COMPONENTS OF HEARING SCREENING

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There are three components of hearing screening: 1) otoscopic inspection, 2) pure tones (PTs) or otoacoustic emissions (OAEs) and 3) immittance screening. All children should be screened with all three components. (Exception: children with audiometrically documented permanent hearing loss do not need to be screened with PTs or OAEs). A child failing any portion of the screening in either ear should be rescreened (with all three components and in both ears) within 4-6 weeks. A child who fails a rescreen should be referred for further evaluation by an audiologist or a physician. (The referral process will be discussed in detail later).

The Joint Committee on Infant Hearing (JCIH) recommends the following indications for use with neonates or infants (29 days through 2 years). These indicators place an infant at risk for progressive or delayed-onset sensorineural hearing loss and/or conductive hearing loss. Any infant with these risk factors for progressive or delayed onset hearing loss who has passed the birth screen should receive audiologic screening every 6 months until age 3 years. These indicators are as follows:

a) Parental or caregiver concern regarding hearing, speech, language, and/or developmental delay.
b) Family history of permanent childhood hearing loss.
c) Stigmata or other findings associated with a syndrome known to include a sensorineural or conductive hearing loss or Eustacian tube dysfunction.
d) Postnatal infections associated with sensorineural hearing loss including bacterial meningitis.
e) In utero infections such as cytomegalovirus, herpes, rubella, syphilis, and toxoplasmosis.
f) Neonatal indications – specifically hyperbilirubinemia at a serum level requiring exchange transfusion, persistent pulmonary hypertension of the newborn associated with mechanical ventilation, and conditions requiring the use of extracorporeal membrane oxygenation (ECMO).
g) Syndromes associated with progressive hearing loss such as neurofibromatosis, osteopetrosis, and Usher's syndrome.
h) Neurodegenerative disorders, such as Hunter syndrome, or sensory motor neurophaties, such as Friedreich's ataxia and Charcot-Marie-Tooth syndrome.

i) Recurrent or persistent otitis media with effusion for at least 3 months.

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Because some important indicators may not be determined during the course of universal newborn hearing screening programs, the presence of all late-onset risk indicators should be determined in the medical home during early well-baby visits. For children 3-5 years old hearing should be screened annually or more often if indicated. Hearing screening programs in schools should include, at a minimum, annual screening for grades K-3 and at least once in middle school/junior high.

Otoscopic Inspection

An otoscopic inspection is a cursory inspection of the external ear canal only, not an examination for the purpose of diagnosis. It provides an additional piece of information (e.g., presence of tubes) but in and of itself does not provide enough information to make further recommendations. Most people doing hearing screening do not have specific training in this area, and most of the otoscopes used for screening do not have the magnification of the instruments used by physicians.

Equipment

Many types of otoscopes are available from medical suppliers. Some use alkaline batteries and others use rechargeable batteries. The less expensive models are usually sold as a unit, whereas the more expensive rechargeable otoscopes are sold by the piece (head, handle, battery, and charging unit). Alkaline batteries do not last as long as the rechargeable nickel-cadmium ones, but an otoscope with a rechargeable battery that is used infrequently may not keep its charge very well. Let your budget and personal preference dictate which otoscope you buy. While you're ordering, get extra batteries and extra light bulbs. When not in use the otoscope should be stored in its case and in a safe place. Some otoscopes come with a few plastic specula. (Specula are the cone shaped pieces of plastic that fit over the tip of the otoscope). The purpose of a specula is to direct the light so that you can better visualize the structures of the ear canal and eardrum. The few plastic specula which come with an otoscope are reusable but must be thoroughly cleaned between each use. Consider ordering disposable specula from medical suppliers, as they are not expensive and it saves having to worry about keeping them clean. The 4mm size (size refers to the size of the opening placed in the ear) works best for most children.

The smaller, longer one may seem better for very young children with small canal openings, but if you use them be aware of how long and sharp they are.

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Procedure

As with all portions of the screening, a firm, direct approach to viewing the external ear canal by using the otoscope is best. Don't ask the child if you can look in his/her ear. If you hesitate, waiting for the child's approval, he/she may hesitate. Simply say, "Now I'm going to take a look in your ear," or you can say you need to see if there are any puppies or kitties in their ear; you don't need to provide more of an explanation. If the child seems frightened, you can calm him/her with a brief demonstration. "This is a little flashlight (put the light in their hand) so that I can see inside your ear because it's dark in there." As you are saying this, proceed with the otoscopic inspection. Some verbal praise, such as "Nice job," "You're being so nice and quiet," while you are looking in the ear may help the child stay calm and still. By the time a child is in school having someone look in their ears is not novel and minimal explanation is needed. Many districts conduct hearing screening in the classroom and group instruction will put most students at ease.

There is a recommended way to hold and use the otoscope. It isn't a hammer so don't hold it like one. If you hold it in your fist, you have very little control of the tip of the specula. Control of the location of the specula is important in the event the child moves while you're doing the otoscopic inspection. Use more of a pencil grasp with your thumb and index finger. Extend your little finger so that it rests on the child's head above and toward the back of the ear, providing a kind of spring to absorb movement from the child. Turn your hand so that the handle of the otoscope rests on your lower index finger. Use the thumb and index finger of your other hand to gently lift the top part of the pinna as this somewhat 'straightens' the curve of the external canal so that you can see clearly. As you begin the inspection, have your eye close to the magnifying glass of the otoscope head and insert the specula in the direction of the ear canal. You might need to move the otoscope slightly in order to follow the direction of the canal and to see the eardrum.
If you encounter wax, it may **not** be occluding the ear but it may prevent you from seeing anything but wax. In this case, your otoscopic inspection is over; proceed with immittance measurements. If you encounter a foreign object other than wax or a P.E. tube, make a medical referral. NEVER attempt to remove wax or any foreign object from an ear.

What you hope to see during the otoscopic inspection is the eardrum. It is usually a pearly-gray color. If you see patches of white on the eardrum, you are probably seeing some scarring. This may alert you that a child has had some ear problems but it is not a cause for alarm or physician referral. Proceed with the immittance screening. An eardrum may be red or even orange-red. Again, you can note these observations on the roster but continue with the immittance screening.

An otoscopic inspection may allow you to see ventilation tubes if they are present. Pressure equalization tubes come in different colors. Some of the more common colors are silver, white, and bright green. The silver and white tubes are generally a bobbin shape, and the green ones are commonly straw-like in shape. Your immittance measurements will give you valuable information as to the status of the P.E. tube(s). Note the presence of tubes on your roster. This, in conjunction with immittance results, is useful information to the physician.

You may be able to see a perforation of the eardrum if the hole is fairly large – small perforations can be difficult to see. Immittance measurements will provide objective data as to the status of the eardrum.

Pure Tones (PT) and Otoacoustic Emissions (OAE)

Pure tone (PT) screening uses pure tones (single frequency sounds without accompanying overtones or other sounds) generated by an audiometer. PT screening has long been the technique used to screen hearing but because it requires a response from the child (e.g., hand raising; block in a bucket) it precludes the successful screening of children who are developmentally less than about three years of age.

Otoacoustic emissions (OAEs) are sounds generated within the cochlea that can be measured in the ear canal. The origin of this emission is thought to be the outer hair cells. Because it requires no response from the child it allows us to gain ear specific information about children who are developmentally unable to participate in traditional PT screening.

Both PTs and OAEs give us information about each ear but because pure tones can be presented at lower levels than OAE screening equipment uses, they should be used as soon as the child is developmentally capable of participating. There is no

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magical age at which this occurs but a guideline is a developmental age of three years. At that age attempt PTs and if unsuccessful, use OAEs.

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Hearing screening in sound field (using loud speakers) is not appropriate for three reasons. First, it does not give ear specific information; it tests only the better ear if there is a difference between ears (like taking an eye test with both eyes). Considering the evidence we have about UHL it is essential that we know the status of both ears. Secondly, while using a loud speaker, it is difficult to determine if a child is responding to an auditory stimuli or simply moving around. In an environment other than a sound-treated room it is very easy to misinterpret a child's responses. Lastly, calibration of sound field equipment is problematic.

Otoacoustic Emissions (OAE) Screening

When doing OAE screening, choose a quiet room. Infants are best screened when they are in a quiet state. Visual stimuli such as a movie, quiet toys, books, computer games, etc. may be useful in diverting the child's attention from the screening. Also, giving the child something to hold in each hand may be useful in keeping wandering hands from removing the probe from their ear. An otoscopic inspection will help you determine an appropriate sized probe tip. Once the probe is in place and the child is quiet and calm, the screening may begin. **The most frequent cause of OAE failure is a poorly fit probe.** Quality of the probe fit is the first and most important factor in collecting accurate data. It is often difficult to achieve a perfect fit on the first attempt; refitting commonly is necessary. The fit of the probe in the canal is crucial to the presentation of an optimal stimulus and also to sealing off ambient noise that may contaminate the measurement.

The most common OAE screening devices currently used in Wyoming Child Development Regions are the Biological AuDX and the ECHOCHECK. Each will be discussed in terms of their operation and failure criteria.

AuDX Procedures

1) Connect the probe assembly to the AuDx box.
2) Place the other end of the probe assembly with the appropriate sized probe tip into the child's ear canal.
3) Press the ON button.
4) Press the DX (SELECT) button to continue.
5) When PERFORM DPOAE appears in the display, press

the DX (SELECT) button.

6) When testing has begun it will continue until completion unless there is a poor probe fit.
7) If REFIT AND RETRY appears on the display, reposition the probe tip and press DX (SELECT).
8) When testing is complete, PASS or REFER will appear on the display.
9) If the result is REFER, immediately repeat the screening.
10) Record the results as PASS or REFER (Fail).

AuDX Criteria

If a REFER appears in the display, check the probe fit and immediately repeat the screening.

A REFER at one frequency in each ear is an overall PASS. A REFER at more than one frequency in either ear is an overall REFER. The equipment makes this calculation; simply record PASS or REFER (Fail).

ECHOCHECK Procedures

1) Connect the probe to the ECHOCHECK box.
2) Press the ON/OFF button and place the probe, with the appropriate sized probe tip, into the child's ear canal.
3) Be sure the green light (LOW NOISE) is on. If it is not, the room noise or the noise generated by the child must be reduced before testing is continued.
4) Press START/STOP to begin testing. The green stimulus light appearing steady indicates the successful delivery of the screening stimulus to the child.
5) When the test is finished the result will be displayed as OAE PRESENT (green light) or NO RESPONSE (no light).
6) If you do not get a green light, check the probe fit and immediately repeat the screening.
7) If the result is NO RESPONSE or TEST INVALID, immediately repeat the screening.
8) Record the results.

ECHOCHECK Criteria

This equipment also provides an automated result. OAE PRESENT constitutes a PASS and NO RESPONSE or TEST INVALID are considered a REFER. The most likely causes of TEST INVALID are a poorly fit probe, excessive noise in the room, or excessive noise or movement from the child.

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Pure Tone (PT) Screening

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The purpose of this section is to present the recommended failure criteria for pure tone screening and the suggested procedures for screening young children (3-5 years) as well as school age children. The failure criteria used in this manual is consistent with the guidelines recommended by the American Speech-Language-Hearing Association and they should be used consistently in a hearing screening program. Pure tone screening for young children can be challenging but the procedures described in this manual are designed to help you develop the necessary skills.

Equipment

The pure tone audiometer is an electronic device designed to produce tones of discrete intensities and frequencies. For the purpose of a hearing screening program the instrument must have air conduction frequencies at 1000, 2000, and 4000 Hz. It must meet the standards for screening audiometers established by the American National Standards Institute (ANSI), and should be **calibrated annually**.

The earphones are an important and integral part of the audiometer. Standard earphones are the phones with the "doughnut" shaped cushion. At present it is nearly impossible to do electroacoustic calibration on audiometers equipped with circumaural muffs. (The circumaural muff is a large earphone cushion designed to enclose the ear and form a barrier against the background noise). This type of earphone may one day provide an answer to problems of interference resulting from noisy environments but until then, the doughnut-shaped earphone should be used.

An audiometer is a precision electronic device, which provides a means of controlling both the pitch and the loudness of pure tones. Like any other electronic device, an audiometer must be handled with care at all times. Generally, the audiometer receives the greatest abuse when it is being transported. This instrument should be protected form heavy jars, shocks, bumps, or extreme temperature changes. Even with proper care an audiometer may, over a period of time, malfunction and/or go out of calibration for no apparent reason. Prior to each screening, the audiometer should be checked. These checks will not replace annual calibration, but are designed to aid the operator in detecting a gross malfunction that will affect the screening results.

Check the earphone cushions; they should be reasonably soft, resilient, and free from cracks. Occasionally, they should be wiped clean with warm water and mild soap. Check the shape of the headband; the earphone cushions should lie together with a small amount of tension. If the cushions do not meet or if they seem to lie together with too much tension, shape the headband by bending it with a twisting motion.

Any extraneous noise present in the earphones may affect screening results. To check for this, set the frequency at 1000 Hz and the intensity level at 90 dB. Interrupt the tone and listen for noise. Listen again with the instrument at 60 dB and again at the lowest setting of the attenuator (hearing level dial). If humming or extraneous noises are heard at these settings, the instrument should not be used until the problem is addressed.

The earphone cords should be checked for breaks and loose connections. Set the attenuator at 40 dB and 2000 Hz. While listening to the tone, flex the cord along its length and especially at its connections (at earphones and audiometer). If a scratchy noise is heard or the tone is intermittent discontinue screening until the cords have been replaced or the connections are made secure. Under no circumstances should headphones from one audiometer be interchanged for headphones of another audiometer. Earphones are calibrated as an integral part of the instrument. Earphones cannot be interchanged even temporarily without conducting calibration using a sound level meter.

Lack of lubrication or the presence of dirt deposits in the attenuator may cause noise to be heard in the earphones when the hearing levels are changed. In order to check for this, set the frequency to 250 Hz and then slowly increase the attenuator from 0-60 dB and listen for scratchy noise. If the noise is detected, the instrument may be used, if necessary, as long as adjustments of the attenuator are made only when the tone is off.

Scratchy noises or clicks may develop in the frequency switch. To check this, set the attenuator at 30 dB and slowly increase the frequency from low to high. If noise is present, you can prevent the noise from getting to the headphones by changing the frequency dial only when the tone if off. With the newer digital equipment, noises and clicks from the attenuator and frequency dials is not a common problem.

All of the preceding checks are made with the earphones properly placed on the adult screener and with the assumption that s/he has normal hearing for 250 Hz through 8000 Hz.

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If repair of the audiometer is required as a result of any of the preceding checks, it should be recalibrated at the time of repair.

A good understanding of the audiometer, including handling, troubleshooting, and calibration, is essential to a quality hearing screening program. The screener must make it their responsibility to be familiar with the troubleshooting and daily checks. Electroacoustic calibration should be done annually at a minimum.

Criteria

The American Speech-Language-Hearing Association (ASHA) recommends the following screening criteria: 20 dB at 1000, 2000, and 4000 Hz. Failure to respond at the recommended screening level at any frequency in either ear constitutes a failure.

Procedures Applicable to 3-5 year old Children

There are several things to keep in mind when screening a young child's hearing. First, children often have difficulty understanding directions that are too wordy or complex. Second, they often have a limited attention span and may lose interest quickly if you make the listening task too difficult. Finally, unlike an adult who is eager to learn if his/her hearing is normal, most young children do not care whether or not their hearing is successfully screened. Remember that this is to be an interesting and pleasant experience for them, and this can be accomplished **only as much as your performance and enthusiasm allow.** As in any other instructional situation, children will attend to, grasp, and remember your instructions to the extent that you command their attention and interest. Present instructions at their level of understanding and use whatever techniques are necessary to command their attention.

The first challenge in testing 3-5 year old children may be getting the child to wear the earphones. Never ask the child if s/he wants to wear the earphones or make a big issue over wearing them. A gentle but firm approach is most successful. Many children have some type of headphones in their homes so the idea of wearing them is not as foreign as you might think. If a child is particularly resistant, having some type of headphone available in the child's classroom may provide an opportunity for the child to become comfortable with them before the next hearing screening.

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Children in this age group will usually understand what you want them to do if you keep it simple and are aware of their language abilities. Examples of useful instructions are: "You're going to hear some sounds, kind of a 'beep' sound. Every time you hear one, I want you to put your hand up very quickly for me." Your enthusiasm will play a role here! Have the child face you while you give these instructions so that you can maintain eye contact. You may want to touch one of their ears as you tell them they're going to hear some sounds. This is an additional tactile cue. Also, touch their hand as you say "put your hand up fast for me." The term 'fast' is important for two reasons. First, 'fast' implies a game thus making it a fun activity. Second, when a child raises their hand quickly, it is easier for you to interpret the action as a response to the sound rather than wondering if the child is simply choosing to scratch his head at that time. Avoid saying "if you hear a sound" as that forces the child to decide whether or not he's heard something. Remember, keep it simple. Do not require the child to raise the hand that corresponds to the ear in which he hears the tone. This only confuses the child and does not improve the validity of the test.

When placing the earphones on a child, be sure that the red earphone is on the right ear and the blue earphone is on the left ear. Adjust the headband so that the earphone openings line up directly with the ear canal openings. The phones must fit snugly, but they should not cause the skin flap (tragus), which protrudes back over the ear canal to seal the canal or cause the canal to collapse. Be aware of glasses, hair bands, and earrings, although they should not pose a serious problem.

Proceed by presenting the pure tones according to established criteria. If you're lucky, the child has raised his/her hand six times and you are finished with this portion of the hearing screening. If the child does not respond to the initial presentation of the tone, it must be established that the child understands the task. (You must answer the question, "Did they fail to respond because they didn't understand or because they didn't hear it?" – there is a significant difference). To do this, set the frequency selector dial at 2000 Hz and the hearing level dial at 60 dB. Two thousand hertz (2000 Hz) is selected rather than 4000 Hz because if there is a sensorineural hearing loss, that loss will probably be greater at 4000 Hz. Present the tone two or three times to orient the child and to assure a response to the correct signal. You may coach the child by presenting the tone and raising the child's hand simultaneously. Be enthusiastic; nod to encourage him/her and don't be afraid to say "good job." If this does not seem to be working, be sure and try the other ear as you may be training on an ear with a hearing loss. When you think the child is getting the idea say, "Now you do it." Present the tone at 60 dB and if

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the child raises his/her hand quickly you have established that the child understands the task. At this point you may want to repeat the presentation a time or two and praise the child for the desired response. Then tell the child, "The beeps are going to get tiny (include appropriate hand gesture) so listen carefully." Reduce the presentation level to 20 dB, proceed with the screening, and remember to praise the child for an appropriate response. At this point if the child responds to some or all of the tones, you can be confident that the screening is valid.

Still having problems? Don't give up. The next section describes a technique called Conditioned Play Audiometry (CPA), which you may find invaluable when screening young children.

The two phases of CPA are: 1) the **Preparation Phase**: when the child is conditioned to respond and 2) the **Measurement Phase**: when the actual screening is completed. The successful screener first must understand the reason for each of these phases and then must develop insight into different ways to successfully complete each phase. Children's interests and abilities differ a great deal so what works with one youngster may not work with another child.

The primary goal for the Preparation Phase is to teach the listener how to respond. Again, with young children, it is best to avoid complex instructions. The screener should demonstrate the response and then teach the child to respond through the practice until s/he has the idea. One method of response is putting a block in a bucket each time a tone is presented. Begin by using tones at 2000 Hz at 40 dB. Put a block in the child's hand and place that hand to his/her ear. The purpose of holding the block near the ear is to help the child make the association between the tone in the ear and the block near the ear. It also allows you to quickly drop the block; you want to teach the child to make a clear response that you can interpret. Present the tone, look surprised and direct the child's hand to quickly drop the block in the bucket. You may also say, "There it is!" as you help him/her drop the block. After three or four demonstrations with the screener helping by holding the child's hand, the child is encouraged to take his/her turn without the screener's help or you can simply say, "Now you do it." If this is successful, instruct the child to "listen for little ones." Keep verbal instructions to a minimum; this entire process can be accomplished with little or no verbalizations since the demonstration is the key. Avoid asking the question, "Do you hear it?" That question will simply open a long and nonproductive dialogue between you and the child. If you do ask that question, you will probably get a head nod from the child that means nothing in terms of getting his/her hearing screened.

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Be aware of the positioning of you and the child during CPA. You should face the child so that you can complete the Preparation Phase yet you need to be able to reach the audiometer. Its' a little tricky but practice will make it easier.

While it is hoped that the response game is motivating, a child may stop responding unless the screener continues to give them ample praise. Throughout the test, a smile, a positive nod of the head or a pat on the shoulder is appropriate praise for playing the listening game well. Upon the initial suspicion of guessing, take the inappropriately thrown block out of the bucket, put it in the child's hand, hold his had near his ear, and try again. If random responses continue, stop the screening and fail the child.

Different children have different interests. While using blocks and a bucket has been mentioned in the preceding discussion, this particular activity is only one of many which can be utilized. Having the child "slap you five" or putting rings on a stick also works well. Avoid tasks that are too time consuming; the child will soon lose the idea of what s/he is suppose to do because they are too absorbed in the physical task. For example, putting a peg in a pegboard may take a long time for the child to accomplish – you want something the child can do quickly. The response does not have to be a motoric response; asking the child to say "yes" may also work. Use your creativity but keep the child's developmental level in mind. Choose a simple task, remain encouraging and enthusiastic, and you will have lots of success screening this age group.

You may need to screen a child that is non-English speaking. Although they may have difficulty following lengthy verbal instructions, these children can be successfully screened by using a demonstration technique. Use your imagination and some gestures; pantomime will effectively convey the instructions. Conditions Play Audiometry can be used but is probably unnecessary.

When screening children 3-5 years of age, begin by asking the child to raise his/her hand; this is the easiest and fastest technique. Even if you think the child is unable to raise his/her hand, give him/her a chance; sometimes the child will surprise you. If that does not appear to be successful, proceed using CPA.

It is assumed that the screener will keep basic principles of good audiometry when working with all children. It is very important that you do not furnish any cues to the child while screening. **Do not look up each time you present a tone**. A child will soon associate your head or eye movement with the presentation of the

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tone and will begin to respond to these movements. However, if a young child seems unsure but responds correctly, tell him/her that they were correct. This may be accomplished a by a smile and nod of the head. Be sure that you indicate that a response was correct **only after** the response was made.

Make sure, in operating the interrupter switch that you do not fall into rhythmical patterns. Some children will perceive this rhythm and will respond even though they do not hear the test tone. The pattern of tonal presentation should be irregular; that is, one time the interrupter switch may be depressed after several seconds and the next time it may be depressed almost immediately after it has been released. In any event, the child should not be able to predict the next presentation of the tone. The appropriate length of tonal presentation is 1-2 seconds. Sometimes a child will continue to signal that s/he hears the tone after you have released the interrupter switch; simply put his/her hand down.

It is critical that screening be undertaken only when the child is quiet and is listening. Your arrangement may vary from child to child. Make sure they are in a comfortable position. You should be comfortable as well and in a position so that you are close to the child and to the audiometer. Be sure that the knobs, dials, and your hand are not in the child's view, even peripherally. With some children, consider sitting in an adult-sized chair and having them stand in front of you. (This is most successful if the child is going to be a "hand-raiser.") If you will be doing CPA, having the child sit in a comfortable chair will probably work better. If there are other children in the room where you are screening, it is best if the child being screened is not facing the other children, as this will reduce distractions.

Immittance Measurements

Immittance is a technique for making measurements regarding the function of the middle ear system. As one of the three components of hearing screening its purpose is to identify children who may have middle ear problems. **Immittance measurements screen for a health issue but do not assess a child's hearing acuity.**

The technique measures the changes in sound pressure level in the ear canal caused by manipulation of the tympanic membrane (TM) and the ossicular chain. Immittance measurements include values for physical volume (PV), tympanic membrane compliance (TMC), middle ear pressure (MEP), and tympanometric width (TW). Immittance screening equipment

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performs the measurements automatically once an adequate seal is obtained by holding the probe tip at the entrance of the external ear canal. The manipulation of the TM-middle ear system is accomplished pneumatically (i.e., via air) and is known as tympanometry.

The acoustic reflex (AR), also known as the stapedial reflex, is the contraction of one or more muscles of the middle ear (stapedius and tensor tympani) in response to the presentation of a loud stimulus. This contraction causes a stiffening of the ossicular chain which in turn "stiffens" the tympanic membrane. An AR is not observable in middle ears with effusion or other tympanic membrane and/or middle ear conditions causing stiffness.
Many immittance screening bridges have the AR feature and they provide a graphic representation of the muscle contraction. This is interpreted as a "present AR".

As a screening tool the presence of the AR can help clarify questionable tympanograms as in the case of low (.1) compliance but with an observable peak. No interpretation can be made when a screening AR is absent because an absent AR may be caused by too little stimulation, instrumentation artifact, or its absence may be normal for a particular ear. However, the presence of an AR rules out significant middle ear pathology.

Because the middle ear system is mechanical, immittance measurements can be made objectively. Children do not need to respond in any way and the test can be performed in a noisy environment.

Tympanometry should not be performed on infants less than 7 months of age. The ear canals of infants in this age group are very pliable and immittance measurements may be the result of pneumatically moving the ear canal wall rather than the TM.

Tympanometry is conducted automatically when the immittance equipment (also called an immittance bridge) creates in sequence, positive and negative air pressures in a sealed ear canal and records the changes caused in the mobility of the tympanic membrane/ossicular chain system. This changing relationship is plotted as a tympanogram.

Positive air pressure created in the ear canal increases the stiffness of the TM-middle ear system and reduces its compliance (mobility). This is the starting point of the tympanogram ("A," Fig. 4). As pressure is progressively lowered, compliance is altered. When air pressure on both sides of the TM is equal, a peak on the tympanogram tracing will

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occur; in the normal ear this occurs around 0 daPa ("B," Fig. 4). As pressure continues to be lowered the TM-middle ear system is again stiffened. ("C," Fig. 4).

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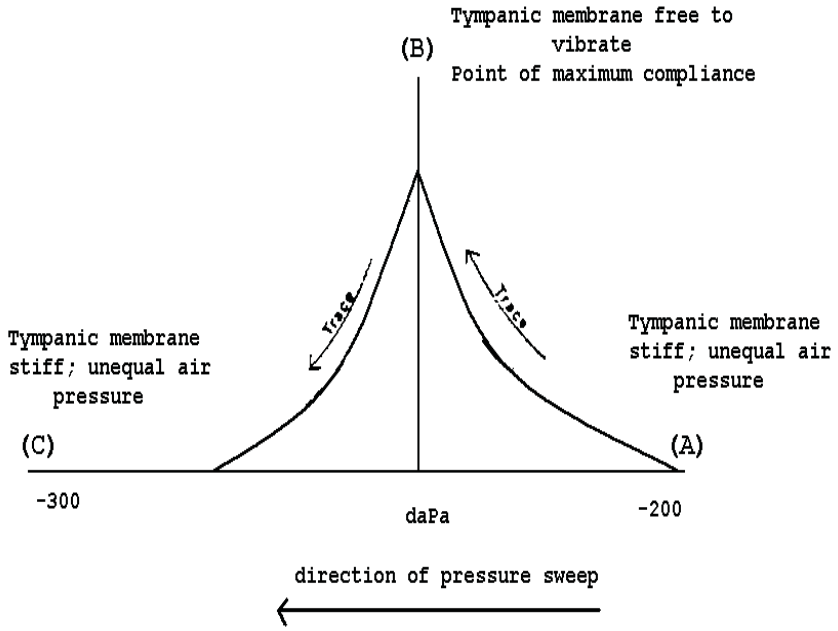

Figure 4: Normal Tympanogram

The tympanogram identifies MEP (point of maximum compliance) along the horizontal axis ("A," Fig. 5). The height of the tracing along the vertical axis is the compliance ("B," Fig. 5). Immittance screening instruments also compute the tympanometric width (TW) or gradient, which describes the shape of the tympanogram. TW is the measure of the pressure interval corresponding to a 50% reduction in the compliance ("C," Fig. 5). (A simplistic way to define TW is to describe the shape of the tympanogram as short/fat vs. tall/skinny.)

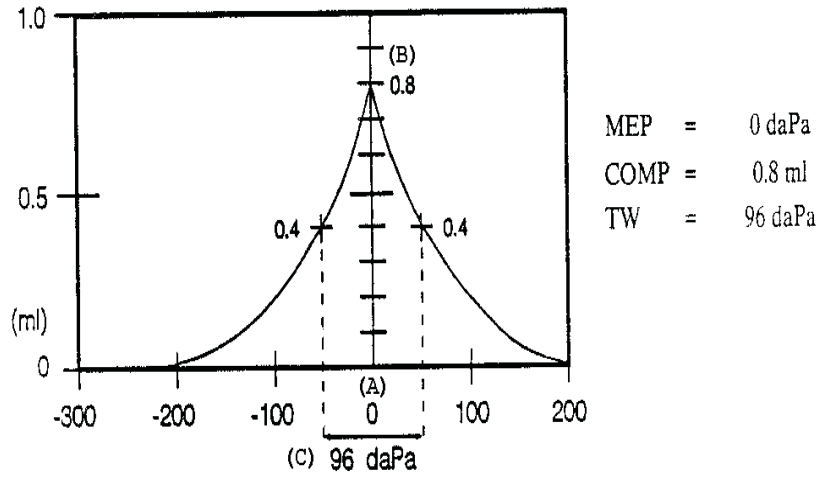

Figure 5: Tympanometric Width (TW)

Ear canal volume, also called physical volume (PV) or equivalent canal volume is obtained when an air pressure of +200 daPa is applied to the ear canal and "clamps" the TM. PV is simply a measurement of the amount of space between the probe tip and "wherever the air can't get any farther." Volume measurements are helpful in determining if ventilation tubes are patent (open), if the TM has a perforation, or if the ear canal is occluded with wax or other foreign objects.

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Equipment

Immittance screening equipment provides a visual representation of the tympanogram and most display numeric values for MEP, TM compliance, PV, and TW. Some instruments measure TM compliance and PV in cubic centimeters (cc) and some use milliliters (ml). This manual will use ml, but practically speaking, they are interchangeable. Older equipment measures MEP in mmH2O but current models use decaPascals (daPa). This manual uses daPa but, again, the terms are essentially interchangeable.

Immittance screening equipment is designed to be completely automatic; i.e., once it starts it doesn't stop, no matter what! The result is a measurement for every aspect (MEP, PV, TM compliance, and TW). **By knowing the significance of each measurement and their relationship to each** other you can determine the validity of the values and make appropriate decisions from your screening results.

A daily check of your immittance bridge is recommended. First, calibrate the unit according to the manufacturer's specifications. Next, run a tympanogram on yourself. One of the most common problems with an immittance bridge is a blocked probe assembly. Consult the manual about cleaning the probe and follow the directions carefully and regularly. Probe assemblies can be replaced but they are expensive.

Criteria

The failure criteria for immittance screening for children is

- MEP > -250 daPa
- TM compliance < .2 ml. (Note: If the compliance is .1 AND a peak is observed AND an acoustic reflex is present it is considered a PASS.)

The estimated equivalent ear canal volume measures of preschool children prior to and following placement of tympanostomy tubes (ECV for most ears with and without tubes)

- Pretube 0.3 – 0.9 cm3
- Post-tube 1.2 – 5.5 cm3

NOTES

	1st grade	2nd grade	3rd grade	5th grade
n	80	82	90	80
Range	1.0 - 2.1	1.0 - 1.9	1.0 - 2.3	1.1 - 2.2
Range (minus lowest and highest value)	1.1 - 1.9	1.2 - 1.8	1.1 - 2.2	1.2 - 2.1
Mean	1.46	1.501	1.592	1.667
Mode	1.5	1.5	1.5	1.6; 1.9

Ear canal volumes (in ml) for students in 1st, 2nd, 3rd, and 5th grades.

Previously, abnormal physical volume (PV) was used as a failure criteria for immittance screening but because of the huge variability among children it is difficult to determine what is "too large" or "too small." PV must be viewed in relationship to the compliance and MEP values and by doing so you can estimate the status of the middle ear (ME) system. (Is the eardrum intact? Is the tube patent? Is there a perforation? Is the ME system normal?)

The use of PV, in isolation, as failure criteria is problematic because of the huge variability among children. What is important to know (and what will be discussed in the next chapter) is the relationship of PV to other aspects of immittance screening. This knowledge will assist you in making appropriate referrals from your hearing screening program.

Any child failing TM compliance or MEP measurements should be rescreened (with all three components of hearing screening in both ears) within 4-6 weeks. Children failing the immittance rescreen should be referred for medical evaluation.

Procedure

To conduct immittance screening, position the child in such a way that you can visually inspect the external ear canal for size and direction of the ear canal. With preschoolers try sitting in an adult-size chair while having the child stand in front of you. For infants and toddlers have a familiar adult hold the child on their lap. Select an appropriate sized probe tip for the size of the ear canal opening. The probe tip should be larger than the opening of the external ear canal. The intent is to obtain an airtight seal at the canal opening; the probe tip should NOT be inserted into the canal itself. Fit the base of the rubber probe tip over the end of the metal or plastic probe stem assembly on the immittance bridge so that it goes completely over the probe stem. Generally, the same size tip is appropriate for a similar age group. Clean the probe tip with an alcohol wipe after each child.

Getting and maintaining a good seal at the opening of the external ear canal opening is the most important variable to accurate and reliable immittance screening. In order to obtain the best external ear canal seal, gently pull the top of the test ear up and back to straighten the ear canal. Apply the probe tip firmly to the canal opening. Depending on the unit you are using, you may see a flashing light or a steady green light as long as the seal is being maintained. Some immittance bridges will display 'air leak', 'block', or 'testing' on the display screen depending upon the status of the external ear canal seal. If you are having difficulty maintaining a seal, it is best to remove the probe, reexamine the direction of the canal, and try again. Changing the size of the probe tip may help maintain an external ear canal seal. If the child fails the immittance screening, immediately repeat the measurement.

The directions you give to the child should be very simple; all they really need to do is stand (sit) quietly. Sometimes they will ask, "What's that?" Assuming you have already done an otoscopic inspection, you can respond with, "It looks at your ear like I did." Occasionally, a child might ask "What does it do?" "It checks your eardrum," is an appropriate response. Don't forget to praise and encourage the young child while doing immittance measurements. If the child is 'squirmy' you will be able to complete the measurements by talking to him/her as the test is performed. If your immittance unit has lights, you can simply ask the child to watch the lights. Some children also enjoy watching the tracing being completed.

Screeners have reported a variety of techniques and situations, which help divert an infant, toddler or preschooler's attention away from the screening procedures thus enabling the screening process to be completed. Some of their "tricks" include having the child watch themselves in a mirror, providing a TV/VCR cartoon for the child to watch, or allowing the child to scribble on a piece of paper.

<u>Immittance Measurements As They Relate To Disorders</u>

In the case of atresia, you will probably not be able to obtain immittance measurements simply because there usually is no canal opening. If there is an opening, your immittance results will probably be low compliance (there may be no eardrum to pneumatically move) and possibly a small external ear canal volume measurement (depending on where the malformation of the ear canal begins).

NOTES

You may not be able to visualize the eardrum because of wax, but if the air from the immittance bridge can get around the wax, you can still get a tympanogram. If your otoscopic inspection revealed excessive cerumen, it still is appropriate to perform the immittance screening. If your otoscopic inspection revealed a foreign object (this does not include excessive wax), stop the screening and refer the child to their physician for removal of the foreign object.

The presence of a poorly functioning Eustachian tube is indicated by negative middle ear pressure (MEP). The significance of negative MEP is that it occurs before effusion develops and again as effusion resolves. Normally, MEP is at or near 0 daPa. When the Eustachian tube is not functioning adequately negative middle ear pressure occurs. If this negative middle ear pressure persists for a period of time, the vacuum which is created in the middle ear cavity may begin to draw moisture from the mucosal lining in the middle ear cavity and fluid (effusion) may form. As the effusion resolves, negative middle ear pressure is again seen before the middle ear pressure returns to, or near, 0 daPa.

Tympanic membrane compliance may be normal in the presence of negative MEP but as the MEP becomes more negative the compliance decreases and the TW increases. In other words as the TM is 'pulled in' by the negative MEP it becomes less mobile and the shape of the tympanogram becomes shorter and wider. Low compliance produces a screening failure and thus identifies the child with possible middle ear problems.

Check the manual for your immittance bridge to find out the pressure range of your equipment. Most are from +200 to approximately –300 daPa. If the child's MEP is in excess of that range the unit may display a question mark or other indicator rather than a numerical value. This doesn't mean the child doesn't have a MEP, it simply means the equipment can't find it.

Although unusual, you may see positive MEP. A reading in excess of +100 daPa can also reflect an error in the immittance procedure. If this occurs immediately repeat the measurement.

When fluid is present in the middle ear space the tympanogram will be flat. The tracing may 'bounce' along the bottom of the scale or you may see a rounded tracing without a peak. The immittance bridge will display a compliance value < .2 ml. Most equipment will be unable to specify a MEP value (the unit cannot identify a point of maximum compliance) and MEP will be identified as '?' or No Peak (NP). This flat tracing occurs because the fluid behind the TM produces resistance or 'pushes' from that side of the TM, which prevents air (via tympanometry) from moving the eardrum from the other side.

NOTES

The TM must be intact in order to be pneumatically moved. In other words, using air to move an eardrum with a perforation (or patent tube) is like trying to blow up a balloon with a hole in it.

Conversely, if an ear canal is completely occluded with wax trying to move the eardrum with air is like pushing against a brick wall. Keep these simple concepts in mind as you review the following scenarios.
In the case of a visible PE tube you would expect the volume to be large because the air goes through the TM and fills the ME cavity. If, however, TM compliance and MEP are normal you know the TM is intact and ME function is normal. (The tube may have fallen out of the eardrum and the eardrum has healed.) Please be aware that just because you see a PE tube during otoscopic inspection, it does not mean that the tube is in the eardrum and/or patent (open). Immittance measures will give you the information regarding the possible status of the PE tube.

If the volume seems "too large" and the MEP and/or TM compliance criteria are failed a perforation or patent tube would be suspected.

- Continue medical management or medical referral.

If the volume seems "normal" in the presence of a tube but compliance and/or MEP are abnormal, suspect a) the tube is plugged and/or b) the tube is plugged and effusion may be present. (In the case of a plugged tube the weight of the tube prevents the TM from moving normally.)

- Forward the information to the parent/managing physician

If you don't see a tube, the volume appears "large" but MEP and TM compliance are normal a perforation is not present and ME function is normal. If no tube is visible, the volume appears "large" and MEP and/or TM compliance criteria are failed a perforation would be suspected.

- Medical referral.

If you think the PV is "too small" but MEP and TM compliance are normal, ME function is normal – the child simply has a small ear.
If you suspect wax is occluding the ear canal and the PV is "small" in conjunction with abnormal TM compliance and/or MEP your suspicion is supported. (Low compliance is due to the air's inability to move the wax and the small volume is related to the space occupied by the wax.)

- Medical referral.

NOTES

Again, it is the relationship of the PV to the other immittance values that determines its significance. PV is irrelevant in the presence of normal TM compliance and normal MEP but significant when MEP and TM compliance are abnormal. It is critical for you to understand how your particular piece of equipment (immittance bridge) obtains and displays data (results).
When it is necessary to communicate screening results to parents or physicians either verbally or in writing keep in mind that immittance screening does not allow a medical diagnosis to be made – that is done by the physician. Appropriate phrases include: "Immittance measurements suggest…."; "Results are consistent with..."; "…support the presence of…"

NOTES

THE AUDIOGRAM

This section is included to help you interpret audiograms and reports you receive from other facilities. A basic knowledge of the audiogram should facilitate your communication with audiologists and with families and teachers.

An audiogram is a graphic representation of a person's hearing at a specific point in time. For children with conductive hearing loss, audiograms can be different from one evaluation to the next due to fluctuations in hearing. As you use the IEP/IFSP process to plan for children you should have current audiological information. For infants with sensorineural hearing loss hearing should be evaluated every 3-4 months for the first year after identification, at lease twice a year through the preschool years and, at a minimum, annually after entering school. The purpose of close audiological monitoring is to identify progressive hearing loss.

In the past young children were tested in sound field. The child sat on a parent's lap inside a sound proof booth with a speaker on either side. As stimuli were presented via the speakers and the child turned toward the signal she/he was reinforced with a blinking light. The technique, called Visual Reinforcement Audiometry (VRA) does not provide ear specific information; it only tests the better ear if in fact there is a difference. If you are referring a child because they failed the OAE component of the hearing screening **you should expect and request ear specific information from the audiological assessment.**