Recommended Procedure:

Tympanometry and Acoustic Reflex Thresholds

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General foreword

This document presents a Recommended Procedure by the British Society of Audiology (BSA). This Recommended Procedure represents, to the best knowledge of the BSA, the evidence-base and consensus on good practice, given the stated methodology and scope of the document at the time of publication. Although care has been taken in preparing this information, the BSA does not and cannot guarantee the interpretation and application of it. The BSA cannot be held responsible for any errors or omissions, and the BSA accepts no liability whatsoever for any loss or damage howsoever arising. This document supersedes any previous recommended procedure by the BSA and stands until superseded or withdrawn by the BSA.

This document replaces the previous BSA guideline "Recommended Procedure: Tympanometry" (2013).

This document will be reviewed by the date given on the front cover. However, should any individual or organisation feel that the content requires immediate update, review or revision, they should contact the BSA using the email bsa@thebsa.org.uk. Please add 'BSA document revision request' in the title. You will be asked to complete a short form with your reasons and this will be passed to the Professional Guidance Group for assessment. Comments on this document are welcomed and should be sent to:

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Declarations of interests (please edit and delete as appropriate)

- Declaration of interests by the authors: none declared.

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Shared Decision-Making

It is implied throughout this document that the service user should be involved in shared decision-making when undertaking audiological intervention, receiving subsequent information and understanding how it will impact on the personalisation of care. Individual preferences should be taken into account and the role of the clinician is to enable a person to make a meaningful and informed choice. Audiological interventions bring a variety of information for both the clinician and the service user that can be used for counselling and decision-making regarding technology and anticipated outcomes.

Contents

1. Introduction

The purpose of this document is to describe recommended procedures for conducting tympanometry as a means of analysing middle-ear function for service users of all ages and acoustic reflex threshold measurements. The recommendations are deemed suitable for routine clinical measurements applicable to most types of instruments measuring acoustic admittance using a nominal probe frequency of 226 Hz for service users whose corrected age is equal to or greater than 6 months, and a frequency of 1000 Hz for service users below 6 months corrected age. Basic guidance is also provided on test precautions and interpretation, although it is essential that the competent person carrying out the test (the "tester") uses professional judgement when deciding on the particular approach to be used with each "service user" (the person being tested) given the specific circumstances and the purposes of the test.

Unless stated otherwise, the procedure described here represents the status of the current evidence base, taking into account other factors that influence desirable procedure, as interpreted by the Professional Guidance Group of the BSA in consultation with its stakeholders.

The term 'shall' is used in this document to refer to essential practice, and 'should' is used to refer to desirable practice.

2. Abbreviations

ART	Acoustic reflex threshold
BBN	Broadband noise
CN	Cochlear nucleus
IE	Inner ear
HL	Hearing level
ME	Middle ear
SL	Sensation level
SOC	Superior olivary complex
SPL	Sound pressure level
WAI	Wideband acoustic immittance
Y	Admittance
Y_{tm}	Peak-compensated static acoustic admittance magnitude
Z	Impedance

3. General Considerations

Tympanometry is a quick and safe procedure when following this Recommended Procedure. Most adults (>90%) will not have a significant middle ear pathology (Browning and Gatehouse, 1992), but there may be a small number of serious pathologies identified and, more frequently, temporary effects on hearing thresholds that may affect assessments or hearing aid fittings. Tympanometry shall therefore be conducted in all adult and paediatric hearing assessment clinics alongside audiometry where clinically indicated (e.g. where any air-bone gap is observed, otoscopy raises concerns or service users report a blocked sensation). Tympanometry should also be employed prior to hearing aid fitting where indicated (e.g. a service user reports a change in hearing, congestion or blocked sensation). Audiology clinics in which diagnostic audiometry is conducted shall therefore have access to tympanometers. Diagnostic audiometry is distinct from surveillance audiometry and involves making a distinction between sensorineural hearing loss and likely temporary or permanent conductive hearing loss.

The examiner shall adopt appropriate hygiene and infection control procedures conforming to relevant local policies, including as a minimum: hand-cleaning prior to and after examination, the covering of breaks in the skin, the avoidance of direct contact with bodily fluids and the disposal of tips. Single-use disposable tips should be used and the same tip shall not be used for different service users. The same tip shall not be used for each ear of a service user where there is a risk of transferring an infection between the ears, as judged by the examiner based on otoscopic examination, the service user's symptoms, medical history or advice provided by another (e.g. medical) professional. If the examiner is in doubt they shall use a separate tip for each ear.

It is essential that the competent person carrying out the test, or responsible for it, uses professional judgement when deciding on a particular approach to be used with the person being tested given the specific circumstances and the purposes of the test and the tester's level of competency. For details on appropriate training and competency to perform tympanometry, reference should be made to the latest version of the BSA's Minimum Training Guidelines in Basic Audiometry and Tympanometry.

4. Background and Terminology

4.1 Tympanometry

Tympanometry measures the acoustic immittance of the middle ear. This is achieved by measuring the sound level in the ear canal, largely reflected from the tympanic membrane, over a range of air pressures. The reflected sound level will be reduced by sound energy

transmitted through middle ear structures, which will be greatest when the pressure external to the tympanic membrane equals that of the air cavity in the middle ear.

Immittance is a general term used to describe the concepts of impedance and admittance. Impedance (Z) describes the opposition to acoustic flow, whereas admittance (Y) describes the ease of acoustic flow and is the reciprocal of impedance (Y = 1/Z). A tympanometer measures the total admittance presented at the probe tip, which includes components of admittance from the air column in the ear canal and that of the middle ear. However the contribution of the ear canal can be measured with a low frequency stimulus (where the wavelength of sound is much greater than the ear canal dimensions) and at pressures much greater or lower than the middle ear pressure. The ear canal component of total admittance is then removed (or "compensated") in the result presented by the tympanometer. The remaining admittance reflects the contribution of the tympanic membrane and middle ear structures, and is referred to as the peak-compensated static acoustic admittance magnitude (Y_{tm}). The greater the value of the admittance, the greater the flow of sound into the middle ear, although this does not define how much sound is transmitted to the cochlea.

Admittance and impedance vary with frequency. A single-frequency stimulus tone of 226 Hz was adopted as standard practice because, at this frequency, 1 mmho is equivalent to the admittance of a 1 cm^3 volume of air at normal atmospheric pressure (sea level) and room temperature (20^{o}C), enabling a measurement of ear canal volume. At low frequencies such as 226 Hz, the behaviour of a normal middle ear is dominated by the stiffness of the tympanic membrane and connected structures, rather than its mass, and a normal tympanogram should have a single peak. Increasing the mass of the middle ear structures will reduce the resonant frequency and may result in a "notched" (double-peaked) tympanogram at 226 Hz, which may be pathological. However the ear canal and middle ear structures of neonates (less than 6 months corrected age) are significantly different, including cartilaginous ear canals, such that 226 Hz tympanometry is unhelpful and a 1000 Hz tone was found to be more likely to differentiate between flat or peaked tympanograms. Tympanometric measurements at multiple frequencies may be able to provide additional audiological information, described in the "Wideband Acoustic Immittance" section.

It is not the purpose of this document to detail the acoustic components of immittance; reference should be made to reviews such as Hunter & Sanford (2015) for further background and detail.

4.2 The Acoustic Reflex

A brief background summary of the acoustic reflex is offered here, but clinicians should be aware of its function and relevance; for example, see Feeney & Schairer (2015). The acoustic reflex is defined as the lowest sound level needed to elicit a middle ear muscle contraction.

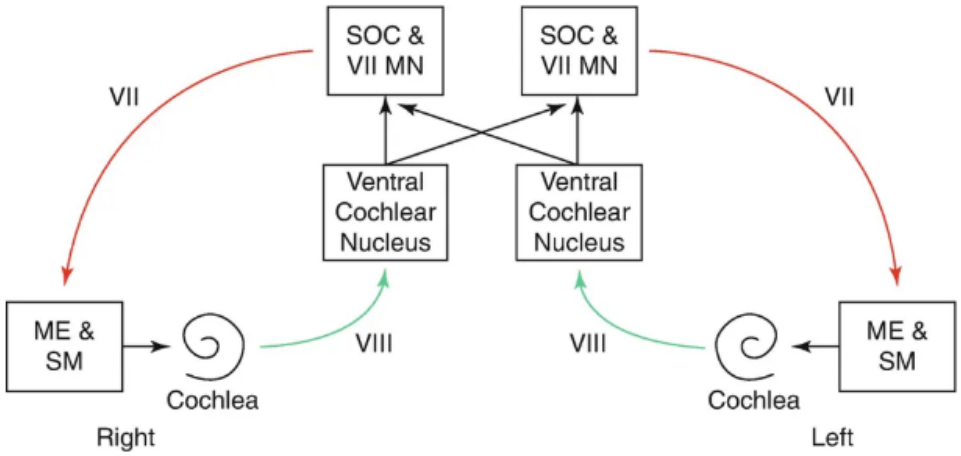
The acoustic reflex is not a measure of hearing threshold but has a long history of defining middle ear, cochlear and 8th cranial nerve disorders.

Contraction of the stapedius muscles occurs bilaterally in response to sound presented to either ear. This contraction can be measured in the same ear as the stimulus (ipsilateral) or the opposite ear (contralateral). This leads to four distinguishable reflex arcs (Figure 1) whereby the reflex is uncrossed (ipsilateral measurements) or crossed (contralateral measurements).

Measurement of an acoustic reflex can be gained through presentation of pure-tones, typically at 500, 1000, 2000 and 4000 Hz or using broadband noise. Acoustic reflex measurements provide information about the middle and inner ear, in addition to the 8th and 7th nerve and brainstem function.

A reflex can also be initiated with an electrical stimulus from a cochlear implant and this can be used as a tool in setting the functional parameters of the implant; see Hodges et al. (1997) and Wolfe et al. (2018) for a more detailed consideration. The focus of the remainder of this Recommended Procedure is on standard, acoustically-evoked reflexes.

Figure 1: *The acoustic reflex arc, including the middle ear (ME), stapedius muscle (SM), 7th cranial nerve (VII, facial), 8th cranial nerve (VIII, vestibulocochlear), medial nucleus of the 7th nerve (VII MN), and superior olivary complex (SOC).*



5. Equipment

The tympanometer and probe tip shall be clean and in good condition (i.e. free from dust and dirt and in compliance with local infection control standards). Tympanometers shall

meet the performance and calibration requirements of BS EN 60645–5:2005. It is particularly important that the air channels of the probe tip are kept clean and free of any cerumen (or other debris) as any blockage can cause measurement errors. The manufacturer's instructions should be consulted for the correct cleaning procedure. In most cases this involves removing the probe tip and cleaning the channels with cleaning floss. Cleaning fluid must not be used to clean the probe tip and cleaning wires must not be pushed into the probe channels with the tip mounted on the probe as this can damage the probe transducers. If the cleanliness of a probe tip is in doubt, then it should be replaced with a new tip.

An airtight seal is required for tympanometry and it is important that the correct type and size of ear tip is selected to ensure a good seal to the ear canal. The two main types of ear tip are umbrella and mushroom. The manufacturer's instructions should be consulted to determine which ear tips are recommended for use with the instrument (an incompatible ear tip may not fit correctly to the probe tip and may lead to leaks and measurement errors). The umbrella ear tip is designed for screening testing where the probe is pressed into the entrance of the ear canal and held while a quick test is carried out. The mushroom ear tip is designed for diagnostic testing where the ear tip is inserted into the ear canal so that the test can be carried out without the probe being held. Ear tips are single use only and should be discarded between each service user tested.

6. Daily Check & Calibration

The calibration of the instrument shall be checked daily with the probe fitted to an appropriate cavity such as the one supplied by the manufacturer. The performance of the instrument shall also be checked on an ear known to produce a normal, peaked tympanogram.

The dimensions and use of calibration cavities are defined by BS EN 60645-5-2005. Cavities must be hard, non-porous devices with dimensions that are small compared to the wavelength of sound at 226 Hz. Diagnostic tympanometers (type 1) require at least three test cavities with volumes of 0.5 cm^3, 2.0 cm^3 and 5.0 cm^3. A calibration check should produce a horizontal line, and the volume measured must be within ±5% of the equivalent volume or within +/- 0.1 cm^3, whichever is greater. Acceptable values for cavity volume are given in the following table.

Cavity	Acceptable value	
	Tympanometers with one decimal place	Tympanometers with two decimal places
0.5 cm^3	0.4 - 0.6 cm^3	0.40 - 0.60 cm^3
2.0 cm^3	1.9 - 2.1 cm^3	1.90 - 2.10 cm^3
5.0 cm^3	4.8 - 5.2 cm^3	4.75 - 5.25 cm^3

Table 1: *Acceptable values for calibration.*

If the calibration check does not produce a horizontal line (i.e. it slopes upwards with decreasing pressure) this may indicate a leak in the test cavity or the probe, or the probe may not have been inserted into the test cavity correctly. Correct insertion of the probe should be verified and the calibration check repeated using a different cavity if necessary. The exception to this is the 5.0 cm^3 cavity, in which there may be an upward sloping line with decreasing pressure. This occurs because the susceptance component of admittance increases with decreasing pressure, which is more noticeable when larger volumes of air are measured.

Where 1000 Hz probe tones are to be used, a high-frequency test cavity provided by the manufacturer shall be used. This test cavity is not sealed, so volume is not measured. A measurement of admittance should be taken at 0 daPa and compared to the specifications of the manufacturer.

A full calibration shall be made no less than once per year in accordance with BS EN 60645–5:2005. Equipment found to be out of calibration shall not be used. Note that type 2 and 3 tympanometers may be used for screening, with broader calibration criteria as defined by BS EN 60645–5:2005, however these are not recommended in a diagnostic audiology clinic. The tympanometer type shall be defined in clinical reports.

Acoustic Reflex testing occurs subsequent to tympanometry, so all calibration and service user preparation will have been undertaken during the initial procedure.

7. Wideband Acoustic Immittance and Tympanometry

Sound propagation through the middle ear varies in a frequency-dependent manner and can change depending on ear status. For example, pathologies will change the resonant

frequency of middle ear structures such that tympanometric shapes may be altered at 226 Hz and other frequencies.

Wideband Acoustic Immittance (WAI) is an umbrella term encompassing a variety of acoustic measurements over a wider frequency range using wideband stimuli (i.e. clicks, chirps) and can be obtained by varying the pressure in the outer ear (as in standard tympanometry) or can be obtained at normal ear canal pressure. Wideband tympanometry refers to measurements of acoustic absorbance over a range of frequencies and ear canal pressures, presented as a three-dimensional graph. Consensus terminology was defined by Feeney et al. (2012) and a mathematical summary of various WAI measurements was provided by Rosowski et al. (2013). Reflectance and absorbance (absorbance = 1 – reflectance) have gained the most focus in research in terms of middle ear analysis, and the latter most resembles the morphology of standard admittance tympanometry (Liu et al., 2008).

Measurement of middle ear function across a broad frequency range has the potential to become a diagnostic tool that can differentiate middle ear pathologies (e.g. Sanford and Brocket, 2014; Prieve et al., 2013; Nakajima et al., 2013). Whilst data exists on the test-retest reliability of WAI measures (Mishra et al., 2017), and normative data are available, the clinical devices for measuring WAI are relatively new to the commercial market. As such, further consensus is needed regarding the test protocols and procedures for such tests, there are likely gaps in knowledge, and training needs to ensure that the interpretation and reporting of results is consistent. Further work is therefore needed before wideband tympanometry can be recommended for routine clinical use.

8. Considerations for testing

This section is intended as a guide when considering whether it is safe and appropriate to proceed with tympanometry and/or acoustic reflex measurements. The procedures must be preceded by otoscopy. Contraindications and cautions are based on consensus expert opinion, for example Nakayama & Ramsey (2013). This section is not exhaustive, nor is it intended to be prescriptive, so the discretion of sufficiently competent clinicians shall always be employed.

- Otorrhoea contraindicates tympanometry in all cases.

- Acute otitis media:
  Where a red and bulging tympanic membrane is observed during otoscopy, tympanometry is contraindicated.

- Tenderness/ soreness in the ear and otitis externa:

If possible, testing should commence with the healthy ear so that the service user is better able to judge whether they are happy for the "sore" ear to be tested. If it is deemed that it would be of clinical value to perform tympanometry, this shall only proceed with the express consent of the service user and the service user must know how to signal that the test should be aborted if they experience discomfort.

- Presence of foreign body in the ear canal:
  It can sometimes be desirable and appropriate to conduct tympanometry in the presence of a grommet that has or may have extruded, although testing should proceed with caution. Otherwise foreign bodies shall be removed prior to tympanometry by a person qualified and competent to do so in order to ensure that no damage is caused to the outer ear or eardrum.

- Excessive wax:
  It can be useful to undertake tympanometry in an ear where a view of the tympanic membrane is obscured by wax. This can assess whether the wax is occluding, investigate the tympanic membrane mobility or the possibility of a perforation. Caution must be exercised because wax may prevent identification of other contraindications, such that an appropriate case history is required and the process shall only be performed by a sufficiently qualified, competent and experienced clinician, able to make a judgement that it is safe and appropriate to proceed.
  Testing is contraindicated where there is a risk that insertion of the probe tip may push against impacted wax, risking damaging the eardrum and potentially giving misleading results.
  Soft wax in the cartilaginous portion of the ear canal can damage or block the tympanometer probe. Wax may be removed prior to tympanometry by someone who is qualified and competent to do so.

- Previous ear surgery:
  There is no agreed standard on when it is safe to conduct tympanometry following ear surgery.
  Testing shall only be performed on the basis of medical advice that it is safe to proceed following ossicular surgery (e.g. stapedectomy, stapedotomy) or reconstruction of the eardrum (e.g. tympanoplasty, myringoplasty).
  In order to take a cautious approach, it is recommended that tympanometry should not be carried out within two months of ear surgery unless formally approved and documented by the service user's medical ear, nose and throat (ENT) specialist. It should be noted that a referral from ENT does not indicate implicit approval for testing, and that there should be a discussion with the ENT team where any doubt exists as to whether the test is safe to perform.
  A wideband acoustic immittance/tympanometry protocol could be used immediately following surgery if a non-pressurised protocol is used. This decision should be taken in

conjunction with the surgical team, and no changes in outer ear pressure shall be made as part of the testing procedure.

- Outer ear defects such as stenosis or microtia:
  It may be more comfortable for the service user, and more effective when testing, to hold an umbrella-type probe over the entrance to the ear canal.

- Vestibular dysfunction following ear trauma:
  Air pressure changes may cause vertigo and nausea in service users with a perilymphatic fistula and should be avoided where indicated by case history.

- The acoustic reflex is affected by several classes of drugs:
  The acoustic reflex may be affected by barbiturates and alcohol, albeit with a considerable degree of variability between service users. Barbiturates have been known to produce elevated acoustic reflex thresholds, with a greater effect contralaterally than ipsilaterally, as well as produce increases in acoustic reflex latency. Ethyl alcohol results in elevated acoustic reflex thresholds. This result is similar for both ipsilateral and contralateral reflexes. The acoustic reflex may also be absent in those with an alcohol dependence.

- Tinnitus/Hyperacusis/severe recruitment:
  Service users should be asked if they have tinnitus or sensitivity to loud sounds. If tinnitus is intrusive, severe or exacerbated by loud sounds, or if recruitment/hyperacusis is present, these should be seen as a contraindication to ART tests. However, an ART may be valuable in identifying retrocochlear pathology in service users with tinnitus. For example, an ipsilateral ART may be absent in the presence of a vestibular schwannoma on the affected side. If the ART is deemed to be of diagnostic importance in these service users, testing shall only proceed with the express consent of the service user, and acknowledgement that they know how to terminate the test if they experience discomfort.

- Tympanic membrane (TM) perforation:
  If otoscopy shows an evident TM perforation, tympanometry should not be performed as it will not add any additional information. When the TM cannot be clearly visualised, tympanometry may identify a possible perforation by indicating a large ear canal volume (ECV) and may similarly differentiate between open and blocked grommets. Tympanometry should not be performed on a discharging or moist perforation.

- Other rare conditions:
  There are various rare syndromic and other conditions which can markedly alter the anatomy of the outer and middle ear, potentially causing a weakness of the middle ear structures, which would be at risk if tympanometry were to be conducted. Otoscopy

should always be conducted prior to tympanometry. However, this may not be sufficient to assess the potential risks. Where there is a known condition that may affect the middle ear, audiologists must apply caution and seek further medical advice prior to proceeding with tympanometry.

9. Service user preparation

The tester shall adopt an effective communication strategy with the service user (or their representative) throughout testing. This must take account of the service user's age, hearing, language skills and any other communication difficulties.

Before examination, the service user (or the person responsible for the service user) should be asked if they currently have any ear-related symptoms (including discomfort, pain and/or discharge), are currently being treated for any ear-related problems or have previously had surgery involving the ears. Before proceeding, any symptoms (or other relevant issues) should be explored by questioning or alternative investigation. When testing a child, enquire about recent illness (especially a cold or other respiratory symptoms), fever, ear pain, and question recent behaviours such as ear tugging or hearing difficulty.

The service user should be seated comfortably and should remain as still as possible during the test. Young children may need to be held by an appropriate adult, which should be the person responsible for the child. For example, the child could be seated sideways on the adult's lap, with the child's hands secured by one hand and the child's head held against the chest with the other hand. In older children and adults, an instruction to remain still will usually suffice. Any objects that may interfere with insertion of the probe (e.g. a piercing) should be removed.

The examiner shall explain, and where necessary demonstrate, the procedure to the service user and/or person responsible for the service user. Where possible, the service user should be instructed to report immediately any discomfort or pain experienced during the test. Informed consent shall then be obtained (e.g. verbally) from the service user or person responsible for the service user.

The tester shall inform the service user that the test can be discontinued at any point, such as if they become uncomfortable, and how to signal any discomfort to the tester (e.g. by raising their hand or saying "stop"). The following instructions or equivalent should be used and it is helpful to show the service user the probe whilst giving the instructions:

"I will insert a soft tip into the opening of your ear canal. You will feel a slight pressure in your ear for a few seconds while I measure the function of your middle ear. You don't need to do anything, other than sit still and remain quiet. You may hear a sound, but you do not need

to respond or tell me about it. Should you find the procedure uncomfortable and want me to stop, please say 'stop' or raise your hand."
If acoustic reflex tests are to be performed automatically, or manually, immediately following tympanometry, this information should be included in the instructions given to the service user to ensure that the probe remains in position until the testing is completed. The service user should be warned that acoustic reflex tests involve the presentation of loud sounds.

"*This test consists of two parts. First I will insert a soft tip into the opening of your ear canal. You will feel a slight pressure in your ear for a few seconds while I measure the function of your middle ear. You may hear a sound but you do not need to respond or tell me about it. The second part will then begin, which involves playing short, loud sounds. These may take you by surprise when they first begin, and they may get quite loud. You do not need to do anything other than sit still and remain quiet. Should you find any of this procedure uncomfortable, or the sounds too loud, please say 'stop' or raise your hand*".

10. Test procedure

Tympanometry shall be preceded by otoscopic examination, following the latest version of the BSA "Recommended Procedure: Ear Examination", to ensure that there are no contraindications. ART measurements must be preceded by tympanometry. Testing shall proceed only with informed consent and where it is safe to do so. In the context of tympanometry, otoscopy in neonates is only intended as a general inspection of the outer ear for obvious signs of disease, blockage or malformation. Care shall be taken not to insert the speculum deep into the ear canal of young babies.

When testing adults and children on the same equipment, all test parameters shall be checked and set appropriately prior to testing.

If an unexpected result is obtained the test shall be repeated in its entirety, that is, by removing the probe, inspecting the ear, checking the probe to ensure it is not blocked and re-testing. False negatives (i.e. flat tympanograms) can easily be produced in error, so these should always be carefully re-tested. A flat tympanogram with a small ECV can indicate the probe has been placed against the ear canal wall. A service user may be allowed to pop their ears, e.g. with a Valsalva manoeuvre, if they believe their ears have temporarily pressurised.

The tester should be familiar with the specific hardware and interface being used. Some tympanometers have settings for "screening" and "diagnostic" tests. These can impact on when the measurement starts and if this is initiated by the tester or by the software. The tester should pay particular attention to the first measurements in a series, and mindful of how likely eartip movement is for hand-held vs non-hand-held devices.

10.1 Service users with a corrected age over 6 months using a 226 Hz probe tone

Fit a clean tip of sufficient size to achieve a hermetic seal in the ear canal and straighten the ear canal by gently pulling the pinna. The most effective manipulation of the pinna varies between service users, particularly between adults (where manipulation is typically upwards and backwards) and young children (where manipulation is typically backwards and sometimes also downwards). Gently insert the probe, giving it a slight twist to encourage an airtight seal. Point the probe in the direction of the tympanic membrane to avoid the risk of occluding the probe aperture against the wall of the canal. A shallow insertion is possible if using a hand-held probe, though a deeper insertion is desirable if using a hands-free probe (to minimise probe movement in the ear canal during measurement). When performing tympanometry on a young child, an umbrella shape tip that covers the entrance of the ear canal may be preferable. In all cases where using a hand-held probe, an appropriate brace should be adopted to avoid unnecessary pressure and discomfort if the service user moves.

Insertion of the probe to obtain an airtight seal is sometimes difficult, especially for an inexperienced operator. If difficulties arise, the position or size of the probe tip should be changed. Care shall be taken not to apply extra pressure or insert the tip too deeply into the ear canal. It is sometimes helpful to apply a smear of white petroleum jelly to the tip (taking care not to block its aperture), particularly if the entrance to the ear canal is hairy. This may, however, lead to the probe slipping out of the ear when positive pressure is applied. Testers should be aware of the possibility of artefacts being introduced by movement when the probe is hand-held during the pressure sweep. If the probe is not supported by the tester during the test, it should be ensured that the probe cable is appropriately positioned and supported so that it does not pull on the probe, causing it to move during the test. Care shall be taken that the trace is free from artefacts and, if necessary, repeated to obtain a clear trace.

A slow rate of change of pressure (50 daPa/s 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 the instrument, should normally be selected but occasionally it may be necessary to go to –600 daPa in search of a peak. In cases of normal tympanograms, tracking should stop at –200 daPa for adults and –300 daPa for children to minimise discomfort.

After tympanometry, and any necessary acoustic reflex test, has been completed, the measurement shall be stopped to allow outer ear pressure to return to normal. Once the pressure has returned to normal, the probe tip shall be removed and all contaminated tips shall be disposed of as per local policy.

10.2 Service users with a corrected age under 6 months using a 1000 Hz probe tone

A probe frequency of 1000 Hz is used for babies because the admittance of their ears is mass-dominated and a higher frequency tone is more likely to distinguish pathologies from normal middle ears (Hunter & Sanford, 2015).

Fit a clean tip of suitable size and shape to the probe and straighten the ear canal (e.g. by gently pulling the pinna 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. Movement of the infant and crying can result in a false peak in the tympanogram. The baby should be resting quietly during the test.

The direction of pressure change should be from positive to negative and the range should be at least from +200 daPa to –400 daPa (and preferably –600 daPa). A fast screening mode speed of up to 600 daPa s^{-1} should be used.

The recommended classification system is that of Baldwin (2006), adapted from Marchant et al. (1986). This is described below with further examples given in the Appendix 1. The scheme uses admittance as a measure and the equipment should be set to measure this, rather than any sub-component of admittance.

Traces should be repeated where possible to check for consistency and exclude any artefacts such as baby movement. It is especially important to retest any ear with an abnormal or difficult-to-interpret tympanogram. After tympanometry has been completed the probe tip shall be removed and all contaminated tips shall be disposed of as per local policy.

10.3 Acoustic Reflex Thresholds

Acoustic reflex assessment involves the presentation of tonal and/or broadband noise stimuli to elicit a response from the stapedius muscle. The resulting changes in the immittance of the ear are monitored using a tympanometer. Acoustic reflex assessment usually uses a 226 Hz probe tone unless testing neonates, for whom higher frequency 1000 Hz probe tones are used. The stimulus level is preferably expressed in terms of hearing level (HL) and may be expressed as dB sound pressure level (SPL), although corrections will need to be applied in order to interpret the results relative to normative data.

The ear that contains the probe assembly is known as the probe ear and the ear receiving the stimulus is known as the stimulus ear. Ipsilateral acoustic reflex assessment involves stimulation and measurement of the reflex in the same ear and contralateral assessment

involves presenting the stimulus in one ear and monitoring the acoustic immittance in the opposite ear.

In ipsilateral assessment there is no question regarding which reflex pathways are being tested, however as the contralateral pathway is testing both ears the conventional term of "test ear" should not be applied. For this reason, reflexes are identified by side and configuration. For example "right, contralateral" indicates that the stimulus is in the right ear and the probe is in the left ear.

Diagnostically significant reflex patterns result when ipsilateral reflexes are combined with contralateral reflexes. There may be situations where one method is more appropriate than the other, depending on the clinical question. However contralateral assessment has three advantages over ipsilateral assessment:

- Contralateral assessments are more sensitive to disorders involving the crossed reflex pathways (meaning retrocochlear pathology could be missed if not carried out).
- Ipsilateral reflex testing is highly susceptible to artefact. The ear canal provides a non-linear cavity which gives rise to a measurement of acoustic impedance which is synchronous to the stimulus. The magnitude of this artefact increases with the intensity of the stimulus.
- Contralateral measurements do not suffer from artefact, as the stimulus and probe tones are played by independent transducers, situated in opposite ears.
- There is more extensive normative data available for contralateral assessment

Ipsilateral acoustic reflexes are sensitive to middle ear pathology and are not affected by disorders of the opposite ear. Ipsilateral testing may be possible in young children or difficult to test service users whose behaviour precludes the use of headset/inserts.

The acoustic reflex threshold is the lowest level of sound stimulus that elicits an acoustic reflex. A change of reflectance of 0.02ml (relative to a baseline of zero) is usually taken at the minimum change required to confirm the presence of a reflex (Figure 2).

The measurement should commence once it has been established that the probe is correctly placed and that the ongoing pressure and compliance measurements are sufficiently stable to facilitate reflex measurements. Once suitable recording conditions have been established, the test operator shall commence stimulus presentation.

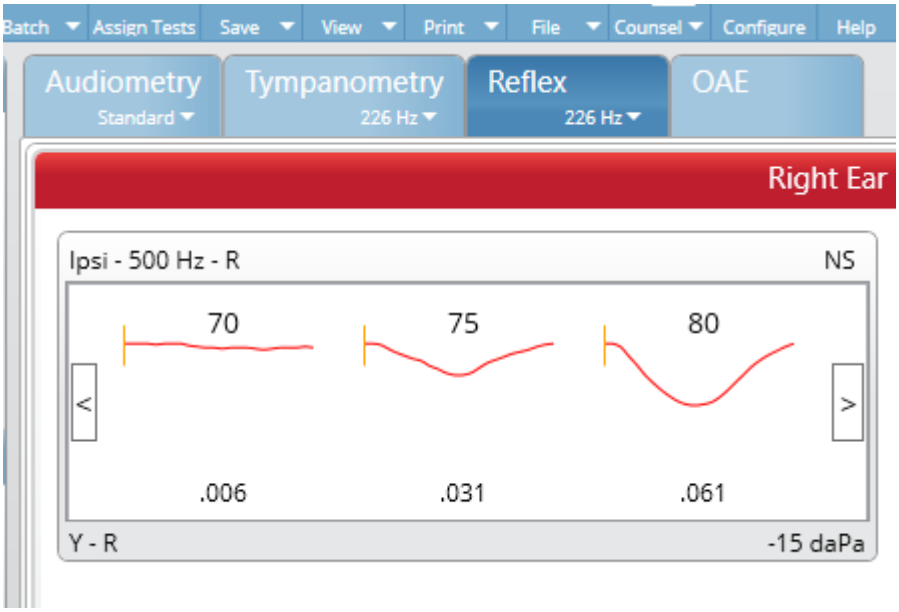


Figure 2: Example of acoustic reflex recording, with the reflex first observed at 75 dB HL

Acoustic Reflex Thresholds are usually measured at 500, 1000 and 2000 Hz. Should reflexes not be observed using tonal stimuli, the use of broadband noise (BBN) is recommended. BBN can be helpful in assessing the likelihood of significant hearing impairment, see Hunter & Sanford (2015). The intensity should start from 60-70 dB HL (60 dB HL for BBN and 70 dB for pure tone stimuli). If a reflex (a change in reflectance of 0.02 ml) is not observed, the stimulus intensity shall be increased by 5 dB. This continues until a change in reflectance of 0.02 ml is observed and the morphology of this change is typical (see figure 2). Once a reflex is observed, the intensity shall be increased by 5 dB to confirm a growth in compliance. If growth is confirmed, reduce the sound by 10 dB and repeat to confirm the lowest sound intensity at which an acoustic reflex is consistently present; this intensity is taken as the acoustic reflex threshold.

If a reflex is observed upon the first presentation, reduce the stimulus intensity by 10 dB, and begin the process again. This could represent a genuine reflex or artefact due to the probe placement and seal. A reflex that shows no growth 5 dB above threshold should also be carefully repeated to check that probe artefact is not causing an issue.

It is not recommended that presentation levels go above 105 dB HL. Literature suggests a risk to residual hearing at presentation levels between 105 and 115 dB HL, so the lower limit is proposed for prudence. Furthermore, broadband stimuli should be limited to 95 dB SPL. These limits are based on data from Arriaga and Luxford (1993). If there is a strong, clinical rationale for exceeding these specified limits, then this should be detailed and documented before doing so.

Note that collapsed canals can lead to false results, particularly if the headphone is used on the contralateral ear. If this is suspected and the results do not fit with other test battery results, the test should be repeated.

11. Results and reporting

The following is offered as a guide. Full interpretation of results is beyond the scope of this document. Some typical patterns of reflex measurements which may be observed can be found in Appendix 2.

Single-frequency tympanometric results do not identify pathology uniquely and cannot be correlated with hearing sensitivity. Results should be interpreted in the context of other information from the test battery being conducted and with particular regard to the otoscopic findings and case history.

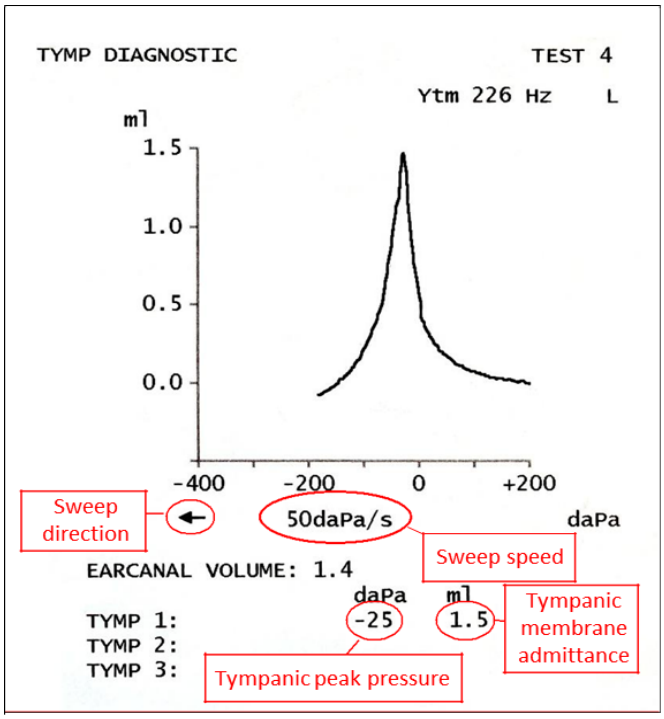
Where spurious results or artefacts are suspected, the test should be repeated and the probe tip should be inspected to ensure it is not blocked, for example by wax. These include flat traces, traces with more than one peak, changes in ear-canal volume during testing, noisy traces and ear-canal volumes that are significantly higher or lower than expected (especially if asymmetrical).

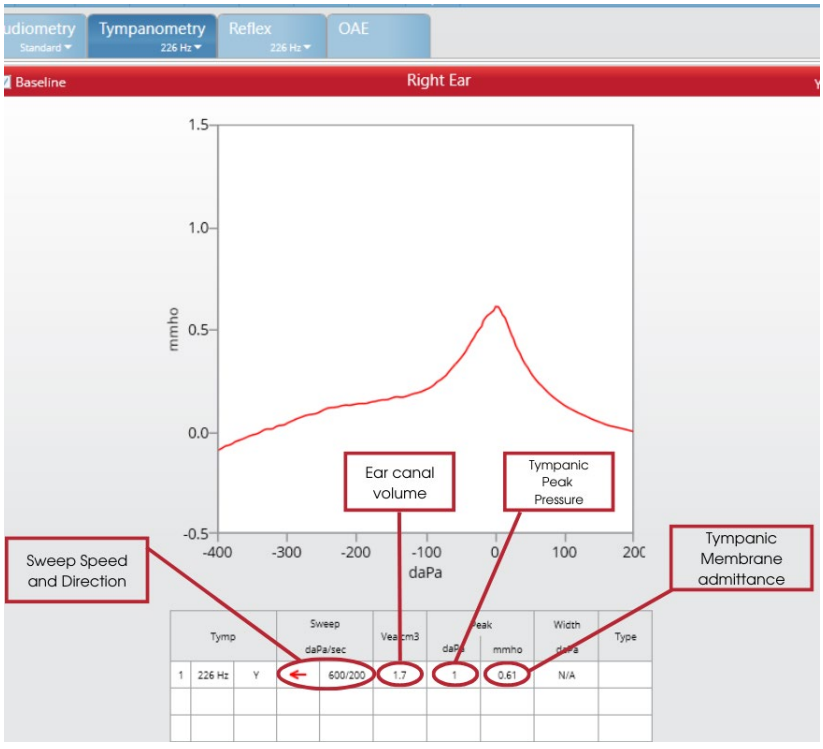
11.1 Service users with a corrected age over 6 months using a 226 Hz probe tone

11.1.1 Tympanometric shape

A normal trace should have a single sharp peak, as in Figure 3. Double (or “bifid”) tympanograms generally indicate mass-loading of the tympanic membrane or ossicles, causing a reduction in resonant frequency, and may be indicative of a pathology (Margolis, 2006). Bifid peaks, and other unusual morphology such as rounded or wide peaks, should also be checked by repeating the test. The tympanometric width (TW, width at 50% height) may be used as a descriptor. Nozza et al. (1994) suggested that TW was a more sensitive measure of MEE than static admittance, where a value of TW < 200 daPa may be considered normal for children between 1 and 7 years of age.

Figure 3: Examples of a normal tympanogram from an adult left ear.





11.1.2 Tympanic peak pressure and middle ear pressure

Tympanic peak pressure (TPP) is the value on the horizontal axis of the tympanogram at which the peak occurs. This is used to estimate the middle-ear pressure (MEP). However TPP can overestimate MEP by 30–70 daPa, particularly with small middle ear volumes or hypermobile tympanic membranes (Eliachar and Northern, 1974; Flisberg et al., 1963; Renvall and Holmquist, 1976), when higher sweep speeds are used and, in some circumstances, can exaggerate the value of negative pressures (Hunter & Sanford, 2015). Normal middle-ear pressure has a mean value of zero. Pressures from -50 to +50 daPa can be considered normal in adults. However normative studies show a much wider 90% range in normal adult service users (Hunter & Sanford, 2015) such that pressures down to –100 daPa may be of little clinical significance in isolation. A better indication of the effect of negative MEP might be considered by assessing the air-bone gap at low frequencies in pure tone audiometry. It should also be remembered that tympanometry is an instantaneous measurement that may not reflect the values for an individual at other times. As such, negative MEP may be taken to be indicative of Eustachian tube dysfunction, but cannot be said to confirm it without measurements over a longer period.

Mildly negative middle-ear pressures are common in children and a TPP as low as -150 daPa may have little clinical significance. Lildholdt et al. (1979) suggested that a middle ear pressure lower than -150 daPa should be considered likely to cause a hearing impairment in children. Flat tympanograms are considered a sign of middle ear effusion (MEE), but the presence of negative middle ear pressure can also be indicative. It should be remembered that we cannot entirely differentiate between a flat tympanogram and negative middle ear pressure because a trace may be peaked at a pressure lower that that measured. Palmu et al. (2001) found MEE in 15% of ears with negative pressure below -100daPa, so a greater proportion might be expected if the pressure criterion is set lower. Smith et al. (2006) found that the lower the pressure and the broader the TW, the greater the likelihood of MEE. In summary, measurements of a flat tympanogram or negative MEP cannot be separately equated to MEE and Eustachian tube dysfunction, but should be regarded as indicating a likelihood which is along the same scale, and should be interpreted in combination with otoscopy.

11.1.3 Peak admittance

Admittance is the quantity on the vertical axis (figure 1). The peak-compensated static acoustic admittance magnitude (Y_{tm}) is the maximum value, assuming that the contribution of the ear canal has been removed (or “compensated”, as described in Section 3). Note that the units ml, cm^3 and mmho are interchangeable when using a 226 Hz probe tone.

Peak admittance is in the range 0.3 to 1.6 mmho for 90% of adults (Hunter & Sanford, 2015); 0.2 mmho is acceptable as the lower limit in children aged under 6 years but over 6 months

(Margolis and Heller, 1987). In children aged 5-7 years, the 90% range is 0.2–1.0 mmho (Swanepoel et al., 2014).

Peak admittance Y_{tm} is often referred to as "middle ear compliance (MEC)" or, simply, "compliance". In normal adult ears the total admittance is dominated by compliance (the reciprocal of stiffness) and the effects of mass are negligible, such that it is understandable that these terms have been utilised interchangeably, although it not strictly correct to do so. On the whole it is preferable to refer to peak admittance (Y_{tm}) because compliance is just one component of admittance and the two are not the same in middle ears affected by a pathology or those of neonates.

11.1.4 Ear-canal volume (ECV)

At the extremes of the pressure sweep (e.g. at -400 daPa or +200 daPa) it is assumed that the middle ear structures are stiff such that the admittance of the middle ear is effectively zero. The measured admittance at these pressure levels therefore represents that of the air volume in the ear canal, if it is also assumed that the canal walls are rigid (which will not be true for neonates). When using a 226 Hz stimulus, this value represents the "equivalent ear canal volume" which can be expressed in units of cm^3. As described above, this value is usually removed (or "compensated") automatically in the results presented by the tympanometer. Tympanometry can overestimate ear canal volume by as much as 24–39% (Margolis and Smith, 1977; Moller, 1965; Rabinowitz, 1981; Shanks et al., 1988; Vanpeperstraete et al., 1979). Using descending sweeps and slower sweep speeds minimises this effect.

Asymmetrical ECV suggests unilateral probe occlusion or perforation. 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 cavity volume to that of the canal, giving an abnormally large result. Probe occlusion and an open perforation will both be accompanied by a flat tympanogram.

The 90% range of ECV in adults is 0.6–2.2 cm^3 and is typically larger in males than females (Hunter & Sanford, 2015). In cases where moderately larger ECV is observed this may be normal, so it is advisable to compare the ECV of both ears. A moderately higher ECV that is the same in both ears is unlikely to be clinically significant. A perforated eardrum will result in a flat tympanogram and is likely to exhibit a much higher value of ECV, although tympanometry results should always be combined with otoscopy. Research from various sources (Mehta et al., 2006; Aslier et al., 2019) suggest middle ear volumes of between 3.0 - 7.0 ml. Where ECV is measured to be 3.6 ml or more and the larger volume is different from the other ear, it may be due to perforation and includes the middle ear volume.

The average ECV in babies during the first 12 months of life does not appear to change significantly and averages 0.6 cm^3 with one standard deviation of 0.2-0.3 cm^3 (Hoffman et al., 2013). The ECV in children increases with age (Margolis and Heller, 1987). The 90% range of ECV in children aged 5-7 years is 0.7–1.3 cm^3 (Swanepoel et al., 2014).

11.1.5 Reporting results

The report of results using 226 Hz tympanometry should include the measurements obtained for middle-ear pressure, peak admittance and ECV. ECV is particularly important where a flat trace (one with no discernable peak) is seen in order to identify a possible open perforation and exclude blockage or incorrect placement of the probe (i.e. against the wall of the ear canal). The shape of the tympanogram should also be described and simple descriptions such as “normal”, “rounded”, “flat”, “wide” or “M-shaped” are acceptable (Feldman 1975). In the case of rounded or wide traces, a tympanometric width measurement may also be included for service users aged between 1 and 7 years.

The use of classification systems (Jerger 1970, Jerger et al. 1972) of tympanograms according to their shape alone is not recommended since this can lead to confusion or mistakes. It is also possible that not all parties receiving a copy of the report will be familiar with the classification system used. Where Jerger classifications are used, these should be accompanied by a supporting descriptor together with numerical values of middle-ear pressure, peak admittance and ECV.

A copy of the tympanogram shall 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, peak admittance and ECV, 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”.

Report forms should include normal values as an aid to interpretation. It may also be useful to note whether the testing was a screen or a diagnostic test and whether a hand-held probe was used or not.

11.1.6 Subsequent action and onward referral

It is not the purpose of these guidelines to suggest local service user pathways. Nevertheless competent testers shall be aware of the implications of tympanometry results. Evidence of MEE in children and the implications of bifid peak are discussed above and should be referred to the appropriate specialists where appropriate. Adults with MEE should be monitored and also referred where appropriate.

11.2 Service users with a corrected age under 6 months using a 1000 Hz probe tone

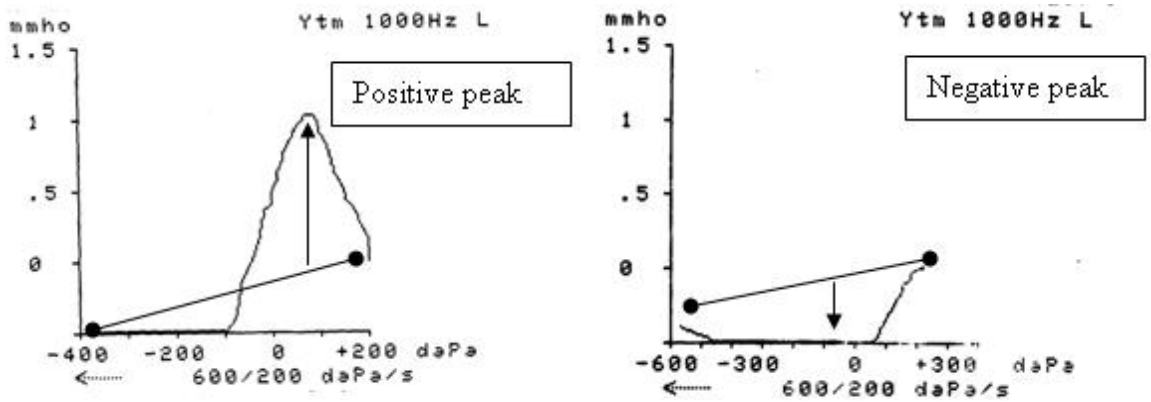
The value of ear canal volume should be disregarded when high-frequency probe tones are used because it will not be precise. The exception is for use as an indicator of a possible blockage (i.e. very small volume given), although this should be verified (e.g. with otoscopy and checking the probe).

It is recommended that the traces recorded are classified as normal or abnormal using the classification system reported by Baldwin (2006), adapted from Marchant et al. (1986); see Figure 4:

- Draw a baseline on the trace at pressure extremes (–400/–600 to +200 daPa); if the trace disappears below the x axis, the baseline should be drawn to the x axis, as shown in Figure 4.
- Identify the main peak which can occur at any middle-ear pressure.
- Draw a vertical line from the baseline to the peak of the trace.
- If the peak is above the baseline it is a positive peak and normal.
- If the peak is below the baseline it is a negative peak and abnormal.
- If there is a positive and negative peak the trace should be classified as normal.
- A positive peak at a positive or negative middle-ear pressure is classified as normal, whereas a flat or “trough-shaped” (i.e. negative peak) is abnormal.

Traces should be repeated to check for reliability. Repeated traces should be classified in the same category of positive or negative. Further examples are given in the Appendix 1.

Figure 4: Examples of a positive and negative peak (adapted from a method used by Marchant et al., 1986).



11.3 Acoustic Reflex Thresholds

Low-frequency tonal acoustic reflex thresholds (using elicitors in the range 0.25-2 kHz) do not change with increasing age in service users with normal hearing thresholds. Acoustic reflex thresholds for Broadband Noise (BBN) and 4-6 kHz elicitors do increase with increasing age, by around 8 dB when comparing listeners younger than 30 years to those older than 50 years (Wilson 1981). It is estimated that 5% of the adult population have an idiopathic absence of acoustic reflexes (Golding et al., 2007). In a larger sample of over 15,000 people, it was estimated that acoustic reflexes are common but not pervasive, and are present in approximately 85% of the population (Flamme et al., 2017).

Typical ARTs for young (20-30 years) listeners with clinically normal hearing are well-established, see Table 2. Tonal ARTs (500-2000 Hz) should be 75-95 dB HL where middle ear function is within normal limits, or a sensorineural hearing loss between 20-45 dB HL exists (Gelfand, Schwander and Silman, 1990). Ipsilateral ART measurements may therefore be useful as an addendum to tympanometry prior to pure tone audiometry where non-organic behaviour is suspected. Average ipsilateral ARTs vary by frequency but are approximately in the range 80-86 dB HL ±10 dB for 95% of the young adult population (2 SD) (Table 2). A conductive hearing loss will abolish the presence of an acoustic reflex when the probe is placed in the affected ear. The stapedius muscle is innervated by the seventh cranial nerve (CN VII) so, in the presence of CN VII paralysis, the stapedius muscle and presence of an acoustic reflex is also likely to be affected.

Contralateral ARTs are generally around 2-5 dB higher than ipsilateral ARTs (Wiley et al., 1987) and BBN ARTs are approximately 20 dB lower than tonal ARTs (Cacace et al., 1991; Moller, 1962). Note that the 4 kHz ART may be elevated or absent in service users with normal hearing, so this should not be taken as clinically significant.

Gelfand et al. (1990) collected contralateral reflexes from approximately 1,400 listeners at 500, 1000 and 2000 Hz. Tonal ARTs could not be used to differentiate between degrees of hearing loss ≤ 55 dB HL. In other words, contralateral ARTs are likely present in most cases of mild-to-moderate sensorineural hearing loss, and likely not present where the hearing loss is ≥ 60 dB HL.

Table 2: acoustic reflex thresholds for young adults, from Wiley et al. (1987), showing average ARTs in dB HL (and the 95% range) and one standard deviation (SD).

Frequency	Contralateral		Ipsilateral	
	Mean (95%)	SD	Mean (95%)	SD
500 Hz	84.6 (95)	6.3	79.9 (90)	5.0
1000 Hz	85.9 (95)	5.2	82.0 (90)	5.2
2000 Hz	84.4 (93.25)	5.7	86.2 (95)	5.9
4000 Hz	89.9 (108)	8.9	87.5 (90)	3.5
BBN	66.3 (80)	8.8	64.6 (75)	6.9

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Appendix 1: Examples of 1000 Hz tympanometry traces

Figure 6: Examples of 1000 Hz tympanograms classified as normal.

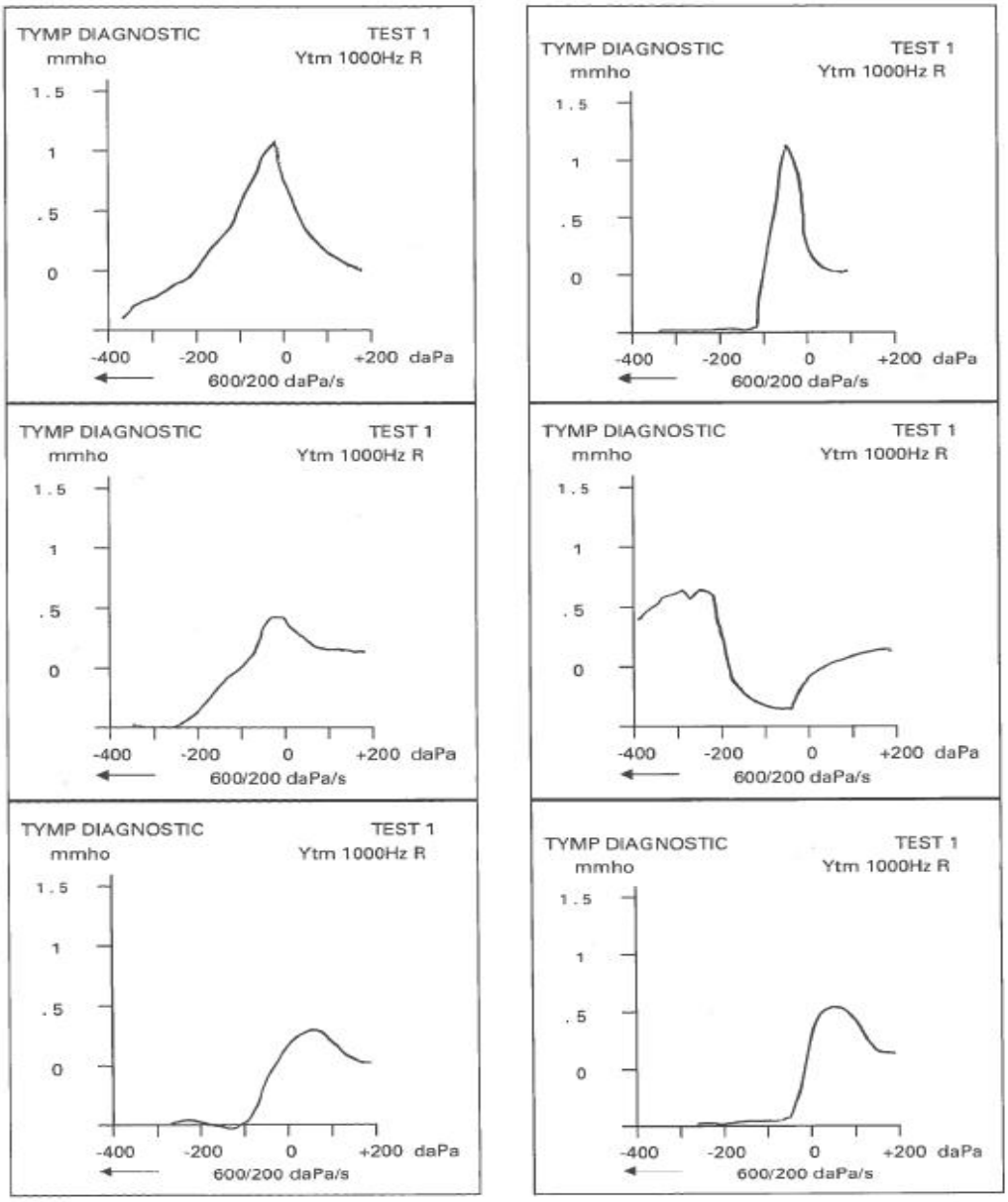
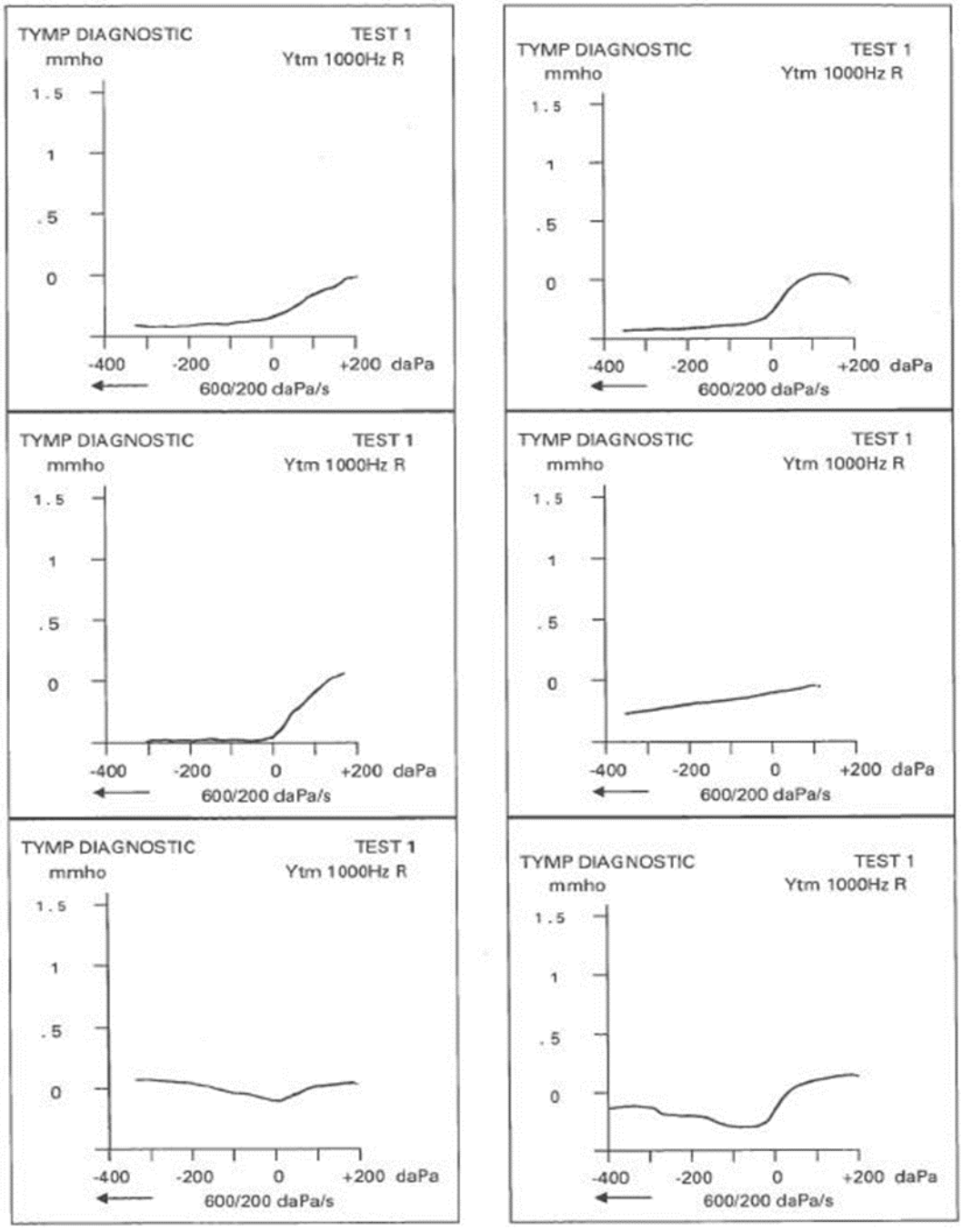


Figure 7: Examples of 1000 Hz tympanograms classified as 'abnormal'.



Appendix 2: Acoustic Reflex Patterns

Below are examples of reflex patterns that may be presented during testing. Different authors publish patterns or record results in different ways and therefore these tables below are a guide only. Note that reflexes at 4000Hz may or may not be present due to variability at this frequency (discussed earlier).

Normal Hearing and middle ear function

Generally for service users with normal hearing and normal middle ear function, both ipsilateral and contralateral reflexes will be present at all frequencies.

Example 1: Normal hearing / middle ear function

		500Hz	1000Hz	2000Hz	4000Hz
Probe R	Stim R (Ipsi)	85	85	85	85
	Stim L (contra)	90	90	90	90
Probe L	Stim L (Ipsi)	80	80	80	80
	Stim R (Contra)	85	85	85	85

Conductive hearing loss

Acoustic reflexes will be absent when a probe is placed in an ear with a middle ear disorder. This is due to the fact that middle ear disorders typically prevent the probe from measuring a change in compliance when the stapedius muscle contracts. Reflexes will therefore be absent even in the case of a mild conductive hearing loss. In the presence of a negative tympanogram, depending on the degree of negative pressure in the middle ear, reflexes can be either present or absent.

If acoustic reflexes are present in the probe ear, it is unlikely that a conductive hearing loss exists, except in the rare case of Superior Semi-circular Canal Dehiscence (SSCD).

Example 2: Normal hearing in the right ear & a mild conductive loss in the left ear

		500Hz	1000Hz	2000Hz	4000Hz
Probe R	Stim R (Ipsi)	85	85	85	85
	Stim L (contra)	100	100	100	105
Probe L	Stim L (Ipsi)	NR	NR	NR	NR
	Stim R (Contra)	NR	NR	NR	NR

In this example, the raised left contralateral reflex thresholds (probe right, stimulus left) are due to the additional SPL needed to overcome the mild loss in the L ear. The mild middle ear

pathology may affect signals travelling through the left ear or being measured in the left ear. They will either be absent or raised.

Example 3: Normal hearing in the right ear & a moderate conductive loss in the left ear

		500Hz	1000Hz	2000Hz	4000Hz
Probe R	Stim R (Ipsi)	85	85	85	85
	Stim L (contra)	NR	NR	NR	NR
Probe L	Stim L (Ipsi)	NR	NR	NR	NR
	Stim R (Contra)	NR	NR	NR	NR

In this example, because of the moderate loss in the left ear, the stimulus (even at maximum levels) was not loud enough to elicit the stapedius reflex in the left contralateral recording (probe right, stimulus left).

Cochlear hearing loss

In ears with a cochlear hearing loss, it is possible for the acoustic reflex to be elicited at sensation levels (SL) of less than 60dB. The sensation level is the difference between the acoustic reflex threshold and the hearing threshold. For example, if the hearing threshold at 1kHz is 50dB HL and the acoustic reflex thresholds is 90dB HL, the sensation level is 40dB SL. A sensation level less than 60dB indicates a cochlear site of lesion (sensorineural loss) due to the loudness recruitment phenomenon.

Example 4: A mild to moderate cochlear loss in both left & right ears

		500Hz	1000Hz	2000Hz	4000Hz
Probe R	Stim R (Ipsi)	85	80	80	100
	Stim L (contra)	85	90	90	NR
Probe L	Stim L (Ipsi)	85	90	85	100
	Stim R (Contra)	90	80	85	NR

In this example, note that the acoustic reflexes occur at about normal levels. This is because the acoustic reflex threshold in an ear with a cochlear loss may resemble the results of a normal ear when the air conduction thresholds are below about 50dB HL. As the hearing threshold increases above this level, the chance of recording a raised or absent acoustic reflex increases.

Example 5: Severe to profound cochlear loss in left ear, normal hearing in the right ear

		500Hz	1000Hz	2000Hz	4000Hz
Probe R	Stim R (Ipsi)	85	85	85	95
	Stim L (contra)	NR	NR	NR	NR
Probe L	Stim L (Ipsi)	NR	NR	NR	NR
	Stim R (Contra)	90	90	90	95

In this example, the stimulus (even at maximum levels) was not loud enough to elicit a stapedius reflex due to the severe/profound loss in the left ear. Therefore, whenever a stimulus is presented to the affected ear, reflexes will be absent/raised in both ipsilateral and contralateral recordings as shown above.

Retrocochlear hearing loss

Acoustic reflex thresholds in ears with retrocochlear pathology are usually elevated above what they would have been for normal hearing or a cochlear hearing loss. Often they are absent at maximum stimulus levels. Keep in mind that acoustic reflex results should be analysed in combination with the service user case history, audiogram, speech and tympanometry findings for differential diagnosis.

General considerations:

- Ears with retrocochlear pathology and normal hearing do not have reflexes 30% of the time
- With a mild 30dB hearing loss, the likelihood of absent reflexes increases
- The absence of reflexes at 500, 1000 and 2000Hz in the presence of normal/near normal hearing must be considered suspicious unless proven otherwise
- The affected ear will show absent acoustic reflexes when a stimulus is presented to it in the case of CN VIII (eighth cranial nerve) lesions

Example 6: Retrocochlear lesion in the left ear; normal hearing in both ears

		500Hz	1000Hz	2000Hz	4000Hz
Probe R	Stim R (Ipsi)	80	80	80	90
	Stim L (contra)	105	110	NR	NR
Probe L	Stim L (Ipsi)	110	NR	NR	NR
	Stim R (Contra)	85	80	85	95

In this example, note the raised/absent acoustic reflexes with presentation to the left ear.

Example 7: Retrocochlear/CN VIII lesion in the left ear; a mild hearing loss in the left ear & normal hearing in the right ear

		500Hz	1000Hz	2000Hz	4000Hz
Probe R	Stim R (Ipsi)	80	80	85	85
	Stim L (contra)	NR	NR	NR	NR
Probe L	Stim L (Ipsi)	NR	NR	NR	NR
	Stim R (Contra)	85	85	90	90

In this example, note the absent acoustic reflexes when sound is presented to the left ear. Note the similarity with example #5.

Facial Nerve / CN VII involvement

Acoustic reflexes are absent when measured on the affected side in the case of a facial nerve disorder (e.g. probe in the affected ear). This is because the stapedius muscle is innervated by the CN VII. Often, CN VII disorders are easily recognisable (e.g. facial paralysis in the case of Bell's Palsy) and measurement of the acoustic reflex is used as a tool to monitor the recovery process in such service users.

Example 8: Facial nerve/CN VII lesion in the left ear due to Bell's Palsy; normal hearing in both ears

		500Hz	1000Hz	2000Hz	4000Hz
Probe R	Stim R (Ipsi)	80	80	85	85
	Stim L (contra)	85	85	85	90
Probe L	Stim L (Ipsi)	NR	NR	NR	NR
	Stim R (Contra)	NR	NR	NR	NR

In this example, note that the acoustic reflexes are absent when the probe is coupled to the affected (left) ear. Also, you will recognise this is a similar pattern of results for a CN VIII lesion.

Intra-axial brainstem lesion

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- Acoustic reflexes are normal ipsilaterally and absent contralaterally. The left and right pathways are disrupted by a lesion involving the auditory fibres.

Example 9: Intra-axial brainstem lesion; normal hearing in both ears

		500Hz	1000Hz	2000Hz	4000Hz
Probe R	Stim R (Ipsi)	80	80	85	85
	Stim L (contra)	NR	NR	NR	NR
Probe L	Stim L (Ipsi)	85	80	80	85
	Stim R (Contra)	NR	NR	NR	NR

The Acoustic Reflex is usually maintained close to its maximum value over the length of the stimulus period. Abnormal decay of the response is often indicative of retrocochlear pathology. It is not the purpose of this guideline to describe AR decay in detail, but clinicians should be aware that abnormal decay may need to be investigated.