Acoustic Immittance (ME measures)

Tympanometry
Introduction

**ME role**

- ME is aiming to transfer sound energy from the air (ear canal) to cochlear fluids (IE).

> The anatomical structures of the ME increase the force of sound wave to match the impedance of inner ear fluid (Areal ratio and Lever system)

- **Areal Ratio:** (between TM & stapes of footplate)
- **Lever system:** (Manubrium of the Malleus and long process of Incus)
Areal Ratio

- Ratio of area of TM is 20 times of area of stapes footplate

- Therefore, acoustical pressure increased at the OW

- This increment, gives about 26 dB boost

- Remember that pressure = force per unit area
  \[ \text{Pressure} = \frac{\text{Force}}{\text{Area}} \]
Lever System

- Manubrium of the Malleus & long process of Incus lie roughly in parallel with former about 1.3 time longer

- This forms a lever system supplying additional amplification

- Lever increases pressure at the short arm (Incus) with lever decreases velocity by the same proportion. Therefore, the incus long process moves 1.3 times less rapidly than the manubrium
Illustrating image
Increase in pressure and decrease in velocity at oval window will:

- Allows weak air borne vibrations to be efficiently transformed into fluid vibrations of the IE - they partially match the impedance of air in the EAM with the fluids of the IE

- This is not a perfect system!
  - A significant amount of energy is reflected rather than transmitted.
Imittance measurements assess the success of this energy transfer by monitoring the amplitude and the phase of the reflected probe tone.
Terminology

- **Impedance:**
  - It is the opposition of flow of energy in a system (OE & ME)
  - It expresses in ohms
  - It’s made up of components that are influenced by mass, stiffness and frictional resistance of the system
- **Admittance**
  
  - The ease with which the acoustic energy is transmitted within the system (OE and ME)
  
  - It expresses in mhos (ohm spelled backward)
  
  - It’s the synonym of compliance
• Immittance

- Immittance ME measures encompass measurements of both admittance or impedance (ASHA, 1979, 1990)
• **Compliance**

- It’s the inverse of stiffness, i.e. it is the ease of acoustic energy transmission

- It’s the synonym of admittance

- It’s together with static compliance are measured in equivalent volume of air in cubic centimeter (cm\(^3\)) or milliliter (ml)
How it works

- **Immittance measures are based on the notion That**;

  - When any sound delivered to the ear, part of it will be transferred through the ME and reached the cochlea and perceived as sound.

  - In the same time, some of the acoustic energy will be reflected through the TM and external ear structures.
• The amount of the reflected energy will be vary depending on the impedance of the system

• Stiffness is stated to be the dominant factor affecting the ME measures

✓ When any acoustic energy reaches the ear canal, stiffness determines how much sound delivered to the IE and how much will be reflected
When the system (OE & ME structures) **stiffer** (less compliant/ less flaccid/ less mobile), more energy will be reflected.

Conversely, **when the system is less stiff** (more compliant), more energy will be transmitted (admitted).
Applications of ME measures

1. To identify and classify the structural and functional defects within the auditory system from the external auditory canal up to the auditory brainstem

2. When it used in conjunction with other diagnostic audiological procedures, immittance measures used to:

  ✓ Identify and monitor TM immobility associated with OME
✓ Confirm diagnosis of auditory neuropathy

✓ Provide diagnostic information on facial nerve lesions

✓ Diagnosis of TM perforation

✓ Detect presence of otosclerosis
However, immittance measures cannot eliminate the need for behavioral measures (PTA, Speech tests..etc) or electrophysiological tests (ABR, ASSR..etc) and they should be used side by side.

- A patient may show normal results of immittance measures while he is suffering from bilateral SNHL.
Immittance Instrument

- It’s known as immittance audiometer or immittance bridge. However, both are inaccurate and not widely used.

- When the ear probe inserted into the ear canal, the area between the probe tip and the external ear and TM will be closed and its volume depending one:
  - Each person physical size of the ear canal
  - The insertion depth of the probe tip

- The probe inserted into the ear canal using probe tip to obtain hermetic seal
Acoustic Immittance Instrumentation

- Block diagram

Figure 18–3  Principles of immittance measurement in the probe ear (see text for description).
• The probe tip connected to the Immittance instrument which has 4 tubes;

1. Oscillator (1) and loudspeaker (2a):
   - To introduce the pure tone to the ear canal

2. An air-pump and manometer (4a):
   - To change the air pressure in the ear canal to measure the mobility of eardrum and ME structures
3. A microphone (5a) and system analyzer (6):
   - To compute the immittance measures (elicit the responses)

4. Ipsilateral acoustic reflex eliciting system (7a) and (7b):
   - Which introduce a signal into the ear canal to elicit the ipsilateral acoustic reflexes
The immittance probe measures the stiffness or the static admittance of ME system as following:

- A probe tone of 220/226 Hz generated by the oscillator and produced by the loudspeaker
This tone introduced to the ear canal by the probe tip port (2b)

Some energy will be transmitted (admitted) to the inner ear and some will be reflected depending on the condition of the ear canal and ME

The reflected energy will be sent through the second port of the probe tip (5b) and delivered to the microphone and the system analyzer to identify different features of the response (intensity, voltage..) that is resulted from the signal
• These measures can be obtained as TM in resting (static) position

• TM moving as the pressure changed by the pressure pump and it measured using the manometer (Tympanometry)

• Contraction of stapedial muscle in response to loud signal that is delivered to either probe ear (7) – ipsilateral or contralateral to probe ear (insert earphone) and these recorded via the system analyzer (acoustic reflexes)
Test might take about 1 minute for each ear and the collected data will be presented on device screen and it could be printed in hard copy format.
Responses indications

- **If higher amount of energy reflected**, the system stiffer (less compliant) than normal like in otitis media and ossicular fixation.

- **While, less reflection**, indicates less stiff or more compliant system like ossicular dislocation or discontinuity and flaccid TM.
Tympanometery

- **Tympanograms**
  - Are the graphic display of eardrum mobility as a function of mechanical variation of air pressure in hermetically sealed external ear canal

- Tympanometery originally measures the eardrum mobility in cm³, which measures it now in ml
A tympanogram is plotted by introducing a positive air pressure (+200 dapa) into the probe ear and reducing it to negative pressure ( -200 to -300 dapa)

Compliance obtained depending on the amount of reflected energy

Tympanogram shape affected by ME system stiffness
Pressure/admittance (compliance) principle

- Understanding the principle of pressure/compliance will clarify how varying air pressure affects the amount of reflected energy.

- Check the following graph.
Illustrating graph for pressure/admittance relationship

Figure 18–5 Schematic representation of how varying air pressure in the external ear canal affects the stiffness of the eardrum and the reflected energy of the probe tone (see text for description).
The graph shows:

• **The amount of reflected energy will be the lowest, when the pressure in the external ear canal is at atmospheric pressure (0 dapa) in normal ear;**

  1) There is an equal pressure between external ear canal and ME cavity (pressure equal across the TM)
2) The amount of absorbed energy from the probe tone by the TM and ME is at the highest level

3) The amount of reflected energy from the probe tone is at the lowest level
However, when positive or negative pressure introduced into the external ear canal, the normal TM will be stretched and stiffened,

- As the system stiffened, the compliance decreased and the amount of reflected energy increases.

- The amount of reflected energy is highest at +200 and – 300, static admittance at the lowest point.
Results interpretation and Tympanograms classification

- In tympanogram, the compliance in ml on the y-axis and the pressure in dekapascals (dapa) is on the x-axis

- **Jerger (1970)** has categorized the tympanometric results into different types (classical description), that relay on the tympanogram shape
• **Type A:** (large inverted V shape)
  
  - The point of greatest compliance is at 0 dapa (normal pressure)
  - Seen in subjects with normal middle ear functions

• **Type As:** “s” stands for stiffness or shallow
  
  - Normal pressure (0 dapa) or near to 0
  - Shallower peak than type A
  - Seen in patients with immobile stapes
Type AD: “D” stands for discontinuity or deep

- In some cases the amplitude of the curve is unusually high or in other cases, the positive and negative sides of the spikes do not meet at all
- Associated with TM flaccidity or separation of the ME bones
• **Type B**

- The point of greatest compliance cannot be found

- It’s seen in the following cases:
  - ME fluids
  - Wax blocking the external ear canal
  - Small amount of wax or debris blocking the tiny tube of the probe
  - Hole within the TM
- **Type C:**
  - When the pressure falls below the normal
  - The TM become most compliant at negative pressure
  - Maximum compliance recorded at negative pressure (-200 dapa)
Occasionally, the peak found at positive pressure

- possibly seen in crying babies or subjects who are blowing their noses
- It should be resolved in short time
- If it persists for long time ask for medical advise
Extra information

- In some cases, incorrect flat shape tymanogram resulted and truly it’s extreme negative ME pressure
  - Extending the negative pressure sweep to -400 dapa might provide useful information to seek for the appropriate medical referral

- Direction of pressure sweep from negative to positive or vise versa may influence results interpretation
  - From negative to positive, the wave peak is lower than from positive to negative. However, it is rarely affecting the results
Graph representing shapes of tympanograms types

![Graph showing tympanograms types](image.png)
### Table summary for classical tympanogram types

<table>
<thead>
<tr>
<th>Tympanogram Type</th>
<th>Compliance (mL)</th>
<th>Static Admittance</th>
<th>Peak Pressure (daPa)</th>
<th>Clinical Audiologic Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A</td>
<td>0.4 to 1.5</td>
<td>0.27 to 2.8</td>
<td>+50 to −150</td>
<td>Represents normal middle ear function; the peak (point of maximum compliance) occurs within normal static admittance limits and at pressures between +50 to −150 mm H₂O</td>
</tr>
<tr>
<td>Type A₁</td>
<td>0.4 to 1.5</td>
<td>&lt;0.27</td>
<td>+50 to −150</td>
<td>Represents abnormal stiffness in the middle ear system, resulting in a fixation of the ossicular chain as in otosclerosis; static admittance measures are abnormally low</td>
</tr>
<tr>
<td>Type A₂</td>
<td>0.4 to 1.5</td>
<td>&gt;2.8</td>
<td>+50 to −150</td>
<td>Represents a flaccid tympanic membrane resulting from scar tissue or a possible disarticulation of the middle ear ossicles; compliance measures are abnormally high</td>
</tr>
<tr>
<td>Type B (perf)</td>
<td>&gt;1.5</td>
<td>&lt;0.27</td>
<td>No peak</td>
<td>Represents some pathological condition exists in the middle ear; static compliance (admittance) measures are abnormally low, but initial compliance values are high</td>
</tr>
<tr>
<td>Type B (o.m.)</td>
<td>&lt;0.4</td>
<td>&lt;0.27</td>
<td>No peak</td>
<td>Represents restricted tympanic membrane mobility and would indicate that some pathological condition exists in the middle ear; static compliance measures are abnormally low</td>
</tr>
<tr>
<td>Type C</td>
<td>0.4 to 1.5</td>
<td>0.27 to 2.8</td>
<td>−200 or worse</td>
<td>Represents significant negative pressure in the middle ear cavity (considered significant for treatment when more negative than −200 mm H₂O); this may indicate a precursor or resolution of otitis media; compliance measures are usually within normal limits</td>
</tr>
</tbody>
</table>

*perf*, tympanic membrane perforation; *o.m.*, otitis media.
Another way to approach tympanograms classification

- Classical classification that relies on the tympanogram shape has some negative points:
  - It’s more subjective
  - It’s qualitative

- For that, more audiologists prefer more quantitative method

>>>>>
Method relies on measures of Tympanometric peak pressure (TTP), tympanometric height (compliance) and calculation of tympanometric width (TW) (check following table)

<table>
<thead>
<tr>
<th>Age</th>
<th>Admittance/Compliance</th>
<th>TW (daPa)</th>
<th>V_\text{ea} (cm^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children (3 to 10 years)</td>
<td>0.25 to 1.05</td>
<td>80 to 159</td>
<td>0.3 to 0.9</td>
</tr>
<tr>
<td>Adults (18 years and older)</td>
<td>0.30 to 1.70</td>
<td>51 to 114</td>
<td>0.9 to 2.0</td>
</tr>
</tbody>
</table>

*Data from Margolis & Hunter, 2000.*
Multi-frequency Tympanometry

- **Probe tone of 226 Hz** is used for standard clinical practice because

  - This frequency is most effective for general identification of
    a) TM abnormalities like (perforation)
    b) ME conditions (effusion and abnormal pressure) and
    c) Estuation tube dysfunctions in many patients
• However, studies showed that single frequency tympanometery is sometimes not enough to diagnose the high impedance pathologic conditions affecting the ossicular chain like neoplasms, otosclerosis and ossicular fixation

• As a result, probe tones that sweep through frequencies 200 to 2000 Hz has been suggested for more accurate diagnosis
Multi-frequencies tympanometry showed improvement in audiological diagnosis. Especially for patients with restricted TM mobility.

However, up to now, the audiologists failed to embrace the use of multi-frequency tympanometry as a routine assessment tool.
Tympanometery in infants

- Researches and clinical data have documented that recording the tympanometry from newborn infants is widely different from that in older infants, toddlers, and children.

- Tympanograms obtained from infants less than 6 months using 226 Hz probe tones are not sensitive to ME disorders and this might be due to
Incomplete ossification of external auditory canal and ossicular chain mechanisms

TM orientation

Fortunately, tympanograms obtained with high frequency probe tones (660 to 1000 Hz, 1000 is more recommended) are accurate in diagnosing ME and OE status in infants from 0 to 4 or 6 months
Responses interpretation

- Positive peak, negative peak or indeterminate