear pressure:** Static pressure in the middle ear relative to ambient atmospheric pressure, estimated from the tympanic peak pressure.
- **Tympanogram peak pressure:** The ear canal pressure at which the peak of the tympanogram occurs.

### Definitions (5)
- **Tympanometry:** The measurement of acoustic impedance/admittance (or compliance) as a function of air pressure within the external ear canal.
- **Tympanogram:** A graph of acoustic impedance/admittance (or compliance) as a function of air pressure within the external ear canal.
- **Tympanometric width:** Calculated by measuring the width of the tympanogram curve at 50% of its height.
- Also sometimes referred to as tympanogram gradient.
Energy does not flow efficiently from a low impedance medium (e.g., air in the external ear canal) to a high impedance medium (the fluid filled inner ear). The middle ear acts as an impedance match between air in outer ear and fluid-filled cochlea.


- Ratio of area of TM to stapes footplate (+ 20 dB)
- Ossicles lever mechanism (+ 2 dB)
- Shape of the TM (+ 6 dB)
- The middle ear provides an impedance matching transformer otherwise 99.9% (~ 30dB) of the incoming sound will be reflected

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Making the Most of Middle Ear Measurements

Clinical Instrumentation

- Ear canal volume
- Static compliance
- Tympanometry
  - 220 vs. 1000 Hz probe tones for adults vs. neonates
  - Multiple admittance components
  - Toynbee and Valsalva procedures
  - Fistula test
- Acoustic reflexes
  - Ipsilateral and contralateral
  - Reflex decay

Theory of Admittance Measurement: Part 1

Why is a 220 or 226 Hz Probe Tone Frequency Used?

- Available transducers where nonlinear at higher frequencies when Terkildsen & Scott-Nielsen (1960) conducted their classic experiments
- A frequency of 220 or 226 Hz is not an even harmonic of the typical power line frequency in Europe (50 Hz)
- A one-component admittance measurement technique can be used at low frequencies as the phase angle is relatively constant in tympanometry
- The acoustic reflex is typically not elicited with a very low frequency stimulus, even at high intensity levels
- There is vast clinical experience with a 220/226 Hz probe tone
- Impedance standards apply to the 226 Hz probe tone

Making the Most of Middle Ear Measurements:
One Component Tympanogram (Admittance or Impedance)
### Static Admittance Normal Values (mmho)

**For Tympanogram Peak Analysis**

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>226 Hz</strong></td>
<td>0.44</td>
<td>0.20</td>
</tr>
<tr>
<td>Lower Limit</td>
<td>0.83</td>
<td>0.37</td>
</tr>
<tr>
<td>Median</td>
<td>1.60</td>
<td>0.82</td>
</tr>
<tr>
<td>Upper Limit</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>678 Hz</strong></td>
<td>0.98</td>
<td>0.75</td>
</tr>
<tr>
<td>Lower Limit</td>
<td>1.53</td>
<td>2.29</td>
</tr>
<tr>
<td>Median</td>
<td>2.22</td>
<td>3.94</td>
</tr>
<tr>
<td>Upper Limit</td>
<td>3.80</td>
<td></td>
</tr>
</tbody>
</table>


### Making the Most of Middle Ear Measurements:

**Multi-Component (B & G) Tympanograms**

**Normal Conductance (G) and Susceptance (B) Tympanograms for a 678 Hz Probe Tone**

### Making the Most of Middle Ear Measurements

**Classifications of Multi-Component Tympanogram Peaks**

![Diagram showing classifications of tympanogram peaks]
Making the Most of Middle Ear Measurements: Normal Distribution of Peaks for 678 Hz Probe Tone

<table>
<thead>
<tr>
<th></th>
<th>(Study A)</th>
<th>(Study B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1G 1B</td>
<td>1</td>
<td>Y</td>
</tr>
<tr>
<td>1G 3B</td>
<td>1</td>
<td>Y</td>
</tr>
<tr>
<td>1G 3B</td>
<td>3</td>
<td>Y</td>
</tr>
<tr>
<td>3G 5B</td>
<td>3</td>
<td>Y</td>
</tr>
</tbody>
</table>

Making the Most of Middle Ear Measurements Tympanogram Gradient

- Computation of tympanogram admittance relative to pressure range
- First reported by
  - Cooper et al, 1982
  - de Jonge, 1986
  - Koebsell & Margolis, 1986
  - Tompkins & Hall, 1990
- A half-amplitude admittance (Y) point is determined on the positive and negative side of the tympanogram
  - Total amplitude on each side is divided by two
  - The difference in air pressure between each of these points on the slope of the tympanogram is referred to as delta (difference) pressure (dP) and expressed in daPa

Making the Most of Middle Ear Measurements Tympanogram Gradient

\[ GdP = Pb - Pa \]

\[ Ya \quad Pb \quad GdP \quad Yb \]

\[ \text{Compliance mm} \]

\[ \text{Air Pressure (daPa)} \]

\[ \text{Ad} \quad \text{Lower GdP} \]

\[ \text{As or B} \quad \text{Higher GdP} \]
Wideband Reflectance/Absorbance
(Courtesy of Bue Kristensen, Interacoustics, 2013)

\[
\text{Energy Absorbance} = \frac{\text{Absorbed Power}}{\text{Incident Power}} = 0
\]

1 - Energy Reflectance

Wideband Reflectance/Absorbance
Depends on Frequency

Hunter, AAA convention 2005

Wideband Reflectance/Absorbance
(Voss et al. Ear & Hearing, 2008)
(Courtesy of Bue Kristensen, Interacoustics, 2013)
## Wideband Reflectance/Absorbance: A Good Recent (2014) Reference on the Topic

#### Acoustic Immittance Measures

**Basic and Advanced Practice**

Lisa Hunter
Navid Shahnaz

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## Wideband Power Reflectance/Absorbance: Recent Publications

- Feeney, Kei, Lilly, Margolis, Nakajima, Neely, Prieve, Rosowski, Sanford, Schairer, Shahnaz, Stenfelt & Voss. Consensus Statement: Eriksholm workshop on wideband absorbance measures of the middle ear. *Ear & Hearing, Supplement 1*, 2013
  - Terminology
  - Research needs
  - Clinical Applications

## Making the Most of Middle Ear Measurements

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- Multi-Frequency Tympanometry and Wideband Reflectance
- Applications of Acoustic Reflexes in Infants and Young Children
### Diagnosis of Hearing Loss: Protocol for Confirmation of Hearing Loss in Infants and Toddlers (0 to 6 months)

**Year 2007 JCIH Position Statement**

- Child and family history
- Otoacoustic emissions
- ABR during initial evaluation to confirm type, degree & configuration of hearing loss
- Acoustic immittance measures (including acoustic reflexes) using high frequency (1000 Hz) probe tone
- Supplemental procedures (insufficient evidence to use of procedures as "sole measure of auditory status in newborn and infant populations")
  - Auditory steady state response (ASSR)
  - Auditory middle ear reflexes for infants < 4 months
  - Broad band reflectance
- Behavioral response audiometry (if feasible)
  - Visual reinforcement audiometry
  - Conditioned play audiometry
  - Speech detection and recognition
- Parental report of auditory & visual behaviors
- Screening of infant’s communication milestones

### Low (226 Hz) versus High (1000 Hz)

**Probe Tone for Infant Tympanometry**

- The middle ear system of a newborn infant is mass dominated with a lower resonant frequency (Kei et al, 2007)
- The adult middle ear system is stiffness dominated with a higher resonance frequency
- External ear canals of neonates are distensible under applied air pressure because of the underdeveloped osseous portion of the ear canal (Kei et al, 2007)
- "Compensating for the ear canal contribution by making measurements of admittance at extreme ear canal static pressures (i.e., +200 or -400 daPa) may introduce errors in estimating the static admittance." (Kei et al, 2007)
- Use a 1000 Hz probe tone with infants up to the chronological age of at least 4 months
- Calculate ear canal volume with a 226 Hz probe tone
- Ear canal volume measurements at extreme positive or negative pressures may not be accurate in neonates.
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Acoustic Reflex Measurements: Historical Perspective (1)

- Luscher (1929) In Germany observed acoustic reflex
- Jepsen (1951) Confirmed stapedius muscle acoustic reflex
- Klockhoff (1961) Clinical study of acoustic reflexes
- Anderson, Barr & Wedenberg (1970) Early detection of 8th nerve tumors with acoustic reflex

Acoustic Reflex Measurements: Historical Perspective (2)

- Keith (1975) Acoustic reflex in neonates
- Jerger & Hayes (1976) Crosscheck principle in pediatric audiology
- Weatherby & Bennett (1980) Acoustic reflex in neonates
Acoustic Reflex Measurements

- Background information
- Historical overview
- Functional anatomy
- Making acoustic reflex measurements & what do they mean?
- Clinical applications and value ... remarkable diagnostic return on an investment of a few minutes of test time
- Choosing the right equipment for the job

Acoustic Reflex Measurements

Middle Ear Muscles (Stapedius and Tensor Tympani)

- **Stapedius muscle**
  - Small striated muscle (smallest in the body)
  - Located in a canal posterior to tympanic cavity
  - Attached at one end to the canal and the other to the neck of the stapes
  - Innervated by a branch of the 7th (facial) cranial nerve
  - Consensual reflex (unilateral stimulus bilateral response)
  - Stimulated in various ways including
    - Acoustic reflex by sounds of about 85 dB HL
    - Gentle tactile stimulation of outer ear
    - Electrical stimulation of ear canal wall
    - Voluntary contraction (can you wiggle your ears?)

- **Tensor tympani muscle**
  - Striated muscle
  - Located in a small canal above the auditory canal
  - Attached at one end to the walls of the canal and the other to the manubrium of the malleus
  - Innervated by mandibular branch of the 5th (trigeminal) cranial nerve
  - Contracts as part of general startle response
  - Response is usually transient and not repeatable
Middle Ear Muscles

Acoustic Stapedial Reflex Pathways According to Erick Borg

Acoustic Reflex Pathways Revisited
### Acoustic Reflex Measurements

#### Theories on the Function of Middle Ear Muscles (1)

- **von Bekesy (1960)**
  - Restricted ossicular movement, prevent sub-harmonics
  - Prevention of the separation of inter-ossicular joints during transmission of energy from high intensity sound

- **Wever & Bray (1956)**
  - Acoustic reflex contributes to maintaining relatively constant level of sound as stimulus intensity varies
  - "Automatic gain control" for high intensity low frequency sounds thus minimizing distortion

- Prevention of damage from high intensity sound *but* ...
  - Protection limited to sound frequencies < 1000 Hz
  - Latency of reflex (up to 60 ms) would limit protection
  - Muscle fatigue would limit protection with sustained sound

### Acoustic Reflex Measurements

#### Theories on the Function of Middle Ear Muscles (1)

- Improved perception of important external sounds
  - At high intensities low frequency sounds can mask higher frequency sounds (e.g., speech sounds)
  - Middle ear muscle contraction might enhance perception of complex signals such as speech in noise

- Reduction of masking effect of self-produced sound
  - Muscles contract during swallowing and vocalization
  - Contraction may reduce masking self-produced sounds, as in chewing

- Stabilization of middle ear response
  - Resting muscle tone may "smooth out" the middle ear response to sound
  - Minimize natural dips and peaks due to resonances

### Making the Most of Middle Ear Measurements: Acoustic Reflex Measurements

- Acoustic threshold (ART) or minimum response level
- Acoustic reflex amplitude
- Acoustic reflex decay
- Acoustic reflex latency
- Estimation of hearing threshold with acoustic reflex
- Differentiating among auditory disorders with acoustic reflexes
Acoustic Reflex Measurements

Acoustic Reflex Threshold

- Acoustic threshold (ART) or minimum response level
- Acoustic reflex amplitude
- Acoustic reflex decay
- Acoustic reflex latency
- Estimation of hearing threshold with acoustic reflex
- Differentiating among auditory disorders with acoustic reflexes
Clinical Application of Acoustic Reflexes: Amplitude in Young Normal Subjects (Dissertation: James W. Hall III, 1979)

- Acoustic threshold (ART) or minimum response level
- Acoustic reflex amplitude
- Acoustic reflex decay
- Acoustic reflex latency … cannot be measured with current clinical instrumentation
- Estimation of hearing threshold with acoustic reflex
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Making the Most of Middle Ear Measurements
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- Acoustic reflex decay
- Acoustic reflex latency
- Estimation of hearing threshold with acoustic reflex
- Differentiating among auditory disorders with acoustic reflexes

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**Predicting hearing loss from the acoustic reflex. JSND, 39, 11-22**

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**SPAR Criteria**

<table>
<thead>
<tr>
<th>Noise-Tone Difference</th>
<th>BBN ART in dB SPL</th>
<th>Prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;20 dB</td>
<td>Anywhere</td>
<td>Normal</td>
</tr>
<tr>
<td>15 to 19</td>
<td>≤ 80</td>
<td>Normal</td>
</tr>
<tr>
<td>15 to 19</td>
<td>&gt; 80</td>
<td>Normal-Moderate</td>
</tr>
<tr>
<td>10 to 14</td>
<td>Anywhere</td>
<td>Mild-Moderate</td>
</tr>
<tr>
<td>&lt;10</td>
<td>≤ 90</td>
<td>Mild-Moderate</td>
</tr>
<tr>
<td>&lt;10</td>
<td>&gt; 90</td>
<td>Severe</td>
</tr>
<tr>
<td>AR not observed</td>
<td></td>
<td>Profound</td>
</tr>
</tbody>
</table>
Estimation of Hearing Thresholds with Acoustic Reflexes:
A Sampling of Publications

- Hall JW III and Koval C. Accuracy of hearing prediction by the acoustic reflex. The Laryngoscope 92: 140-149, 1982

Simplified SPAR (Sensitivity Prediction by the Acoustic Reflex)

Probe Tone and Acoustic Reflex Findings in Neonates
(From Sprague, Wiley & Goldstein (1983). Tympanometry and acoustic reflex studies in neonates. JSHR, 28, 265-272)

<table>
<thead>
<tr>
<th>Probe Frequency</th>
<th>Stimulus</th>
<th>Presentation</th>
<th>Reflexes Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>220 Hz</td>
<td>BBN</td>
<td>Ipsilateral</td>
<td>51%</td>
</tr>
<tr>
<td>600 Hz</td>
<td>BBN</td>
<td>Ipsilateral</td>
<td>74%</td>
</tr>
<tr>
<td>220 Hz</td>
<td>BBN</td>
<td>Contralateral</td>
<td>49%</td>
</tr>
<tr>
<td>600 Hz</td>
<td>BBN</td>
<td>Contralateral</td>
<td>83%</td>
</tr>
<tr>
<td>220 Hz</td>
<td>1000 Hz</td>
<td>Ipsilateral</td>
<td>43%</td>
</tr>
<tr>
<td>600 Hz</td>
<td>1000 Hz</td>
<td>Ipsilateral</td>
<td>81%</td>
</tr>
<tr>
<td>220 Hz</td>
<td>1000 Hz</td>
<td>Contralateral</td>
<td>34%</td>
</tr>
</tbody>
</table>
### Acoustic Reflex Presence as a Function of Age

(From Kankkunen & Liden (1988). Ipsilateral acoustic reflex thresholds in neonates and in normal-hearing and hearing-impaired preschool children. Scand Audiol, 13, 139-144)

<table>
<thead>
<tr>
<th>Age of Child</th>
<th>Percentage of Children with Reflexes Present (600 Hz Probe Tone)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 month</td>
<td>100%</td>
</tr>
<tr>
<td>2 months</td>
<td>92%</td>
</tr>
<tr>
<td>3 months</td>
<td>90%</td>
</tr>
<tr>
<td>4 months</td>
<td>87%</td>
</tr>
<tr>
<td>5-11 months</td>
<td>85%</td>
</tr>
<tr>
<td>1 year</td>
<td>72%</td>
</tr>
<tr>
<td>2 years</td>
<td>67%</td>
</tr>
<tr>
<td>3 years</td>
<td>47%</td>
</tr>
<tr>
<td>4 years</td>
<td>47%</td>
</tr>
</tbody>
</table>

### Acoustic Reflexes in Neonates


- 66 full term infants
- Acoustic reflexes recorded with 1000 Hz probe tone
- Tone and BBN stimuli
- All neonates had acoustic reflexes

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Median ART (dB HL)</th>
<th>90% Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 Hz</td>
<td>80</td>
<td>70 - 95</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>70</td>
<td>60 - 85</td>
</tr>
<tr>
<td>4000 Hz</td>
<td>65</td>
<td>50 - 80</td>
</tr>
<tr>
<td>BBN</td>
<td>55</td>
<td>50 – 75</td>
</tr>
</tbody>
</table>

* N = 68 ears
### Acoustic Reflex Measurements

**Clinical Applications and Value**

- Confirming normal versus abnormal middle ear function
- Differentiation among
  - Sensory hearing loss
  - Conductive hearing loss
  - Neural hearing loss
  - Central auditory (brainstem) dysfunction
- Objective prediction of hearing loss in young children
- Diagnosis of auditory neuropathy spectrum disorder (ANSD)

#### Plotting the Results of Acoustic Reflex Measurements

<table>
<thead>
<tr>
<th>Abnormal Acoustic Reflex</th>
<th>Acoustic reflex patterns (“faces”)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conductive/efferent pattern</td>
</tr>
<tr>
<td></td>
<td>Sensory pattern</td>
</tr>
<tr>
<td></td>
<td>Neural pattern</td>
</tr>
<tr>
<td></td>
<td>Brainstem pattern</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crossed (contralateral) Sound in ear</th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
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</table>

<table>
<thead>
<tr>
<th>Uncrossed (ipsilateral) Probe and sound in ear</th>
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</table>

#### Vertical pattern
- Mild conductive hearing loss pattern or efferent (7th CN) pattern (normal tymp and no air bone gap) on right ear

<table>
<thead>
<tr>
<th>Contralateral (Crossed) Sound Right Probe Left</th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Ipsilateral (Uncrossed) Sound Right Probe Right</th>
<th></th>
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<tbody>
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</tbody>
</table>
Plotting the Results of Acoustic Reflex Measurements

- Abnormal Acoustic Reflex

Inverted "L" pattern
- Moderate or severe conductive hearing loss on right ear

<table>
<thead>
<tr>
<th>Right</th>
<th>Left</th>
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</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

Contralateral (Crossed)
- Sound Right
- Probe Left

Ipsilateral (Uncrossed)
- Sound Right
- Probe Right

Contralateral (Crossed)
- Sound Left
- Probe Right

Ipsilateral (Uncrossed)
- Sound Left
- Probe Left

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Plotting the Results of Acoustic Reflex Measurements

- Abnormal Acoustic Reflex

Diagonal pattern
- Severe sensory hearing loss or 8th nerve auditory dysfunction on right ear

<table>
<thead>
<tr>
<th>Right</th>
<th>Left</th>
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<tbody>
<tr>
<td><img src="image3.png" alt="Diagram" /></td>
<td><img src="image4.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

Contralateral (Crossed)
- Sound Right
- Probe Left

Ipsilateral (Uncrossed)
- Sound Right
- Probe Right

Contralateral (Crossed)
- Sound Left
- Probe Right

Ipsilateral (Uncrossed)
- Sound Left
- Probe Left

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Plotting the Results of Acoustic Reflex Measurements

(From Hall JW III. *Introduction to Audiology Today*. Boston: Pearson, 2014)

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Plotting the Results of Acoustic Reflex Measurements

Abnormal Acoustic Reflex  
Horizontal pattern  
• Brainstem auditory dysfunction

- Right
- Left
- Contralateral (Crossed)
  Sound Right
  Probe Left

- Contralateral (Crossed)
  Sound Left
  Probe Right

- Ipsilateral (Uncrossed)
  Sound Right
  Probe Right

- Ipsilateral (Uncrossed)
  Sound Left
  Probe Left

Acoustic Reflex Measurements  
Clinical Applications and Value

- Confirming normal versus abnormal middle ear function
- Differentiation among types of auditory dysfunction
  • Sensory hearing loss
  • Conductive hearing loss
  • Neural hearing loss
  • Central auditory (brainstem) dysfunction
- Objective prediction of hearing loss in young children
- Diagnosis of auditory neuropathy spectrum disorder (ANSD)

Acoustic Reflexes in the Diagnosis of Auditory Neuropathy Spectrum Disorder (ANSD)

  • 5% of children with hearing loss diagnosed with ANSD
  • Acoustic reflexes played role in the diagnosis
Assorted Applications of Admittance Measurement:
Assessment of Non-Organic Hearing Loss

- Other terms for "non-organic hearing loss
  - Pseudohypacusis
  - Functional hearing loss
  - False or exaggerated hearing loss
- Risk factors for false or exaggerated hearing loss
  - Children
    - Adolescent girls
    - Trauma (physical, sexual, psychological)
  - Adults
    - Potential compensation
    - Legal action
    - Trauma (physical, sexual, psychological)

Assessment of False or Exaggerated Hearing Loss

Why Prompt Diagnosis is Important

- Elimination of unnecessary health care costs, e.g.,
  - Radiological studies
  - Laboratory studies
  - Compensation for non-existent impairment
  - Referral to specialists
- Prevention of inappropriate treatment, e.g.,
  - Medical
  - Surgical
  - Audiological
- Prompt intervention for underlying cause or factors
  - Counseling
  - Psychological or psychiatric management

Assorted Applications of Admittance Measurement:
Neonates, Non-Organic Hearing Loss,
Eustachian Tube Dysfunction

- Application of admittance measurement in neonates
  - Importance of probe tone frequency
  - Differentiation of sites of dysfunction
- Assessment of hearing level
  - Sensitivity Prediction by the Acoustic Reflex (SPAR)
  - Simplified technique with BBN signal
- Eustachian tube (ET) function
  - Valsalva technique
  - Toynbee technique
Assorted Applications of Admittance Measurement: Assessment of Eustachian Tube Dysfunction

- Types of ET Dysfunction
  - Obstruction
    - Mechanical blockage due to mucosal edema secondary to allergy, URI, large adenoids
    - Inflammation in suppurative otitis media
    - Distention of ET walls due to soft cartilage (young children)
  - Patency (patulous or open ET). Patient may hear:
    - Own voice loudly
    - Rushing sound associated with breathing

- Inflation-Deflation Test
  - Record baseline tympanogram
  - Create high positive or negative pressure in the external ear canal (e.g. 400 daPa or -400 daPa)
  - Patient swallows several times
  - Tympanogram is repeated
  - Small shift in tympanogram peak (away from applied pressure) suggests normal ET function
Assorted Applications of Admittance Measurement: Assessment of Eustachian Tube Dysfunction with Intact TM (2)

- **Valsalva Procedure**
  - Named after Antonio Maria Valsalva, a 17th century Italian physician and anatomist
  - Record baseline tympanogram
  - Patient pinches nose while attempting to exhale through the nose to inflate the nasopharynx
  - Tympanogram is repeated during Valsalva maneuver
  - Clear positive shift in tympanogram peak is observed if procedure is successful

- **Toynbee Procedure**
  - Named after Joseph Toynbee, a 19th century British otologist
  - Record baseline tympanogram
  - Patient pinches nose while swallowing water
  - Tympanogram is repeated after Toynbee maneuver
  - Clear negative shift in tympanogram peak is observed if procedure is successful, indicating ET functioning
## Middle Ear Measurements:
*Billing (CPT) Codes*

- **Deleted code**
  - 92569: Acoustic reflex testing, decay (deleted 2010)

- **92567: Tympanometry (impedance testing)**

- **92568: Acoustic reflex testing, threshold**

- **92550: Tympanometry and reflex threshold measurements**
  - Do not report in conjunction with 92567 or 92568

- **92570: Acoustic immittance testing, includes**
  - Tympanometry (impedance testing)
  - Acoustic reflex threshold testing
  - Acoustic reflex decay testing
  - Do not report in conjunction with 92567 or 92568

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**Thank You!**

*Questions?*

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