Sonotubometry: Eustachian Tube Ventilation Function Test

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Fig. 1. Eustachian tube patency test by Gruber (1870)
Valsalva Test

- Visual inspection of the tympanic membrane while forced expiration with the mouth closed and the nose occluded by the thumb and forefinger.

- Positive ➔ when an intact tympanic membrane is observed moving, or by air heard through a perforated TM.
Valsalva Test
Politzer Test

- Visual inspection of the tympanic membrane while compressing one naris into which the end of a rubber tube attached to an air bag
- Repeat the letter K or to swallow while air is injected into the nasal cavity
- Positive → the overpressure that develops in the nasopharynx is transmitted to the middle ear
Toynbee Test

- Visual inspection of the tympanic membrane while the patient swallows with their nose manually occluded
- Negative middle-ear pressure or temporary negative middle ear pressure followed by return to ambient pressure → normal eustachian tube function
Eustachian Tube Catheterization

- Eustachian Catheter
Other Tests

- Pneumatic otoscopy
- Nasopharyngoscopy
- Imaging (CT, MRI …)
Non-intact Tympanic Membrane Test

- Forced Response Test
- Pressure Equilibration Test
- Clearance Test
- Nine-step Inflation-Deflation Test
Forced Response Test

- Measures the pressure at which the ET opens passively when the middle ear pressure is increased

Pressure Equilibration Test

- Measures the ability to equilibrate positive and negative pressures applied to the middle ear
Clearance Test

- Contrast medium was instilled into the middle ear via a drumhead perforation and 1 scan/sec taken during swallowing
  1) Movement of the cartilaginous portion
  2) Contrast medium in the ET
     ① Movement present, contrast medium seen in ET
     ② Movement absent, contrast medium present in ET
     ③ Movement present, no contrast medium in the ET
Nine-step Inflation-Deflation Test

- A tympanometer is used to measure the resting middle ear pressure.
- A negative pressure of -300 mm H2O is applied to the external auditory canal to create relative overpressure in the middle ear. Repeated with the application of a positive pressure.
- In a physiologically normal middle ear and auditory canal, the pressure normalizes to the resting pressure after the subject swallows three times.
Intact Tympanic Membrane Test

- Pressure Chamber Technique
- Tube-tympanoaerodynamic Graphy
- Tympanometry
- Sonotubometry
Tube-Tympano-Aerodynamic Graphy (TTAG)

- Using pressure transducers, simultaneous recording of the pressure in the external ear canal and the nasopharyngeal cavity was made during Valsalva's maneuver.
Sonotubometry

- Politzer introduced the principle of sonotubometry in 1869
- Holding a tuning fork in front of the nostrils of a test subject → the sound could be heard more loudly when the test subject swallowed
- The ET opened during swallowing and conducted more sound through the ET into the middle ear
Sonotubometry

- Perlman used low-frequency sounds to evaluate ET conductance
- Test sounds were transmitted through a rubber tube into the nasal cavity
  → the response was affected by the length of the rubber tube, because of resonance
Sonotubometry

- Naunton and Galluser: adjusting the length of the tube according to the wavelength of the sound (1967)
- A 38-mm thick wooden box around the ear microphone
  → still the risk that the microphone would pick up unwanted noise
Sonotubometry

- Elpern et al.: used a filter set with a center frequency of 200 Hz and bandwidth of 3.7 dB
- Satoh et al.: designed a tight attachment for the microphone to the ear and taped the speaker hermetically to the nostril
Sonotubometry

- Virtanen: the first investigator to suggest the use of frequencies in the range of 1 to 20 kHz to examine ET function (1978)
- Physiological swallowing: produced sounds in the range of 100 to 2000 Hz that interfered with test sounds in the same frequency range
- Frequencies in the range of 6 to 8 kHz were most suitable to measure opening of the ET
Sonotubometry -- Methods

- An earphone: could generate a continuous sound of 6, 7, or 8 kHz → inserted into the nostril of the test subject
- Sound source: was fixed tightly within the nostril to minimize sound leakage
- A microphone embedded in a circumaural ear muff was placed in the ipsilateral external auditory canal
Sonotubometry -- Methods

- The microphone and insert earphone were connected to a heterodyne analyser (consisted of an analyser and a frequency oscillator).
- A continuous tone generated by the oscillator with filter set the earphone inserted into the nose.
- Test sound the external auditory canal picked up by a calibrated condenser microphone connected to a preamplifier a sound level recorder.
Sonotubometry -- Methods

- The test subject sat in a quiet room with his or her mouth closed and without moving the head.
- He/she was asked to swallow water while the sound signal in the external ear was being recorded continuously.
- Opening of the tube was reflected → sudden increase in signal in the external ear canal (5 dB).
Sonotubometry -- Results

- Virtanen (1978): 106 ears in 60 healthy subjects → ET opening was considered to have occurred in 90%
- Okubo et al. (1987):
  1) 32 women without otological diseases: ET opening occurred in 89%
  2) 89 normal children: ET opening occurred in 65%
- ET does not necessarily open with each swallowing
- Subjects must be correctly instructed about how to swallow, and the tests must be performed with appropriate intervals
Sonotubometry -- Results

- Jonathan (1989):
  - Tubal function to be normal:
    1) Otologically healthy children: 80%
    2) Children with otitis media with effusion: 29%

- Sonotubometry was feasible and easy to perform in all the children
Sonotubometry -- Results

- Palva et al. (1987): compared pure tones of 6, 7, and 8 kHz and band noise frequencies of 6.5 to 8 kHz → band noise frequencies: less time-consuming
- The mandible-down movement produced poorer results than swallowing
- 44 ears before tympanomastoid surgery and followed up for a period of 4 years after surgery:
  - 70%: positive preoperative response → good surgical outcome and remained well aerated after surgery
  - 30%: poor preoperative response → preoperative otoscopy detected many adhesive changes in the posterior part of the tympanic membrane
Sonotubometry -- Results

- Jonathan: investigated the predictive value of sonotubometry for successful myringoplasty → no significant difference
- All the patients with poor preoperative ET function in whom surgery was successful showed normal postoperative ET function
- Mondain et al. (1997): a portable device to record ET opening → longitudinal evaluations of ET ventilatory function
- Opening occurred 21.7 times (mean value) in 15 minutes
Sonotubometry -- Results

- van Heerbeek N (2007):
- 25 otologically healthy adults, before and after applied histamine to the nasopharyngeal ostium of the ET

→ Sonotubometry is capable of detecting intra-individual changes in ET function
Sonotubometry
Sonotubometry -- Results

![Box plot showing the number of openings before and after histamine application, and the difference between the two.](image)
Sonotubometry v.s. Other Ventilatory Function Tests

- Jonathan et al.: compared sonotubometry with tympanometry in otologically healthy adults → found a high degree of correlation between the two methods
- Jonathan: compared healthy children and children with OME with several ET function tests → sonotubometry and tympanometry had greater specificity than the other function tests (PTA & otoscopy) to predict the presence of OME
Sonotubometry v.s. Other Ventilatory Function Tests

- McBride et al.: compared sonotubometry to the nine-step inflation-deflation test
- 107 otologically healthy young adults
- The nine-step inflation-deflation test: better reproducibility than sonotubometry (52% vs. 34%)
- 78% of the subjects, there was correlation between the results of the two tests
- A combination of the two function tests enabled ET function evaluation in 96% of these healthy subjects
Conditions that Influenced Test Results

- Virtanen (1983): performed sonotubometry on subjects who were lying down or sitting up → no significant differences

- Leider et al.: compared the effect of dry swallowing and 10-cc bolus swallowing and the effect of the position of the head → no significant differences
<table>
<thead>
<tr>
<th>Series (Ref. No.)</th>
<th>Test frequency (Hz)</th>
<th>Loudness (dB)</th>
<th>Population</th>
<th>No. of ears</th>
<th>No. of swallows</th>
<th>Response (%)</th>
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<tbody>
<tr>
<td>Naunton and Galluser, 1967</td>
<td>200</td>
<td></td>
<td>Healthy adults</td>
<td>15</td>
<td></td>
<td>53</td>
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<tr>
<td>Satoh et al., 1970 (25)</td>
<td>2000</td>
<td>Max, 130</td>
<td>Healthy adults</td>
<td>31</td>
<td></td>
<td>74</td>
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<tr>
<td>Virtanen 1978</td>
<td>6000–8000</td>
<td>100–112</td>
<td>Healthy adults</td>
<td>106</td>
<td>6</td>
<td>90</td>
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<tr>
<td>Holmquist et al., 1981 (27)</td>
<td>6000–8000</td>
<td>100</td>
<td>Healthy adults</td>
<td>187</td>
<td>6</td>
<td>66</td>
</tr>
<tr>
<td>Okubo et al., 1987 (30)</td>
<td>5000–9000</td>
<td>Max, 125</td>
<td>Healthy females</td>
<td>51</td>
<td>2</td>
<td>89</td>
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<tr>
<td>Okubo et al., 1987 (30)</td>
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<td>Max, 125</td>
<td>Healthy children</td>
<td>178</td>
<td>2</td>
<td>65</td>
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<td>Palva et al., 1987 (31)</td>
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<td>115</td>
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<td>64</td>
<td>5</td>
<td>80</td>
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<td>Jonathan, 1989 (29)</td>
<td>?</td>
<td></td>
<td>Healthy children</td>
<td>50</td>
<td>5</td>
<td>80</td>
</tr>
<tr>
<td>Jonathan, 1989 (29)</td>
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<td></td>
<td>Glue ear, children</td>
<td>126</td>
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<td>29</td>
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<td>Mondain, 1997 (36)</td>
<td>8000</td>
<td>100</td>
<td>Healthy children</td>
<td>240</td>
<td>Variable</td>
<td>63</td>
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<tr>
<td>Munro et al., 1999 (37)</td>
<td>7000–8000</td>
<td>100</td>
<td>Healthy children</td>
<td>20</td>
<td>6</td>
<td>80</td>
</tr>
</tbody>
</table>
Discussion

- Most of ventilatory function test of the ET:
  1) Can only be performed on ears with a perforated tympanic membrane or a ventilation tube in situ
  2) Can not measure ventilatory ET function under physiological circumstances
  3) Cause an uncomfortable feeling for the test subject, which is a particular disadvantage in children
Discussion

- **Sonotubometry:**
  1) Can be performed in patients with or without an intact tympanic membrane and under physiological conditions.
  2) Inexpensive, painless, and easy to perform in both adults and children.
  → great potential value as a diagnostic tool for individuals with suspected ET disease.
Discussion

- Virtanen: frequencies of at least 5 kHz did not suffer interference from physiological sounds caused by swallowing.
- One or more than one recorded opening was considered to be a positive result (in less than 6 times).
- → 90% of adults and 65% of children with well-aerated middle ears.
Discussion

- Validity and reproducibility: still require further confirmation
  1) Increasing the number of times the subjects swallow during measurement
  2) Scaling the opening frequency according to whether a group has good or poor ET function
- How many times the ET must open in 24 hours to maintain the correct middle ear pressure remains unknown
Conclusion -- Sonotubometry

- Can be performed in patients with or without an intact tympanic membrane
- Can measure ventilatory ET function under physiological circumstances
- Can detect intra-individual changes in ET function
- Is more feasible and easier to perform in children
- Further study is needed to improve the validity and reproducibility
Thank You !!
References

References