

Pediatricians Guide to Otoacoustic Emissions (OAEs) and Tympanometry



Introduction

Hearing loss is not uncommon in children. According to recent estimates, 37.5 million people in the United States report difficulty with hearing. Approximately 6 out of every thousand children have some type of unilateral or bilateral hearing loss. When present from birth, or acquired in the pre-school years, hearing loss of any degree, even mild hearing loss, interferes with speech and language development. Hearing loss among school age children contributes to poor academic performance, including reading disorders. Indeed, in a policy statement approved by the American Academy of Pediatrics, “The Joint Committee on Infant Hearing (JCIH) endorses early detection of and intervention for infants with hearing loss. The goal of early hearing detection and intervention (EHDI) is to maximize linguistic competence and literacy development for children who are deaf or hard of hearing. Without appropriate opportunities to learn language, these children will fall behind their hearing peers in communication, cognition, reading, and social-emotional development.” (Joint Committee on Infant Hearing, 2007, p. 898)

The Joint Committee on Infant Hearing (2007) identified risk factors or indicators for childhood hearing impairment. Factors associated with congenital, delayed onset, or progressive hearing loss, are summarized in Appendix A at the end of this booklet. At the top of the list of risk factors is caregiver concern regarding hearing, speech, language, or developmental delay, followed by family history of permanent childhood hearing loss. A number of risk factors for sensory or conductive hearing loss can be identified in the perinatal period. Others are associated with syndromes or neurodegenerative disorders. Hearing screening with otoacoustic emissions, sometimes in combination with tympanometry, is warranted for children whose medical histories reveal one or more of these risk factors.

In addition to, and related to, obvious communication deficits, the consequences of hearing loss in children include psychosocial problems, such as frustration, irritability, anxiety, the tendency to withdraw from social interactions, and even depression. The psychosocial problems, of course, affect relationships between the person with the hearing impairment and family members, classmates, teachers, friends, and others.

Otoacoustic emissions (OAEs) permit early detection of inner ear abnormalities associated with a wide variety of diseases and disorders, including non-pathologic etiologies like metabolic dysfunction of outer hair cells caused by potentially ototoxic medications. With early detection, the serious consequences of hearing loss can sometimes be prevented. And, fortunately, with proper identification and diagnosis of hearing impairment, medical and non-medical (e.g., audiologic) treatment options almost always lead to effective management.

Tympanometry provides a graphic representation of impedance (stiffness related) changes in the tympanic membrane (ear drum) and middle ear as air pressure is changed in the external ear. Tympanometry quickly, objectively, and non-invasively yields clinically valuable information on the functional status of the tympanic membrane and the middle ear system. Middle ear disorders, a common occurrence in young children, can almost always be detected, and sometimes differentiated, by simple analysis of the results of tympanometry. Tympanometry is easily performed in a physician's office, or any clinical setting.

The ear and hearing

The *external ear* (the pinna) collects sound and funnels sound to the inner ear. Anatomy of the ear is illustrated in Figure 1. The external ear also plays a role in localization (determining the source of sound), and lateralization (which side the sound is coming from). Cerumen (wax) in the ear canal, and the S-shape of the ear canal, contributes to protection of the delicate tympanic membrane (ear drum). External ear canal acoustics also enhance some of the frequencies in the region of 2000 to 4000 Hz that are important for speech perception.

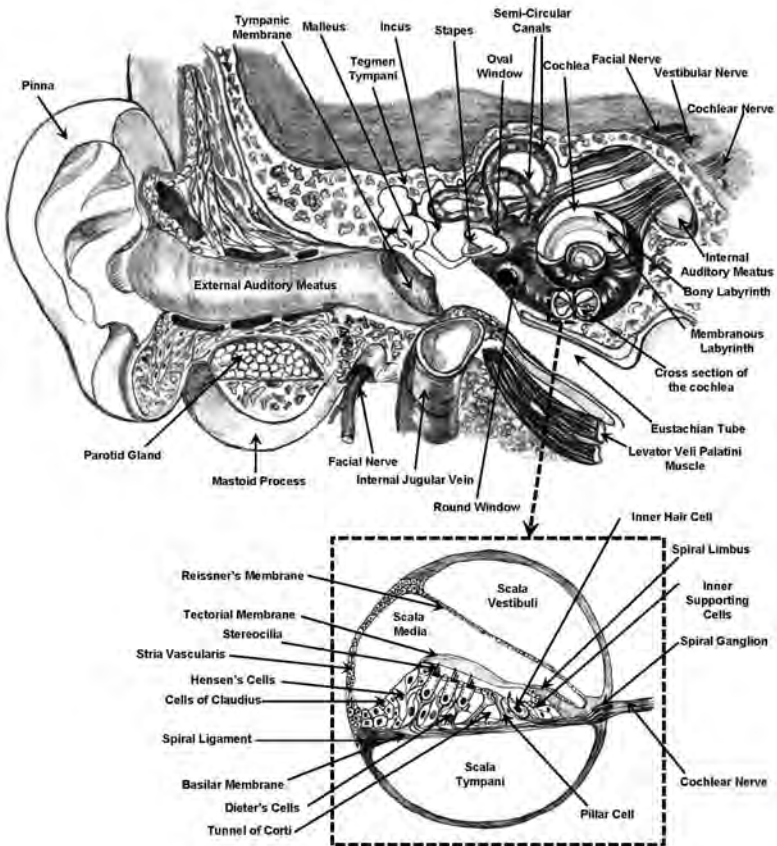


Figure 1. Simplified diagram of three portions of the ear (external, middle, and inner ear), the auditory (8th cranial) nerve, and auditory regions of the brain. Illustration appears with permission of artist Anuradha Bantwal.

The *middle ear* consists of the tympanic membrane and the ossicles (malleus, incus, and stapes). Sound waves reaching the tympanic membrane are amplified by the middle ear system, providing an increase in sound intensity of almost 30 dB. Mechanical energy from sound waves is converted to electrical signals by specialized *hair cells* located within the *inner ear* (the cochlea). The term “hair cells” is used because there are extending from the top of each cell hundreds of thin hair-like protein-based cilia. There are about 15,000 hair cells in the human ear. One third of the hair cells, the *inner hair cells* located medially in the cochlea (see Figure 1), communicate (synapse) with auditory (8th cranial nerve) fibers. Activation of the inner hair cells leads to firing of auditory nerve fibers and stimulation of auditory regions of the central nervous system (also shown in Figure 1). The remaining two-thirds of the hair cells located more laterally within the cochlea, referred to as *outer hair cells*, are capable of motility (movement). Upon activation, metabolism within the outer hair cells increases dramatically, and the outer hair cells rapidly elongate (during hyper-polarization) and become shorter (during depolarization). Changes in outer hair cell length generate energy within the cochlea that contributes to hearing sensitivity and the ability to distinguish small differences in the frequencies of sounds. Outer hair cell movement also produces otoacoustic emissions, as reviewed briefly in the next section.

At this point, it's important keep in mind that although the ear is clearly important in hearing, we really hear with our brain. High level auditory processing, including speech perception, occurs within a complex network of central nervous system pathways and centers (nuclei) containing millions of neurons. Clinically, hearing evaluation is not complete unless it includes procedures for evaluating how the brain processes relatively sophisticated sounds, such as speech. Audiologists regularly perform such procedures in hearing assessment. Audiologic tests used to evaluate function of the ear, such as otoacoustic emissions (OAEs) and tympanometry, are very important in the diagnosis of hearing loss. However, these tests alone are not a test of hearing.

What are OAEs and how are they recorded?

Otoacoustic emissions (OAEs) are sounds measured in the external ear canal that reflect movement of the outer hair cells in the cochlea. Energy produced by outer hair cell motility serves as an amplifier within the cochlea, contributing to better hearing. Indeed, normal outer hair cells are essential for perfectly normal auditory function. OAEs are produced by the energy from outer hair cell motility that makes its way outward from the cochlea through the middle ear, vibrating the tympanic membrane, and propagating into the external ear canal. Although the amplification produced by outer hair cell movement within the cochlea may be as high as 50 dB, residual energy reaching the ear canal ...otoacoustic emissions ... is normally in the range of 0 to 15 dB.

Two types of OAEs may be measured clinically with FDA-approved devices. *Transient evoked OAEs (TEOAEs)* are elicited with very brief (transient) sounds, such as clicks or tone bursts, presented at an intensity level of 80 dB SPL. TEOAEs reflecting cochlear (outer hair cell) activity are generally recorded over the frequency range of 500 to about 4000 Hz. *Distortion product OAEs (DPOAEs)* are elicited with sets of two pure tone frequencies, abbreviated f_2 and f_1 , that are closely spaced and presented simultaneously at moderate intensity levels, such as (respectively) 55 and 65 dB SPL. DPOAEs can be recorded across a frequency region of 500 to 8,000 Hz and sometimes even higher frequencies. Mechanisms and clinical applications of OAEs are described in recent textbooks (cited at the end of the booklet) and in thousands of peer reviewed journal articles. An Internet search for OAE literature can easily be performed via the National Library of Medicine website (www.nlm.nih.gov, Health Care Professionals).

OAEs are non-invasive and technically simple to record, usually requiring only a few minutes for both ears. Sedation is not indicated for OAE measurement, even in children. No behavioral response is required for participating in the testing, so the procedure is not affected by a patient's motivation, attention, or cognitive status. Briefly, a soft disposable probe tip is gently inserted into the outer portion of the external ear canal (Figure 2). An airtight seal between the probe and the ear canal isn't necessary. A miniature speaker within the probe assembly (two speakers for DPOAEs) generates in the ear canal sound stimuli at a moderate intensity level. The stimuli vibrate the tympanic membrane and mechanical energy is transmitted through the middle ear to the cochlea. Tiny waves in the cochlear fluids vibrate a thin membrane, activating outer

hair cells located on the membrane. Energy associated with outer hair cell movement, in the frequency region of the stimulus, is propagated back through the middle ear system and, as sound, into the ear canal. A miniature microphone within the probe assembly detects OAE-related sound, as well as any other sound in the ear canal during the recording. By means of sophisticated algorithms in the OAE device, OAE activity is differentiated from other ambient and physiological noise in the ear canal and the presence of OAEs is statistically confirmed. Amplitude values for the OAEs are then compared to normative data for the device [refer again to Figure 2].

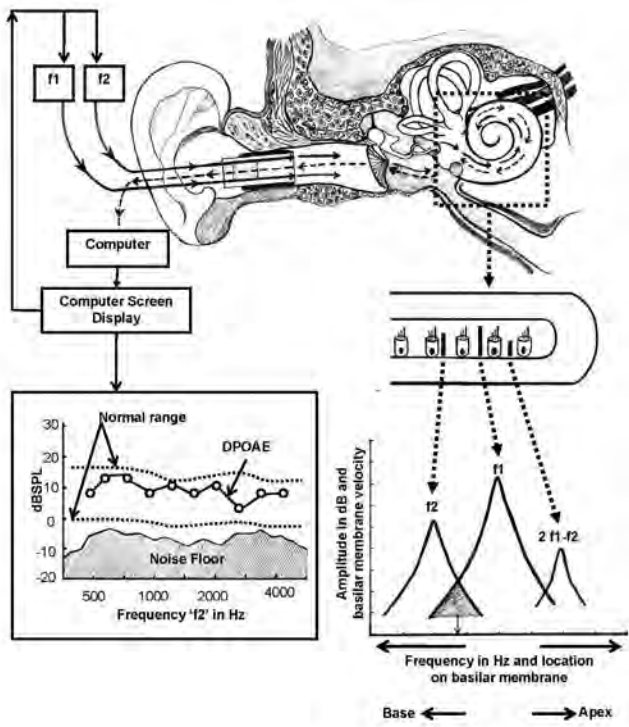


Figure 2. Illustration of the measurement of distortion product otoacoustic emissions (DPOAEs) showing a probe assembly that fits into the external ear canal, the delivery of the signals to the ear via the middle ear, the generation of OAEs by outer hair cells in the cochlea and, finally, propagation of OAE energy as sound into the external ear canal. Illustration appears with permission of artist Anuradha Bantwal.

Analysis and interpretation of OAEs

Modern OAE devices typically include software for automated data analysis in hearing screening, including algorithms for calculation of amplitude values, noise floor levels, and for statistical confirmation the OAEs are present or absent. Visual inspection of OAE data with manual analysis is almost always an option, and particularly important for diagnostic application of OAEs. There are three general steps in the analysis of OAE findings. The first step is to verify adequate measurement conditions. Specifically, noise levels must be sufficiently low (usually less than -10 dB SPL) to permit confident detection of OAE activity and the stimulus intensity levels in the ear canal should be close to the desired (target) levels. OAE devices invariably perform a quick calibration of stimulus intensity levels prior to data collection. The next step in data analysis is to determine whether reliable (repeatable) OAEs are recorded, that is, whether OAE amplitude exceeds the noise level by 6 dB or more at the test frequency. Finally, when the difference between OAE amplitude and noise floor ≥ 6 dB SPL, findings are analyzed with respect to an appropriate normal region for OAE amplitude.

Examples of the Pass and Refer outcomes for OAE screening are illustrated in Figure 3. Amplitudes for distortion product otoacoustic emissions (see DP column) for different stimulus frequencies (2000 to 5000 Hz) are displayed in tabular form, along with the corresponding noise floor (NF) in the ear canal and the signal-to-noise ratio (SNR), i.e., the difference between the distortion product amplitude and the noise floor at that frequency region. As a rule, a SNR of ≥ 6 dB indicates the presence of a DPOAE. Just to the right of the table, in the figure, the bars depict the SNR for each test frequency and, below, amplitude of the DP (at the frequency $2f_1-f_2$) in dB (SPL) plotted as a function of the f_2 stimulus. DP findings are automatically scored, with screening outcome (PASS or REFER) displayed clearly. DPOAE screening over a limited high frequency range (e.g., 2000 to 5000 Hz) is remarkably quick, often taking as little as 10 to 30 seconds.

Distortion-Product Otoacoustic Emission Test Report

Right Ear: PASS

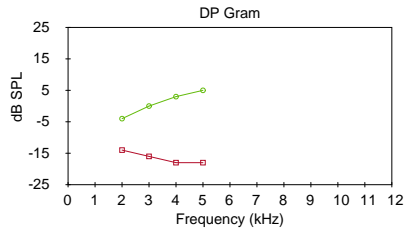
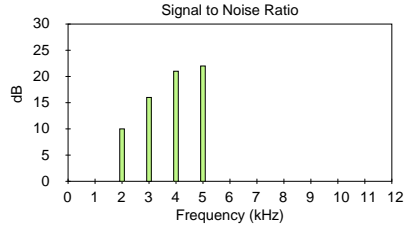
Patient Name: _____

Protocol: DP QuickScreen

Test Number: 26 Test Date: 2009-10-15 15:13:15
Instrument and Probe Serials: 0835019 T0840102

Number of frequencies: 4, minimum for a pass: 3

| F2 | P1 | P2 | DP | NF | SNR | Result |
|------|----|----|------|-------|------|--------|
| 2000 | 66 | 55 | -4.0 | -14.0 | 10.0 | P |
| 3000 | 66 | 55 | 0.0 | -16.0 | 16.0 | P |
| 4000 | 64 | 55 | 3.0 | -18.0 | 21.0 | P |
| 5000 | 65 | 55 | 5.0 | -18.0 | 22.0 | P |



Distortion-Product Otoacoustic Emission Test Report

Right Ear: REFER

Patient Name: _____

Protocol: DP QuickScreen

Test Number: 26 Test Date: 2009-10-15 15:13:15
Instrument and Probe Serials: 0835019 T0840102

Number of frequencies: 4, minimum for a pass: 3

| F2 | P1 | P2 | DP | NF | SNR | Result |
|------|----|----|------|-------|------|--------|
| 2000 | 66 | 55 | -7.0 | -10.0 | 3.0 | R |
| 3000 | 66 | 55 | -7.0 | -10.0 | 3.0 | R |
| 4000 | 64 | 55 | -4.0 | -12.0 | 8.0 | P |
| 5000 | 65 | 55 | -2.0 | -14.0 | 12.0 | P |

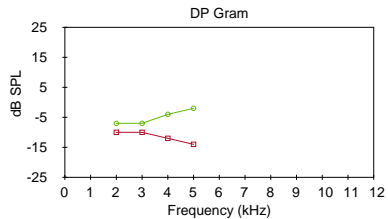
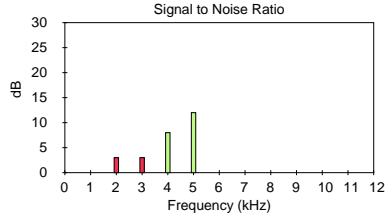


Figure 3

Clinical applications of OAEs

Given their sensitivity to cochlear dysfunction, and the clinical advantages just cited, it's not surprising that OAEs are useful in auditory assessment of diverse patient populations. One of the most common applications of OAEs is screening persons at risk for hearing impairment. OAE screening outcome is generally described as either "Pass" or "Refer." A pass outcome is reported when OAEs are present (≥ 6 dB above the noise floor) for the majority of test frequencies. Although the presence of OAEs does not always indicate normal hearing sensitivity, a pass outcome rules out serious degrees of hearing loss. A refer OAE screening outcome should be viewed as a clear risk factor for hearing loss that could affect communication. Patients who yield a refer outcome for OAE screening should be referred for diagnostic hearing assessment, and possible audiological or medical management.

The literature contains hundreds of peer reviewed scientific papers reporting evidence in support of OAE measurement in children and adults. According to the Joint Committee on Infant Hearing (JCIH), OAEs are a mandatory component of the audiologic test battery. JCIH recommended test batteries for auditory assessment of infants (age 0 to 6 months) and for toddlers (age 6 months to 2 years) are detailed in Appendix B. Selected applications of OAE are summarized in Table 1.

Table 1. Selected applications of otoacoustic emissions (OAEs) in pediatric patient populations

-
- Infant hearing screening
 - Screening hearing in pre-school (e.g., Head Start) years
 - Screening in school age children
 - Monitoring for possible cochlear ototoxicity
 - Early detection of noise induced cochlear dysfunction
 - Diagnosis of pediatric hearing impairment
-

Why are OAEs clinically valuable?

OAE are widely applied in pediatric and adult patient populations for a variety of reasons. As already noted, OAEs are an index of outer hair cell activity. Because of their dependence on normal cell metabolism, OAEs are exquisitely sensitive to even subtle outer hair cell dysfunction. Almost all insults to the cochlea first affect the outer hair cells. Vascular or hypoxic cochlear deficits will be invariably reflected by reduced OAE amplitude. Therefore, assuming normal middle ear function, OAE abnormalities provide early and compelling evidence of cochlear (outer hair cell) dysfunction. Additional clinical advantages of OAE are:

- Brief test time: Usually less than a minute per ear
- Relatively simple technique: Little training is required
- Objective: Unaffected by attention, cognition, cooperation
- Independent of age: OAEs can even be recorded from newborn infants
- Ear specific: Test results for each ear
- Frequency specific: Information for many individual frequencies

What is tympanometry and how is it recorded?

Tympanometry reflects change in physical properties of the middle ear system as air pressure in the external ear canal is systematically varied. Tympanometry was introduced as a clinical procedure in the early 1970s. Since then, a variety of FDA-approved devices have been marketed, and thousands of articles have described the value of tympanometry in the identification and differentiation of middle ear disorders.

Tympanometry begins with insertion of a probe assembly into the external ear canal. The probe assembly, coupled to a soft rubber tip, usually consists of three small tubes for: 1) Presentation of a pure tone sound (known as the probe tone), 2) Detection of sound level within the ear canal via a miniature microphone in the probe assembly, and 3) Air pressure changes in the ear canal. Disposable probe tips are available in a variety of sizes to accommodate patients from newborn infants to school age children. Tympanometry requires an airtight (hermetic) seal between the probe tip and the walls of the external ear canal. An airtight seal is confirmed when positive or negative pressure in the external ear canal is developed at +200 or - 300 mmH₂O (daPa). If neither positive nor negative pressure can be created in the external ear canal, the probe tip should be replaced and reinserted in an attempt to adequately seal the external ear canal. Tympanometry is very quick. The systematic change in external ear canal from +200 to -200 or -300 mmH₂O (daPa), and measurement of the resultant change in middle ear compliance, takes only 5 to 10 seconds.

Patients need to remain reasonably still during tympanometry. Bodily movement will not affect test results. Tympanometry may need to be repeated if first performed with a crying child. Older pre-school and school age children usually tolerate the procedure very well. The test should be explained first to alert patients to the sounds that they will be hearing, and the pressure changes in the ear canal they will be experiencing. Often, with young children cooperation can be enhanced if the child is sitting on the parent's lap and is distracted by a toy, a stuffed animal, or observing some fun activity (a parent or assistant blowing bubbles). It's also helpful to encourage young children to touch the probe tip to see that it's soft, and even to demonstrate tympanometry with a parent before the procedure is performed on the child.

Tympanometry yields a graph called a tympanogram (see Figure 4). The tympanogram is generally recorded as a plot of middle ear system compliance or flexibility (depicted on the Y-axis) as air pressure within the ear canal (depicted on the X-axis) is decreased from a positive to a negative extreme. Compliance of the middle ear is described in terms of equivalent compliance (in ml or cc) for a volume of air. Information obtained with tympanometry includes compliance (flexibility or stiffness) of the middle ear system, ear canal volume, and an estimate of middle ear pressure. Tympanometry may be performed as a single procedure, but it is often included within a series of procedures collectively referred to as immittance measurements. The term immittance is a combination of the two terms impedance (resistance to energy flow through the middle ear) and admittance (ease of energy flow through the middle ear). In addition to tympanometry, immittance measurements include estimation of external ear canal volume (in cm^3 or ml) and measurement of the acoustic reflex (see Hall and Swanepoel, 2010 for a concise and recent review of immittance measurements).

TYMPANOMETRY

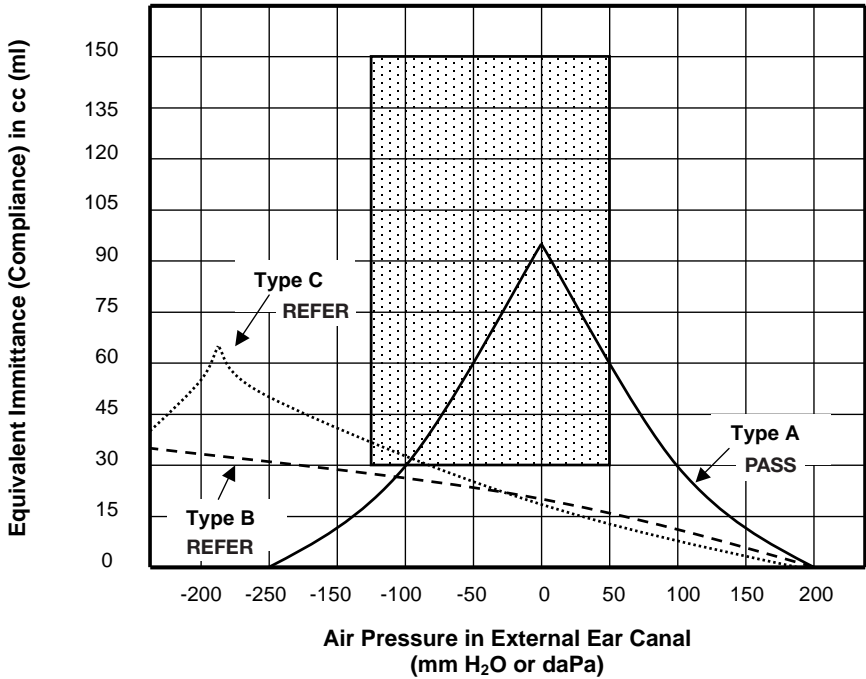


Figure 4

Analysis and interpretation of tympanometry

A simple, time-tested, and clinically popular approach for analysis of tympanograms is also illustrated in Figure 4. Again, air pressure change is shown on the X-axis, whereas equivalent immittance [compliance] of the middle ear system is displayed on the Y-axis. The shaded box indicates the normal region for tympanometry. A normal outcome for tympanometry is characterized by a “type A” tympanogram. With the type A tympanogram, as air pressure in the ear canal is decreased from +200 mmH₂O to atmospheric pressure (0 mmH₂O), there is a systematic increase in middle ear compliance. The normal type A tympanogram peak, with compliance between 0.30 and 1.50 cc (ml), is normally observed within the pressure region of about +50 through - 150 mmH₂O. Then, as air pressure in the ear canal is decreased further, middle ear compliance also decreases to a minimum value, usually at negative pressure of > - 200 mmH₂O. One variation of this pattern is an As tympanogram (the “s” refers to “shallow”), indicating a restriction in the flexibility of the middle ear system. In some cases, a markedly shallow (type A_s) tympanometry is recorded with fixation of the ossicular chain. At the other extreme, a very deep A (A_d) tympanogram (the “d” refers to deep) indicates a highly compliant middle ear system, or tympanic membrane. A type “A_d” tympanogram is often seen with a scarred and hyper-compliant tympanic membrane or, less commonly, a discontinuity of the ossicular chain.

With an abnormal “type B” tympanogram (also shown in Figure 4), there is no clear peak as air pressure is varied across the range of +200 mmH₂O to -300 mmH₂O. Often the type B tympanogram appears as essentially a flat line. The finding of a type B tympanogram indicates a severely restricted mobility of the middle ear system, and often is consistent with otitis media.

At this point it's important to emphasize that tympanometry can be conducted only after an airtight (hermetic) seal is obtained between the probe tip and the external ear canal walls. With a hermetic seal, it's possible with clinical immittance devices to estimate the ear canal volume between the probe tip and the tympanic membrane. For children, ear canal volumes are in the range of 0.40 to 1.0 cm³ (ml) depending on body size. When a hermetic seal is confirmed, the finding of an ear canal volume exceeding 1.0 cm³ (ml) or, a large asymmetry in ear canal volume, suggests the possibility of either a tympanic membrane perforation or a patent (open) ventilation tube in the

tympanic membrane. Estimation of ear canal volume is a clinically useful feature of tympanometry. However, when the tympanic membrane is not intact, air pressure cannot be varied within the ear canal and the requirement for tympanometry cannot be met.

A “type C” tympanogram (Figure 4), also abnormal, has a negative pressure peak exceeding the normal limits (less than $-150 \text{ mmH}_2\text{O}$). Sometimes the type C tympanogram has a rounded maximum point, rather than a distinct peak. The finding is most often an indicator of Eustachian tube dysfunction, and resulting inadequate ventilation of the middle ear space.

Strengths and limitations of tympanometry

Tympanometry is a sensitive indicator of middle ear functional status, often revealing evidence of abnormalities not clearly visible upon visual examination.

Advantages of tympanometry

- Sensitive to middle ear dysfunction
- Objective test
- Non-invasive
- Feasible for patients of any age
- Quantified and documented test results
- Quick (less than 2 minutes for both ears)
- Reimbursable with CPT code

Tympanometry contributes importantly to the description and diagnosis of common abnormalities affecting the middle ear, such as:

- Otitis media (type B tympanogram)
- Tympanic membrane perforation (abnormally large volume measurement)
- Eustachian tube dysfunction (type C tympanogram)
- Disarticulation (discontinuity) of ossicular chain (type A_d tympanogram)
- Otosclerosis (type A_s tympanogram)

Tympanometry can also be useful in determining whether ventilation tubes in the tympanic membrane are patent (open and functioning properly). Test time for tympanometry is short (usually less than 2 minutes for both ears). The procedure can be performed in a physician's office, at bedside in a hospital, and in educational settings. The clinical value of tympanometry in children is confirmed by the requirement for inclusion of the procedure in the JCIH recommended test battery for auditory assessment of infants and for toddlers (see Appendix B).

Different subject and pathological conditions must be taken into account in the interpretation of results for all screening and diagnostic tests. Tympanometry is no exception. It's also important to emphasize that tympanometry is not a valid measure of hearing, or even hearing sensitivity. Normal tympanograms may be recorded in children with sensory hearing loss affecting speech and language development, including severe to profound hearing impairment. Conversely, abnormal tympanometry findings are not always associated with communicatively or clinically significant deficits in hearing sensitivity.

In short, tympanometry findings in isolation cannot be used to diagnose auditory dysfunction or to predict the degree of hearing loss. Using in combination with another objective technique, such as otoacoustic emissions (OAEs), enhances the screening and diagnostic value of tympanometry (Hall & Swanepoel, 2010). For diagnostic assessment of auditory function, however, tympanometry must be included within an appropriate test battery. *It is important to keep in mind that tympanometry is not a test of "hearing."*

OAE and tympanometry billing and reimbursement considerations

Two Current Procedural Terminology (CPT) codes were established in 1996 for reimbursement of OAE procedures, using either TEOAE or DPOAE technology. CPT code 92587 is appropriate for *screening applications* of OAEs in pediatric or adult populations. As a rule, OAE recording under CPT code 92587 is performed with stimuli presented at a single intensity level (for DPOAEs one set of f_2 and f_1 frequencies) over a limited frequency region (e.g., 2000 to 5000 Hz), with outcome categorized as either “pass” (e.g., OAEs are present) or “refer” (e.g., OAEs are not detected). With CPT code 92587, OAEs may be recorded by technicians, nurses, or other personnel and in isolation, that is, not as part of an audiological test battery.

Please Note!

It is important to distinguish between the screening and the diagnostic codes for otoacoustic emissions, and to utilize the codes accordingly. The diagnostic code (92588) is generally used when otoacoustic emissions are recorded by audiologists or otolaryngologists within a test battery in combination with other audiological procedures, such as tympanometry, comprehensive audiological assessment, conditioned play audiometry, and/or auditory brainstem response.

CPT code 92588 is appropriate when OAEs are applied for diagnostic purposes, usually when OAE are measured as one procedure within a battery of diagnostic tests (e.g., with a comprehensive audiological assessment). Using CPT code 92588, OAEs are often recorded several times with stimuli at different intensity levels presented over a wide range of test frequencies (e.g., 500 up to 8000 Hz). OAE results for discrete test frequencies or limited frequency regions may be analyzed separately and then reported according to one of three outcome categories: 1) normal (OAE amplitudes are within a defined normal region), 2) abnormal but present (e.g., OAEs are ≥ 6 dB above the noise floor but below normal limits), or 3) absent (no OAE activity can be distinguished from the noise floor).

Descriptors for OAE CPT Codes

92558: “Evoked otoacoustic emissions, screening (qualitative measurement of distortion product or transient evoked otoacoustic emissions), automated analysis.”

92587: “Distortion product evoked otoacoustic emissions, limited evaluation (to confirm the presence or absence of hearing disorder, 3–6 frequencies) or transient evoked otoacoustic emissions, with interpretation and report.”

92588: “Distortion product evoked otoacoustic emissions, comprehensive diagnostic evaluation (quantitative analysis of outer hair cell function by cochlear mapping, minimum of 12 frequencies), with interpretation and report.”

The CPT code for tympanometry is 92567, whereas the code for acoustic reflexes is 92568. Combinations of measurements also have CPT codes. Code 92550 is used for the combination of tympanometry and acoustic reflex threshold measurements. The other two codes (92567 and 92568) are not used with code 92550. Another code, 92570 includes three procedures tympanometry, acoustic reflex thresholds, and acoustic reflex decay.

Pulling it all together

OAEs are a quick, non-invasive, sensitive, and objective procedure for detecting in the office, clinic, or hospital hearing loss secondary to middle ear or inner ear (cochlear) auditory dysfunction. In other words, OAEs are a handy and proven technique for identifying persons at risk for hearing impairment. Tympanometry offers a rapid and clinically feasible procedure for detection of middle ear disorders in children. By combining OAE measurement with tympanometry, it’s usually possible to distinguish between cochlear (outer hair cell) and middle ear abnormalities. The combination of abnormal findings for tympanometry and OAEs suggests middle ear disorder. On the other hand, the finding of abnormal OAEs in combination with normal tympanometry is most consistent with cochlear (outer hair cell) auditory dysfunction.

Despite the many clinical advantages and applications of OAE measurement, and tympanometry, it’s important to remember that **neither technique is a test of hearing**. OAEs may be absent in persons with normal hearing sensitivity who have residual minor middle ear disorders. Conversely, OAEs may be present, even with amplitudes entirely within normal limits, in children or adults with rarely encountered inner hair cell dysfunction or retrocochlear auditory pathology. Normal tympanometry is not necessarily consistent with normal hearing sensitivity, and abnormal tympanograms.

Selected References

CPT® codes and descriptions are copyright 2011 American Medical Association. CPT is a registered trademark of the American Medical Association.

Dhar S & Hall JW III. (2010). *Otoacoustic Emissions: Principles, Procedures, and Protocols*. San Diego: Plural Publishing

Hall JW III. (2000). *Handbook of Otoacoustic Emissions*. San Diego: Singular Publishing Company

Hall JW III & Swanepoel, D. (2010). *Objective Assessment of Hearing*. San Diego: Plural Publishing

National Center for Hearing Assessment and Management (NCHAM). (2006). Early identification of hearing loss: Conducting periodic otoacoustic emissions (OAE) hearing screening with infants and toddlers during well-child visits. For more information, contact NCHAM at Utah State University, Logan UT 84322. Available online at: www.infanthearing.org or www.hearandnow.org/periodicscreening

Year 2007 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs. *Joint Committee on Infant Hearing Pediatrics*, 120, pp. 898-921

NOTE: Anyone with Internet access can quickly perform a literature review on the topics of otoacoustic emissions or tympanometry at the National Library of Medicine website (www.nlm.nih.gov, Health Care Professionals). A search will produce abstracts of thousands of articles containing the word "otoacoustic emissions." A more refined search can be performed with combinations of terms, such as "otoacoustic emissions" and "dementia." Articles of interest can then be requested via email of the author designated for correspondence.

Credits

James W. Hall III, Ph.D. contributed to the preparation of this booklet. Dr. Hall earned his Masters degree from Northwestern University and his Ph.D. in Audiology from Baylor College of Medicine. He is the author of over 150 journal articles and book chapters, plus 10 textbooks including the Handbook of Otoacoustic Emissions and the recently published Otoacoustic Emissions: Principles, Procedures, and Protocols. Dr. Hall is Clinical Professor in the Department of Communicative Disorders at the University of Florida where he maintains a clinical practice, teaches doctoral level students, and conducts externally funded research.

Kathryn Sutherland, Marketing Manager, served as production coordinator for this booklet.

Anuradha Bantwal provided the artwork appearing in Figure 1 and Figure 2 of this booklet. Ms. Bantwal is an Audiologist and Speech-Language Pathologist working in India.

Additional Resources

American Academy of Audiology. www.audiology.org

American Academy of Pediatrics. www.aap.org

Better Hearing Institute. www.betterhearing.org

National Center for Hearing Assessment and Management (NCHAM).

www.infanthearing.org

Otoacoustic Emissions Portal Zone. www.otoemissions.org

Appendix A. Evidenced-based risk indicators that are associated with hearing loss in childhood, including permanent congenital, delayed onset, or progressive hearing loss, according to the Joint Committee on Infant Hearing.*

- Caregiver concern regarding hearing, speech, language, or developmental delay
- Family history of permanent childhood hearing loss
- Neonatal intensive care of more than 5 days or any of the following regardless of length of stay: ECMO, assisted ventilation, exposure to ototoxic medications (gentimycin and tobramycin) or loop diuretics (furosemide/Lasix), and hyperbilirubinemia that
- In utero infections, such as CMV, herpes, rubella, syphilis, and toxoplasmosis
- Craniofacial anomalies, including those that involve the pinna, ear canal, ear tags, ear pits, and temporal bone anomalies
- Physical findings, such as white forelock, that are associated with a syndrome known to include a sensorineural or permanent conductive hearing loss
- Syndromes associated with hearing loss or progressive or late-onset hearing loss, such as neurofibromatosis, osteopetrosis, and Usher syndrome other frequently identified syndromes include Waardenburg, Alport, Pendred, and Jervell and Lange-Nielson
- Neurodegenerative disorders, such as Hunter syndrome, or sensory motor neuropathies, such as Friedreich ataxia and Charcot-Marie-Tooth syndrome
- Culture-positive postnatal infections associated with sensorineural hearing loss, including confirmed bacterial and viral (especially herpes viruses and varicella) meningitis
- Head trauma, especially basal skull/temporal bone fracture that requires hospitalization
- Chemotherapy

* Source: Joint Committee on Infant Hearing. (2007). Year 2007 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs. *Pediatrics*, 120, pp. 898-921

Appendix B. Joint Committee on Infant Hearing* recommendations for audiological assessment of children less than 3 years of age.

Children from Birth to 6 Months Developmental Age

- A frequency-specific assessment of the ABR using air-conducted tone bursts and bone-conducted tone bursts when indicated to determine the degree and configuration of hearing loss in each ear for fitting of amplification devices.
- Click-evoked ABR testing using both condensation and rarefaction single-polarity stimulus, if there are risk indicators for neural hearing loss (e.g., auditory neuropathy/auditory dyssynchrony), to determine if a cochlear microphonic is present.
- **Distortion product or transient evoked OAEs.**
- **Tympanometry using a 1000-Hz probe tone.**
- Clinician observation of the infant's auditory behavior as a cross-check in conjunction with electrophysiologic measures.

Children from 6 to 36 Months of Age

- Child and family history.
- Parental report of auditory and visual behaviors and communication milestones.
- Behavioral audiometry, including pure-tone audiometry across the frequency range for each ear and speech-detection and -recognition measures.
- **OAE testing.**
- **Acoustic immittance measures (tympanometry and acoustic reflex thresholds).**
- ABR testing if responses to behavioral audiometry are not reliable or if ABR testing has not been performed in the past.

* Source: Joint Committee on Infant Hearing. (2007). Year 2007 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs. *Pediatrics*, 120, pp. 898-921

Notes



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