SONOTUBOMETRY IN CHILDREN AND JUVENILE PATIENTS

E. Di Martino¹, V. Nath¹, A. Telle³, Ch. Antweiler², L. E. Walther³, P. Vary²
¹ Department of Otorhinolaryngology Head and Neck Surgery DAKKO Hospital Bremen, Germany;
² Institute of Communication Systems and Data Processing, Aachen University, Aachen, Germany;
³ Centre of Otorhinolaryngology, Sulzbach, Germany

Introduction
Middle ear and Eustachian tube (ET) work as a single functional unit. The latter is physiologically supporting the former in ventilation, protection and drainage. An impaired ET function is an important factor in the pathogenesis of different middle ear diseases, especially in children and juvenile patients. Since physiology and the impact of ET alterations on the pathogenesis of middle ear diseases are not fully understood, several methods such as tympanometric, manometric, radiologic and sonographic approaches have been developed for the evaluation of the ET function. Most methods used in clinical routine study pressure variations in the middle ear. One major drawback of many methods is that they cannot be applied in both patients with an intact and patients with a perforated eardrum. Sonotubometry is a non-invasive method that offers an assessment of the Eustachian tube (ET) function under physiological conditions. It is based on the passage of a sound through the ET and its recording in the external ear canal.

Patients and Methods
Sonotubometric studies were performed with a custom – made device in 45 otologically healthy individuals:
- Group I: 14 children (6 – 9 years)
- Group II: 31 individuals (10 – 15 years)

Signal application:
Perfect sequences (PSEQ) PSEQs are periodically repeated pseudo noise signals, that are used for acoustic control in mobile communication systems and system identification. Manoeuvres performed in order to induce an ET opening:
- Valsalva
- Dry swallowing
- Water swallowing
- Valsalva manoeuvre

Results
A total of 754 measurements was performed. A multivariate analysis was done for statistical evaluation.
Differnt sonotubogram types could be observed:
- Spike-type sonotubogram
- Double-peak type sonotubogram
- Descendant type sonotubogram
- Plateau curve type sonotubogram
- Multi-peak type sonotubogram

Association of two sonotubogram type in 81.7% measurements an ET opening could be registered:
- Yawning – 85.6 %
- Dry swallowing – 92.5 %
- Water swallowing – 93 %
- Valsalva – 59.1 %

Decongestion of the nose did not cause better results (p< .08)
Regarding the side of signal application there was no significant difference found for the measured signal intensity in either ear (p< .15)
Group I performed significantly worse in Valsalva (59.7 %) due to the patients compliance

Discussions
Acoustic signals offer an alternative for an observation under physiological condition of ET activity. As demonstrated in some of our previous studies, the application of an 8 kHz signal is not reliable enough for the use in practice.

The implementation of a new kind of noise signals, the so-called perfect sequences (PSEQ) show that special signals significantly enhance the use of sonotubometry for clinical application.
Sonotubometry with PSEQs detects ET activity in normal children with a high reliability. Swallowing and yawning are best to provoke an ET opening. Valsalva is not a feasible manoeuvre in younger children due to an limited compliance.
The study demonstrates that this new method is feasible for adults but also for children.

Since ET undergoes profound changes during skull growth this new approach may contribute to a better understanding of the physiology in the developing organ.

Fig. 1 - Sonotubometric device

Fig. 2, 3 – Evaluation of ET function by sonotubometry with perfect sequences (PSEQ) in children

Every sonotubogram was analysed according to its characteristic shape, objective tone increase, and opening duration of the auditory tube for all manoeuvres.

In order to increase reliability of the measurement three different sound levels were defined on the sonotubogram:

Quiet level (no pure tone/PSEQs applied)
Passive level (pure tone/PSEQs, no manoeuvre)
Peak level (maximum over all curves)

Every performed manoeuvre was signalised by the patient with a instantaneously button press and the moment was visualised on the graphic by a red vertical line

Table 1 – Distribution of registrable ET openings according to the performed manoeuvres

<table>
<thead>
<tr>
<th>Manoeuvre</th>
<th>On the sonotubogram registrable ET opening (%)</th>
<th>Group I</th>
<th>Group II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yawning</td>
<td>88.5 %</td>
<td>84.1%</td>
<td></td>
</tr>
<tr>
<td>Dry swallowing</td>
<td>94.2 %</td>
<td>97.1%</td>
<td></td>
</tr>
<tr>
<td>Water swallowing</td>
<td>94.8 %</td>
<td>92.1%</td>
<td></td>
</tr>
<tr>
<td>Valsalva</td>
<td>69.8 %</td>
<td>56.9%</td>
<td></td>
</tr>
</tbody>
</table>

Conclusion
The application of PSEQs can detect ET activity with a high sensitivity and specificity. Thus it enhances the possibilities for clinical use and research on ET physiology. Further work on otologically affected patients are needed in order to determine whether or not sonotubometry with PSEQs can be considered a useful predictor of the return of normal ET function.

Fig. 4 - Spike-type sonotubogram

Fig. 5 - Double-peak type sonotubogram

Fig. 6 - Descendant type sonotubogram

Fig. 7 - Plateau curve type sonotubogram

Manoeuvre | Median increase of sound intensity |
-----------|----------------------------------|
Yawning    | 7.63 dB                          |
Dry swallowing | 10.02 dB                         |
Water swallowing | 11.04 dB                        |
Valsalva   | 9.89 dB                          |

Table 2 – Median increase of sound intensity in different performed manoeuvres

Fig. 8 – Inadequate sonotubogram due to background noise pollution

References: