Sonotubometry in Children With Otitis Media With Effusion Before and After Insertion of Ventilation Tubes

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Objectives: To test the outcome of sonotubometric measurement in children with otitis media with effusion (OME) before and after insertion of ventilation tubes.

Design: Eustachian tube ventilatory function was tested in children with OME. To test validity, sonotubometric testing took place before insertion of ventilation tubes (ie, glue ear) and 1 week and 3 months after grommet insertion (ie, aerated middle ear cavity). One set of measurements consisted of 10 acts of swallowing. The outcomes of the tests were compared with those in otologically healthy controls.

Settings: All testing took place during an outpatient clinic otorhinolaryngologic consultation in a city hospital.

Patients: Thirty-three children with OME and 61 otologically healthy children (controls).

Interventions: Surgical grommet insertion.

Main Outcome Measures: Sonotubometric measurements before and after insertion of ventilation tubes.

Results: Fewer incidences of the opening of the eustachian tube were recorded in the measurements before insertion of ventilation tubes compared with after insertion. The number of incidences of opening recorded after insertion of ventilation tubes did not significantly differ from measurements in healthy controls.

Conclusions: Sonotubometric testing in children with OME reveals a low incidence of eustachian tube opening. Shortly after insertion of ventilation tubes, sonotubometry revealed no difference in eustachian tube ventilatory function compared with measurements in healthy controls. The low incidence of eustachian tube opening before grommet insertion may be attributable to decreased opening or dampening of the sound transmission by the middle ear fluid.


Otitis media with effusion (OME) is a common disease during childhood. Before the age of 4 years, almost every child experiences at least 1 period of OME.1 As a result of this high incidence of OME, it has become a frequent indication for surgical intervention, such as myringotomy, insertion of ventilation tubes, and adenoidectomy in young children.2,4 Disturbance of eustachian tube (ET) function is assumed to play an important role in the development of OME.3,8 Other factors involved include viral and bacterial exposure and a deficient or immature immune status. One of the functions of the ET is equilibration of pressure changes in the middle ear.3,9 At rest, the tube is normally closed, but regular active opening due to contraction of the paratubal muscles allows this equilibration of pressure changes and ventilation.

Earlier studies9 concluded that poor ET function was more a causal factor than a result of OME because the active and passive opening functions of the ET did not improve after grommet insertion but remained at the same poor level after 3 months. Apparently, some children, such as those with cleft palate, are predisposed to have poor ET ventilatory function, which makes them susceptible to the development of OME and perhaps to other middle ear diseases as well.

Unfortunately, in daily otorhinolaryngologic practices no valid test is available to assess ET ventilatory functioning. Eustachian tube function has been studied extensively using manometric function tests,10,14 and sonotubometric tests,15,20 but neither method has proven to be satisfactory. Sonotubometric testing has several ad-
The main advantage is that sonotubometric testing is performed under physiologic circumstances (ie, without applying non-physiologic pressures to the middle ear). In addition, it can be performed on ears with an intact tympanic membrane and is well tolerated by adults and children. Sonotubometry is based on the principle that sound applied to the nasopharyngeal ostium of the ET is conducted through the ET to the middle ear. During active opening of the ET, more sound will be conducted, which means that higher levels of sound can be recorded in the external auditory canal. Recently, the testing method has been studied using modern and more sensitive microphones and sound sources. These technical improvements resulted in high sensitivity in the recording of tubal opening in otologically healthy adults and children, with reproducible results. Because decreased ET ventilatory functioning is considered to be 1 of the factors contributing to OME, it will be of great value to test this method in children with OME before and after insertion of ventilation tubes.

The aim of this study was to evaluate whether ET ventilatory function can be measured in children with OME by means of sonotubometric testing. The outcomes of sonotubometric measurements before and after insertion of ventilation tubes are compared. The outcomes of these measurements are also compared with results of an earlier study regarding sonotubometric testing in otologically healthy children.

**METHODS**

A group of 33 children (20 boys and 13 girls) who underwent an outpatient clinic otorhinolaryngologic consultation and who were diagnosed as having OME during a period of at least 3 months were included in the study. Eighteen of these patients had undergone previous insertion of ventilation tubes. The OME was confirmed by means of history taking, otoscopic findings, audiometric testing (30- to 40-dB conductive hearing loss), and tympanometric testing (type B). Children with complaints of nasal obstruction due to adenoid hypertrophy, allergic rhinitis, or viral infection were excluded from participation in the study. The children were between 4 and 9 years of age, with a mean age of 5 years 8 months at the time of the first measurements. Surgical grommet insertion was planned for all the children. Before undergoing this intervention, each child was tested by an investigator (S.v.d.A.) by means of an updated sonotubometer on the side with the worst audiogram result. One week after grommet insertion, the position of the grommets and aeration of the middle ear were checked, and the measurements with the sonotubometer were repeated in an identical manner as before by the same investigator. The same procedure was also repeated 3 months after grommet insertion.

The sonotubometer used in this study has been described in our earlier studies and has specific properties. To minimize interference with sounds that occur during swallowing, the test tone should be of high frequency, above 5 kHz. However, such high-frequency pure tones might cause standing waves in the occluded external ear canal, which would compromise probe tube microphone measurements. Therefore, we applied high-frequency narrow band noise instead; the test signal comprised filtered white noise with a center frequency of 7 kHz, a bandwidth of 5.5 to 8.5 kHz, and slopes of 48 dB per octave. This test signal was delivered to the nasopharyngeal ostium using an Ear Tone 3A insert phone (E-A-R Auditory Systems, Indianapolis, Indiana) that was fixed with a foam ear tip in 1 of the nostrils. A probe tube microphone (Etymotic Research, Inc, Elk Grove Village, Illinois) was placed in the ipsilateral external auditory canal and fixed with a foam ear tip to minimize interference with...
cordings of 10 acts of swallowing was the outcome of the test moments were recorded carefully. The number of positive re-
as a sign at the moment they were supposed to swallow, and these
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structed to swallow some water at intervals of 10 seconds while
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counted as an opening of the ET, the level of the peak had to
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level was determined by the calculation of the standard devia-
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nose during swallowing. Hence the present setup is free of ir-
herein. No change in sound pressure level was detected in the
sure level was measured after bandpass filtering as described
brated) probe tube microphone during pilot experiments. This
level was chosen because the test signal had to be loud enough
be detected by the probe microphone in the external ear ca-
ual during ET opening; however, the test signal needed to not
be so loud that it would prevent direct airborne stimulation of
the microphone. According to the specifications, the foam ear
tips used to connect the speaker to the nostril and to position
the probe tube microphone to the ear canal attenuate sounds
in the 6- to 8-kHz range by 40 dB each. Therefore, the direct
airborne stimulation of the microphone was considered
negligible.

Additional measurements were taken to study the time course
of the intensity of the test signal in the nose during swallow-
ing. Therefore, the microphone and the sound source were
placed in the same nostril. During swallowing the sound pres-
sure level was measured after bandpass filtering as described
herein. No change in sound pressure level was detected in the
nose during swallowing. Hence the present setup is free of ir-
relevant auditory data that might have occurred by either sounds
of swallowing or sound pressure changes that might have oc-
curred owing to changes in the acoustic conditions in the nose
during swallowing.

First, positive peaks in the microphone recordings in the
ear canal were identified from the registrations by online mark-
ing peaks that occurred during the act of swallowing. Second,
offline, the difference in microphone output between a pos-
sible peak and baseline was tested for significance. Then from
a characteristic period between acts of swallowing, the noise
level was determined by the calculation of the standard devia-
tion from the baseline of the sampled noise amplitude. To be
counted as an opening of the ET, the level of the peak had to
exceed 3 times the standard deviation of the noise.

To evaluate the opening of the ET, all the children were in-
structed to swallow some water at intervals of 10 seconds while
in a sitting position. For that purpose, the children were given
a sign at the moment they were supposed to swallow, and these
moments were recorded carefully. The number of positive rec-
CORDINGS OF 10 ACTS OF SWALLOWING WAS THE OUTCOME OF THE TEST
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IN A SITTING POSITION. FOR THAT PURPOSE, THE CHILDREN WERE GIVEN
A SIGN AT THE MOMENT THEY WERE SUPPOSED TO SWALLOW, AND THESE
MOMENTS WERE RECORDED CAREFULLY. THE NUMBER OF POSITIVE RECORDINGS OF 10 ACTS OF SWALLOWING WAS THE OUTCOME OF THE TEST AND COULD RANGE FROM 0 TO 10.

In this study each child was tested 3 times: 1 week before, 1 week after, and 3 months after grommet insertion. The outcomes of the sets of measurements before and after grommet insertion were analyzed with a commercially available software program (SPSS 12.0.1; SPSS Inc, Chicago, Illinois), and the distributions of differences (mean [SD] difference) before and after were compared using a t test for paired samples. The mean outcomes of the measurements in the group of children with OME were also compared with those of a control group consisting of 61 otologically healthy children (29 boys and 32 girls; mean age, 6 years 4 months) tested in an earlier study.21

Figure 2. Outcomes of sonotubometric measurement. Outcomes of measurements before (group 1), 1 week after (group 2), and 3 months after (group 3) grommet insertion in children with otitis media with effusion, and the outcomes of sonotubometric measurements in an otologically healthy control group (group 4). Score represents the number of incidents of the opening of the eustachian tube. Error bars indicate standard deviation.

Figure 2 shows the results of the measurements in the 33 children with OME before and 1 week and 3 months after grommet insertion and the measurements in the 61 members of the control group. Sonotubometric measurements were performed successfully in all the children in all sets of measurements. In the first set of measurements (ie, those made before the insertion of grom-

In previous studies,21 we tested whether a revised setup for sonotubometric measurement was a feasible and reproducible method to use in the assessment of ET ventilatory function in otologically healthy adults and chil-

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recorded incidences of the opening of the ET after 1 week. Three months after intervention, the data concerning the recorded incidences of the opening of the ET were at the same level as those gathered after 1 week. The results of sonotubometric measurements taken after 1 week and those taken after 3 months after ventilation tube insertion do not differ from sonotubometric results in otologically healthy children but there is a significant difference compared with the outcomes of the measurements before insertion of ventilation tubes (ie, when the children had glue ear). This difference seems to be related to the presence of glueylike fluid in the middle ear cavity at the time of the first measurements. Two possible explanations can be brought forward. First, perhaps in both situations the ET opens with the same frequency, but we do not have the ability to adequately record these incidences in patients with glue ear. This could occur because the glueylike fluid in the middle ear cavity partly absorbs or reflects the increase in sound after the opening of the ET as a result of the difference in impedance between air and the fluid. In this case, false-negative results would be measured. After removal of the glueylike fluid, these incidences of opening can be recorded correctly and cause a significant difference in outcome between the 2 sets of measurements. A second potential explanation is that there are fewer incidences of the opening of the ET before the insertion of ventilation tubes. The presence of glueylike fluid and lower pressure in the middle ear could require stronger forces for the ET to be opened. Ventilatory function could be renewed by the removal of glueylike fluid and pressure equilibration of the middle ear cavity.

Although overall fewer tubal openings could be recorded in patients with glue ear, some incidences of tubal opening could be recorded in certain patients. The questions are why incidences of tubal opening can be recorded in some cases and what might be the significance of this regarding the course of OME. Perhaps the viscosity of the fluid or the amount of middle ear effusion is a factor in the outcome of the measurements. Perhaps the children in whom incidences of ET opening can be recorded are the children who do not need a second or third insertion of ventilation tubes. To answer these questions, a study should be designed with a follow-up of several years and with attention to the properties of the removed middle ear fluid at the time of the surgical intervention, such as the volume and viscosity of the fluid.

Our study found no difference in ET ventilatory function between otologically healthy children (controls) and children with persistent OME who had undergone insertion of ventilation tubes. Perhaps this finding questions whether the healthy controls in past studies may have had OME but did not have clinical symptoms. If so, their hearing loss could have been less obvious, thus there had not been a reason to report symptoms nor to seek otorhinolaryngologic consultation. If this were the case, it would mean that ultimately, the 2 groups do not differ much from each other, but the overall poorer functioning of the ET in children compared with that of adults makes all children more susceptible to OME.

The fact that ET ventilatory function does not significantly differ between the groups favors the theory that OME is multifactorial and explained not only by negative middle ear pressure but also by immunologic abnormalities and the presence of microorganisms and respiratory viruses. Other studies have also shown that manometric measurements of the ET ventilatory function have no value in predicting the recurrence of OME in children.

However, significant differences have been found between sonotubometric measurements in children with glue ear before and after grommet insertion. Whether this is only a result of the presence of glueylike fluid in the middle ear or there is another causal relationship at play could not yet be elucidated. Because sonotubometric measurement in cases of glue ear gives indistinct results, the conclusion must be drawn that this test method is not yet capable of assessing ET ventilatory function in cases of glue ear.

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