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Technical Note

Recommended procedure for tympanometry

British Society of Audiology

1. Introduction

The adoption of tympanometry as a means of analysing middle-ear function has resulted in rapid advances in the development of instruments for clinical use. A technical specification on *Instruments for the Measurement of Aural Acoustic Impedance/Admittance* is available as IEC 1027 (1991). It is considered timely therefore to have recommendations intended to confirm uniform methods for good practice in the conduct of routine clinical tests.

2. Scope

These recommendations describe procedures deemed suitable for routine clinical measurements which are applicable to most types of tympanometer and aural acoustic impedance/admittance measuring instrument using a nominal probe frequency of 226 Hz.

3. Definitions

Acoustic impedance. The complex ratio of sound pressure to volume velocity through a surface.

Acoustic admittance. The reciprocal of acoustic impedance. The acoustic admittance at a surface is the complex ratio of the volume velocity through the surface to the sound pressure averaged over the surface.

Note: Most existing aural acoustic impedance/admittance instruments actually measure the modulus (magnitude) of acoustic admittance but present the result as admittance or compliance expressed as an equivalent volume of air.

Acoustic compliance. The ratio of volume displacement to acoustic pressure at a surface.

Note: Acoustic compliance is the acoustic analogue of electrical capacitance. It is the fundamental property of an idealized acoustic element whose movement in response to sound is determined solely by its elastic (spring-like) properties.

At low frequencies the middle ear behaves for practical purposes as a pure compliance and in tympanometry (at 226 Hz) the compliance presented to the probe may be taken as the sum of the middle-ear compliance and the compliance of the air in the ear canal. The compliance of the middle ear is a measure of its 'mobility' at low frequencies.

The acoustic admittance associated with a pure compliance is directly proportional to the compliance and to the frequency of the sound.

Equivalent volume. The volume of an air-filled cavity having the same acoustic admittance (or impedance, compliance, etc.) as that of the component or system which it represents.

Middle-ear pressure. Static pressure in the middle ear relative to ambient atmospheric pressure. Normally this is taken to be equal to the pressure in the external ear corresponding to peak admittance in the tympanogram.

Probe. A coupling device to the external ear canal connecting the tympanometer to the ear.

Tympanometry. The measurement of acoustic impedance/admittance (or of related quantities such as compliance) as a function of air pressure in the external ear.

Note: The terms impedance/admittance audiometry, acoustic immittance and immittance audiometry are depreciated.

Tympanogram. A graph of acoustic impedance/admittance (or of a related quantity such as compliance) as a function of air pressure in the external ear.

Peak admittance or compliance. In tympanometry, the maximum admittance/compliance; the peak in the tympanogram.

Middle-ear admittance or compliance. In tympanometry, the difference between peak admittance/

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compliance and admittance/compliance measured at a reference pressure sufficient to effectively eliminate the influence of the middle ear.

Note: (i) The reference pressure is normally a positive pressure of 200 daPa. At this pressure the indicated admittance or compliance is that of the air-filled space within the ear canal between the tip of the probe and the tympanic membrane. Tympanometry should normally commence at the reference pressure. (ii) The measured value of middle-ear admittance or compliance may depend on the rate and the direction of the pressure change during tympanometry and also on the time for which a constant pressure (the reference pressure) was applied.

Acoustic reflex. A middle-ear reflex elicited by an acoustic stimulus.

4. Units

Quantity	Absolute unit (SI)	Traditional unit	Recommended unit
Acoustic impedance	Pa s m^{-3}	ohm (cgs)	cm^3 equiv. vol.
Acoustic admittance	m^3 Pa^{-1} s^{-1}	mho (cgs)	cm^3 equiv. vol.
Acoustic compliance	m^3 Pa^{-1}	cm^3 equiv. vol.	cm^3 equiv. vol.
Relative air pressure	Pa	mm water	daPa

Note: (i) At 226 Hz the acoustic admittance of a 1 cm^3 air-filled cavity is 1.0×10^{-8} m^3 Pa^{-1} (1.0 mmho, cgs) at standard atmospheric pressure (1.013×10^5 Pa). (ii) A pressure of 1 mm water is equivalent to 0.98 daPa.

5. Calibration

The calibration of the instrument should be checked daily with the probe fitted to an appropriate cavity such as the one supplied by the manufacturer. Test cavities must have dimensions which are small compared to the wavelength of sound at 226 Hz; metal or hard plastic cylinders with a ratio of length to diameter of between one and three and volumes in the range 0.5 to 5.0 cm^3 are recommended. The performance of the instrument should also be checked frequently on an ear of known characteristics. A more detailed examination and laboratory test of all functions should be made every six months.

6. Preparation of the patient

The patient should be seated in a moderately quiet room [the ambient noise level should preferably be less than 50 dB(A)]. The ears should be examined with an otoscope to detect excessive wax or other contra-indications for tympanometry. These include a discharging ear and tenderness of the ear. In case of doubt medical advice should be sought. To prevent obstruction of the probe (and possible spurious results) excessive wax must be removed by a qualified person.

Briefly describe the purpose of the test and the procedure to the patient. Ask the patient to sit in a comfortable position, to avoid any unnecessary movement and to avoid speaking or swallowing after the probe has been fitted. Inform the patient that the probe has a soft tip to seal the ear.

When testing children it may be appropriate to modify these instructions and explain the procedure to the parents.

7. Tympanometric procedure

Fit a clean tip of suitable size and shape to the probe and straighten the ear canal by gently pulling the pinna upwards and backwards while inserting the probe with a rotary movement. With young children, for whom the ear canal has a different shape, the pinna has to be pulled downwards and outwards. Point the probe in the direction of the tympanic membrane to avoid the risk of sealing the tip against the wall of the canal.

Insertion of the probe to obtain an airtight seal is sometimes difficult, especially for an inexperienced operator. The seal may be checked by applying an excess pressure of 200 daPa for a few seconds to ensure, by observing the manometer or other indicator, that pressure is maintained. If it is not, other probe tips should be tried. It is sometimes helpful to apply a smear of white petroleum jelly to the tip (taking care not to block its orifice). This may, however, lead to the probe slipping out of the ear when positive pressure is applied. It is also possible that a perforation of the tympanic membrane, perhaps undetected by otoscopy, may cause leakage via the middle ear and Eustachian tube.

Routine measurements should be made with a probe frequency of 226 Hz (220 or 275 Hz on some instruments). A slow rate of change of pressure (50 daPa s^{-1} or less) should be used but with young children it may be beneficial to use a faster sweep, sacrificing some accuracy for speed of operation. In the absence of other requirements, tracking should commence at +200 daPa and end once the

peak, if it exists, has been clearly recorded. On automatic systems a lower limit of about −300 daPa, depending on instrument, should normally be selected but occasionally it may be necessary to go to −600 daPa in search of a peak.

If an unexpected result is obtained the test should be repeated in its entirety, that is, by removing the probe, inspecting the ear and re-testing.

After tympanometry has been completed the probe tip should be removed for cleaning. Brushing with warm soapy water is effective but tips used with a discharging or infected ear should be discarded or sterilized. It is important to keep moisture out of the probe itself and tips should therefore be thoroughly dried before re-use.

8. Normal values

There is no agreed standard on normal values for middle-ear pressure and admittance. The following is offered as a guide, applicable when otoscopic appearances are normal.

Middle-ear pressure. Normal middle-ear pressure has a mean value of zero. Under carefully controlled conditions the 95% range in normal subjects is −20 to +20 daPa though pressures from −50 to +50 daPa can be considered normal. Children often have slightly low middle-ear pressures; pressures down to −150 daPa may have little clinical significance.

Admittance or compliance. It is generally agreed that middle-ear admittance or compliance is normally in the range 0.3 to 1.6 cm^3 with a mean of 0.7 cm^3.

9. Enclosed volume of the ear canal

The acoustic properties of the ear canal (from probe tip to tympanic membrane) are necessarily involved in tympanometric measurements. At low frequencies (226 Hz) the canal contributes an admittance (or compliance) which may for practical purposes be added arithmetically to the admittance presented by the middle ear as seen from the tympanic membrane. The canal and middle-ear components are distinguished by applying air pressure in tympanometry. Should the tip of the probe be occluded, for example by the wall of the canal, a seemingly small canal volume will be indicated, whereas an open perforation will add the middle-ear volume to that of the canal so giving an abnormally large result. Both extremes will be accompanied by a flat tympanogram.

10. Acoustic reflex measurements

Most impedance/admittance instruments have facilities for providing an acoustic stimulus to the ear and for detecting the associated middle ear reflex. The diagnostic significance of the acoustic reflex is beyond the scope of this document and reference should be made to manufacturers' instructions and to appropriate textbooks. It may be noted, however, that reflex measurements are normally made at a pressure corresponding to the tympanometric peak so that tympanometry is usually a necessary adjunct to tests involving the reflex. The possibility of artefactual responses to stimuli greater than 100 dB HL should not be ignored, particularly when using ipsilateral stimulation.

11. Eustachian tube function

Tympanometers and related instruments are readily applied to the evaluation of Eustachian tube function. Test methods are beyond the scope of this recommendation but are often described in the manufacturers' handbooks, etc.

12. Reporting results

The main requirements are usually to report middle-ear pressure and middle-ear admittance or compliance and to describe the shape of the tympanogram. The classification of tympanograms according to their shape has been suggested but is not recommended here. Simple descriptions such as 'normal', 'rounded', 'flat', or 'W-shaped' are acceptable.

A copy of the tympanogram will often be included with the report and may form the main part of it, but it is advisable to include numerical values of middle-ear pressure and admittance or compliance, especially if the record charts are printed with multiple scales. If the tympanogram is flat, or nearly flat, middle-ear pressure may be reported as 'indeterminate'.

Tympanometric results do not identify pathology uniquely and should be interpreted in the context of other information and with particular regard to the otoscopic findings. Report forms should include normal values as an aid to interpretation.