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Common Errors in Aural Immittance Measurement: Tympanometry and Acoustic Reflexes

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Learner Outcomes: As a result of this Continuing Education Activity, participants will be able to …

1) List 4 common errors in the clinical measurement of aural immittance
2) Identify the importance of young age in selecting an appropriate probe tone
3) List 3 under-utilized clinical applications of acoustic reflexes
Common Errors in Aural Immittance Measurement: Tympanometry and Acoustic Reflexes

- Introduction and historical perspective (0 – 5 minutes)
- Review of common errors in single frequency tympanometry and analysis (6 – 20 minutes)
- Consequences of inappropriate probe tone frequency in young children (21 – 30 minutes)
- Review of common errors or deficiencies in acoustic reflex measurement and analysis (31 – 45 minutes)
- Rarely applied yet clinically valuable acoustic reflex measurements (46-54)
- Questions and answers (55 – 60 minutes)
Common Errors in Aural Immittance Measurement:  

Historical Perspective  
Otto Metz (1903-1995)

“In October 1943, just as the Nazis were preparing to intern all Jews in Denmark, Otto Metz had the good fortune to be one of the more than 6,000 Jews spirited across the sea to Sweden by the Danish Resistance. Thus escaping capture, Metz was able to continue his pioneering research at the University Hospital of Lund.

After returning safely to Copenhagen in 1945, Metz formulated the basic principles of tympanometry in his dissertation of 1946: “The acoustic impedance measured on normal and pathological ears”. This constituted the earliest substantial set of acoustic impedance measurements in normal and pathological ears – and obtained using a mechanical bridge.

Continuing this work at Rigshospitalet, Metz also published the seminal “Threshold of reflex contractions of muscles in the middle ear and recruitment of loudness” in the Archives of Otolaryngology in 1952. This was the first study of the acoustic stapedius reflex in patients with ear disease.” (GN Otometrics Website)
James Jerger
Classic Impedance Studies in Early 1970s at Methodist Hospital
And Baylor College of Medicine in Houston Texas, USA

Clinical Experience With Impedance Audiometry
James Jerger, MD, Houston

Introduction: Audiometry was performed at the time as a confirmatory tool to diagnose various hearing disorders. The development of electronic equipment made it possible to perform this task in a more standardized and efficient manner. The use of electronic equipment allowed for more accurate and consistent results, which was crucial for the diagnosis of hearing impairments.

Hearing loss can be due to various causes, including infection, trauma, and congenital defects. The use of audiometry helps in identifying the type and extent of hearing loss, which is essential for the appropriate treatment.

Methods: The audiometric test was performed using a computerized audiometer. The patient was seated in a soundproof booth, and the audiometer was used to present pure-tone stimuli at various frequencies and levels. The patient was asked to indicate when they heard the sound.

Results: The test results showed mild to moderate hearing loss in the frequency range of 250 to 8000 Hz. The patient was referred to an otolaryngologist for further evaluation and treatment.

Conclusion: The use of audiometry in the diagnosis of hearing loss is crucial for the management of hearing disorders. The results of the test helped in planning the appropriate treatment, which included the use of hearing aids.

James Hall with Larry Mauldin (circa 1975)
Acoustic Reflex Amplitude in Auditory Dysfunction
Dissertation: James W. Hall III, 1979

Published Articles Based on PhD Dissertation

Additional Published Articles on Impedance/Immittance Measures


Common Errors in Aural Immittance Measurement: Definitions

- Immittance = 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 \( Z_a \)
Common Errors in Aural Immittance Measurement:
Tympanometry and Acoustic Reflexes

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Common Errors in Aural Immittance Measurement:
Review of Common Errors in Single Frequency Tympanometry and Analysis

- Equipment not calibrated at the beginning of clinical day
- No otoscopic inspection before inserting probe
- Use of excessively slow pump speed for tympanometry in young children
- Selecting negative to positive pressure change versus vice versa
- Reporting an invalid Type B tympanogram
- Failure to perform diagnostically useful tests involving tympanometry
- Forgetting that tympanometry is NOT a test of hearing
Common Errors in Aural Immittance Measurement: Calibration

- Introduction
- General considerations
- Equipment
- Calibration
- Subject preparation
- Test procedure
- Results and reporting
- References
- Appendices
  - Authors and acknowledgements
  - Definitions and units
  - Effects of sweep speed and direction

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**Recommended Procedure**

**Tympanometry**

Date of version: August 2013
Date for review: August 2018

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Common Errors in Aural Immittance Measurement: Calibration

- Daily calibration in hard-walled cavities
- Daily biological verification with a known normal "golden" ear
- Biological check anytime unexpected findings are encountered clinically
- Periodical inspection and cleaning of probe assembly ports and tubes

<table>
<thead>
<tr>
<th>Cavity</th>
<th>Acceptable value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 cm³</td>
<td>0.5 cm³</td>
</tr>
<tr>
<td>2.0 cm³</td>
<td>1.9–2.1 cm³</td>
</tr>
<tr>
<td>5.0 cm³</td>
<td>4.8–5.2 cm³</td>
</tr>
</tbody>
</table>
Common Errors in Aural Imittance Measurement:
No Otoscopic Inspection Before Inserting Probe

- Complete otoscopic inspection before aural imittance measurement
- Imittance measures are recorded in the external ear canal
- Imittance may be affected or compromised by:
  - Cerumen
  - Vernix
  - Debris
  - Foreign objects

Use of Excessively Slow Pump Speed for Tympanometry in Young Children
i.e., 50 daPa vs. 200 daPa per Second

- Pump speed options (daPa/sec)
  - 12.5
  - 50
  - 200
  - 600
Take Advantage of New Features of Modern Equipment for Tympanometry in Young Children

Auto Start is here
As soon as a seal is obtained in the ear, the sweep begins without any need to press buttons to save time with challenging patients.

- Screen touch technology
- Programmable user tests
- Test type buttons

A Simple System for Categorizing Tympanograms
Common Errors in Aural Immittance Measurement:

- Reporting an Invalid Type B Tympanogram …

Explanations for a Spurious Flat Tympanogram

- Opening in the tympanic membrane
  - Perforation
  - Ventilation tube (grommet)

- Occlusion of probe tip by sharp turn in ear canal wall

- External ear canal impacted by cerumen (e.g., in an elderly patient with “sudden” presbycusis)

- Blockage of one or more probe tubes
  - Manometer tube (for changing air pressure)
  - Loudspeaker tube (for delivering probe tone)
  - Microphone tube (for detecting admittance change)

- Faulty transducer producing probe tone (*Daily calibration is important!*)
Common Errors in Aural Immittance Measurement:
Valid Type B Tympanogram in a Child with Otitis Media

Common Errors in Aural Immittance Measurement:
Reporting an Invalid Type B Tympanogram …
Patent Ventilation Tubes
Common Errors in Aural Immittance Measurement:

*Invalid Flat Tympanogram in the Same Child with Ventilation Tubes*

Findings Consistent with Patent Ventilation Tubes Bilaterally
Common Errors in Aural Immittance Measurement: Failure to Perform Diagnostically Useful Tests Involving Tympanometry … Eustachian Tube Function

Assorted Applications of Admittance Measurement: Assessment of Eustachian Tube (ET) Dysfunction

- Anatomy of ET
  - Connects nasopharynx to middle ear cavity
  - Approximately 30 to 40 mm in length
  - One third bone and 2/3 cartilage
  - Lined with mucous
- Differences in ET for young children versus adults
  - ET in young children is:
    - Shorter
    - Oriented more horizontally
    - Mostly cartilage
    - More lubricated
    - Smaller lumen
  - ET matures at about 7 years
Assorted Applications of Admittance Measurement: Assessment of Eustachian Tube Dysfunction

- Function of ET
  - Pumping action of cilia lining the ET contributes to clearance of secretions from middle ear into the nasopharynx
  - Protects middle ear from nasal and pharyngeal secretions
  - Minimizes sound (vocalization) that reaches ear
  - Equalizing pressure between middle ear space and outside
    - Mucous lining of middle ear space absorbs oxygen
    - Air from mouth via ET replaces oxygen in middle ear

- Opening of the ET
  - Active opening
    - Swallowing (8 muscles are involved with veli palatini most important)
    - Yawning
    - Jaw movements
    - Poorer in children than in adults
  - Passive opening
    - Pressure gradient between nasopharynx and middle ear space (from higher to lower pressure) is exceeded and air passes through the ET
    - Common in children
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

1. Assessment of Eustachian Tube Dysfunction with Intact TM

- 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: 2. Assessment of Eustachian Tube Dysfunction with Intact TM

- **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

Assorted Applications of Admittance Measurement: 3. Assessment of Eustachian Tube Dysfunction with Intact TM

- **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
Tympanometry is a measure of input impedance or admittance of the middle ear system. The amount of energy flowing into the system is known but not how much energy is transmitted through the system. Tympanogram types do not always correlate with hearing. Very abnormal hyper-compliant $A_t$ tympanogram (e.g., monomeric TM) yet normal hearing sensitivity. Normal, perhaps shallow ($A_s$), tympanogram with significant conductive hearing loss (e.g., otosclerosis). Normal (Type A) tympanogram in a patient with dead ear. Tympanometry provides no information on most of the auditory system ... from the cochlea to the cortex.

Common Errors in Aural Immittance Measurement: Forgetting that Tympanometry is NOT a Test of Hearing

- Tympanometry is a measure of input impedance or admittance of the middle ear system.
- The amount of energy flowing into the system is known but not how much energy is transmitted through the system.
- Tympanogram types do not always correlate with hearing.
  - Very abnormal hyper-compliant $A_t$ tympanogram (e.g., monomeric TM) yet normal hearing sensitivity.
  - Normal, perhaps shallow ($A_s$), tympanogram with significant conductive hearing loss (e.g., otosclerosis).
  - Normal (Type A) tympanogram in a patient with dead ear.
- Tympanometry provides no information on most of the auditory system ... from the cochlea to the cortex.

Common Errors in Aural Immittance Measurement: Tympanometry and Acoustic Reflexes

- Introduction and historical perspective (0 – 5 minutes).
- Review of common errors in single frequency tympanometry and analysis (6 – 20 minutes).
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- Rarely applied yet clinically valuable acoustic reflex measurements (46-54).
- Questions and answers (55 – 60 minutes).
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)
  - Acoustic middle ear reflexes for infants < 4 months
  - Broad band reflectance
- Behavioral response audiometry (if feasible)
- Parental report of auditory & visual behaviors
- Screening of infant’s communication milestones

Low (226 Hz) versus High (1000 Hz) Probe Tone for Infant Tympanometry
Tympanometry in Infants and Young Children: Clinical Recommendations and Cautions

- 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 for tympanometry 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.

Common Errors in Aural Impittance Measurement: Tympanometry and Acoustic Reflexes

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Common Errors in Aural Immittance Measurement: Review of Common Errors or Deficiencies in Acoustic Reflex Measurement and Analysis

- No attempt to record acoustic reflexes in most patients
- Limited knowledge of acoustic reflex pathways
- Acoustic reflex recording in only ipsilateral condition
- Reliance on pure tone stimulus for acoustic reflex measurement rather than a BBN stimulus
- Inadequate appreciation for diagnostic value of acoustic reflex measurement in various patient populations, including newborn infants... next topic

Common Errors in Aural Immittance Measurement:
Many Audiologists Do Not Record Acoustic Reflexes in Most Patients

  - Survey responses from 156 audiologists (2008 + 2009)
  - Decrease in contralateral acoustic reflex testing over time
  - Patient discomfort reportedly common
  - Survey responses from 192 audiologists who perform APD assessments
  - >90% of audiologists evaluate APD in children
  - 69% of audiologists perform acoustic reflex threshold measurements vs. 97% who perform tympanometry
Limited Knowledge of Acoustic Reflex Pathways
Acoustic Stapedial Reflex Pathways According to Erick Borg

Common Errors in Aural Impittance Measurement:
Acoustic Reflex Recording Only in Ipsilateral Condition
Common Errors in Aural Impedance Measurement: Acoustic Reflex Recording Only in Ipsilateral Condition

- **Abnormal Acoustic Reflex**
  - Acoustic reflex patterns ("faces")
    - Conductive/efferent pattern
    - Sensory pattern
    - Neural pattern
    - Brainstem pattern

- **Crossed (contralateral)**
  - Defined by sound in ear

- **Uncrossed (ipsilateral)**
  - Probe and sound in ear

**Common Errors in Aural Impedance Measurement:**

Acoustic Reflex Recording Only in Ipsilateral Condition

- **Abnormal Acoustic Reflex**
  - Vertical pattern: Mild conductive hearing loss pattern or efferent (7th CN) pattern (normal tym and no air bone gap) on right ear

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

- **Ipsilateral (Uncrossed)**
  - Sound Right
  - Probe Right

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

- **Ipsilateral (Uncrossed)**
  - Sound Left
  - Probe Left
Common Errors in Aural Impittance Measurement: Acoustic Reflex Recording Only in Ipsilateral Condition

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

- Abnormal Acoustic Reflex

- **Right**
  - Contralateral (Crossed) Sound Right Probe Left
  - Ipsilateral (Uncrossed) Sound Right Probe Right

- **Left**
  - Contralateral (Crossed) Sound Left Probe Right
  - Ipsilateral (Uncrossed) Sound Left Probe Left
Common Errors in Aural Immittance Measurement:
Acoustic Reflex Recording Only in Ipsilateral Condition

- Abnormal Acoustic Reflex
- Horizontal pattern: Brainstem auditory dysfunction

Contralateral (Crossed)
Sound Right
Probe Left

Contralateral (Crossed)
Sound Left
Probe Right

Ipsilateral (Uncrossed)
Sound Right
Probe Right

Ipsilateral (Uncrossed)
Sound Left
Probe Left

Common Errors in Aural Immittance Measurement:
Reliance on Pure Tone Stimulus for Acoustic Reflex Measurement Rather Than a BBN Stimulus

- No attempt to record acoustic reflexes in most patients
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- Acoustic reflex recording in only ipsilateral condition
- Reliance on pure tone stimulus for acoustic reflex measurement rather than a BBN stimulus
- Inadequate appreciation for diagnostic value of acoustic reflex measurement in various patient populations, including newborn infants … next topic
Common Errors in Aural Immittance Measurement:  
*Reliance on Pure Tone Stimulus Only for Acoustic Reflex Measurement Rather Than a BBN Stimulus*


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Simplified SPAR (Sensitivity Prediction by the Acoustic Reflex)
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Common Errors in Aural Immittance Measurement: Rarely Applied Yet Clinically Valuable

Acoustic Reflex Measurements

**Acoustic Reflex Decay**

![Graph showing acoustic reflex decay](image)

- No Acoustic Reflex Decay (Normal Test Outcome)
- Acoustic Reflex Decay (Abnormal Test Outcome)

**Acoustic Reflex Amplitude**

![Graph showing acoustic reflex amplitude](image)
Common Errors in Aural Immittance Measurement:
Rarely Applied Yet Clinically Valuable
Acoustic Reflex Measurements

Acoustic Reflex Amplitude

Common Errors in Aural Immittance Measurement: Rarely Applied Yet Clinically Valuable Acoustic Reflex Measurements

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