Pediatric Hearing Assessment

Stanton Jones

Key Points

- This chapter outlines the methods of hearing assessment that are appropriate for children from birth to adolescence.
- The importance of timely referral of children with suspected hearing loss for a full hearing assessment cannot be overemphasized. This can be accomplished in a screening and/or a diagnostic hearing assessment.
- The audiogram is the true measure of threshold sensitivity and is considered the “gold standard” for hearing assessment.
- Hearing in children can be assessed from an extremely young age. A reasonable assessment of hearing is now possible in children using physiologic assessment tools including otoacoustic emissions (OAEs), evoked potentials, and tympanometry.
- Behavioral audiologic assessment can include visual response audiometry, conditioned play audiometry, conventional audiometry, speech audiometry, speech reception thresholds, or speech discrimination testing.
- Test batteries consisting of a number of assessment tools are used to make a diagnosis of hearing loss and identify a probable site of lesion. No single tool can provide all of that information.
- Hearing thresholds can range from normal (air conduction better than 15 dB at all frequencies) to a profound loss (one or more thresholds at 80 dB or more) and can be conductive, sensorineural, or mixed.

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Introduction

Hearing assessment is an integral part of evaluating a child with a speech or hearing problem. Hearing loss has the highest incidence rate for any pediatric disability and should be detected as early as possible. Parents may report signs and symptoms of reduced hearing, or the practitioner may identify the symptoms during a routine evaluation of the child. The importance of timely referral of children with suspected hearing loss for a full hearing assessment cannot be overemphasized. The use of informal methods of hearing assessment, such as the whisper test, can lead to late diagnosis of hearing loss and should be discouraged. With modern screening and diagnostic equipment, hearing can and should be quantified. This can be accomplished in a screening and/or a diagnostic hearing assessment.

Hearing thresholds and speech discrimination measurements as well as site-of-lesion detection, are routine practice in the field of audiology. The audiologist can assist in the diagnosis and the determination of the type and degree of hearing loss. With this information, the physician can assess the likely impact of hearing loss on the development of speech and language skills and whether reduced hearing is part of a syndrome. Rehabilitation and intervention measures can then be planned, including medical and surgical therapy, dispensing hearing aids, or evaluating the child for cochlear implants.

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Symptoms of Hearing Loss

The symptoms of hearing loss depend on the degree and nature of the disability. If a child presents with one or more of the following symptoms, a hearing assessment should be considered:

- Delayed language development ***(1)***
- Delayed speech development ***(1)***
- Asking for repetition ***(1)***
- Not waking up to loud sounds
- Not responding when called ***(1)***
- Unable to locate a sound source ***(1)***
- Places ear close to television or speaker or wants television or radio louder
- Speech and language development has slowed down or ceased ***(1)***
- Speech production has become less clear ***(1)***
- Not noticing loud sounds in the environment such as an airplane or dog barking

Risk Factors for Hearing Loss

The incidence of sensorineural hearing loss is 1–3 per 1,000 healthy births and 2–4 per 100 in high-risk children ***(2)***. The following is a list of factors that may place children at risk of hearing loss, either congenital or acquired:

- Family history of hearing loss
- Genetic disorders or syndromes
- Problematic pregnancy
- Drugs or alcohol use during pregnancy
- Maternal infections during pregnancy such as rubella, sexually transmitted diseases, cytomegalovirus, and numerous others
- Trauma during pregnancy
- Trauma during birth
- Anoxia at birth
- Apgar scores below 5 at 1 min or less than 6 at 5 min
- Postnatal infections
- Hyperbilirubenemia
- Ototoxic medications including aminoglycosides alone or in combination with loop diuretics
- Patients undergoing chemotherapy or radiation for cancer treatment
- Craniofacial anomalies
- Recurrent otitis media with or without ventilation tubes
- Mumps, measles
- Noise exposure, particularly excessive use of personal listening devices

Methods of Hearing Assessment in Pediatrics

The audiogram is the true measure of threshold sensitivity and is considered the “gold standard” for hearing assessment ***(3)***. Obtaining an audiogram is not always practical due to the age of the child, level of cognitive functioning, or other confounding factors. Nonetheless, every effort should be made to obtain an audiogram in a child with possible hearing loss.

Hearing in children can be assessed from an extremely young age. A reasonable assessment of hearing is now possible in newborns using otoacoustic emissions (OAEs), evoked potentials, and tympanometry. Testing leads to early intervention measures which ultimately aim to minimize developmental delays. Newborn hearing screening programs are currently mandated by the federal government. All children born in the United States have to undergo a hearing screen soon after birth. Children with congenital hearing loss are therefore identified and diagnosed very early and can be fitted with hearing aids as early as 2 months of age. Below is an outline of the tools and general hearing assessment methods used in different age groups.

Physiologic Assessment Tools

Otoacoustic emissions (OAE) are tests that determine cochlear status, specifically hair cell function. They are mostly used to screen hearing in neonates, infants, or individuals with developmental disabilities. OAEs were first described by Kemp in 1978 ***(4)***, when he measured spontaneous and evoked emissions in the human ear. Spontaneous emissions are sounds emitted from the cochlea without an acoustic stimulus and have little or no clinical application. Evoked emissions are sounds emitted from the cochlea in response to acoustic stimuli and play an important role in screening or diagnosing hearing loss in neonates. A probe is placed in the ear canal of the child. The probe houses two receivers (speakers) and a microphone. The resulting sound from the cochlea that is picked up by the microphone is digitized and processed using signal averaging methodology. The type of stimulus presented into the ear determines the type of evoked emission. The following two Otoacoustic Emissions are the most common types utilized: (a) Distortion product otoacoustic emissions (DPOAEs) ***(4)*** are sounds emitted from the cochlea in response to two simultaneous tones of different frequencies. The response occurs only if there is a sufficient number of outer hair cells in the area of stimulation. (b) The second type, transient evoked otoacoustic emissions (TEOAEs) ***(4)***, are sounds emitted from the cochlea in response to acoustic stimuli of very short duration, usually in the form of clicks, but can also be tone bursts. The stimulus is comprised of numerous frequencies and evokes responses from a large portion of the cochlea. OAEs measure only the peripheral auditory system, which includes the outer ear, middle ear, and cochlea. To obtain an OAE, one needs an unobstructed outer ear canal, absence of significant middle ear pathology, and functioning cochlear outer hair cells. Common reasons for not obtaining OAEs in a normal hearing ear include a lack of an optimal probe fit, cerumen impaction, or a middle ear effusion.

Auditory evoked potentials (AEP) ***(3)***, also referred to as auditory brainstem responses (ABRs), may be used to screen the hearing of newborns or as a diagnostic tool in a full hearing assessment. The auditory brainstem response is an early audiologic, electrophysiological response originating from the cochlea nerve and lower brainstem. Responses are elicited by a click stimulus presented at 25–30 dB in a screening or varied intensities in a diagnostic assessment. Click stimuli are used in screenings, and tone bursts stimuli are used in diagnostic assessments. Responses are recorded by placing electrodes at the vertex of the scalp and ear lobes. Earphones are placed in the ears to deliver the click stimulus into each ear. Several hundred responses are collected and averaged to reduce background recording noise and increase signal-to-noise ratio.

Tympanometry and acoustic reflexes ***(5)***. Tympanometry is used to assess numerous middle ear functions including: the ear canal volume (large canal volumes may indicate a perforation of the tympanic membrane) (Fig. 1, amount of sound admittance and sound impedance at varying pressure levels, ear drum movement, eustachian tube function, and acoustic reflex thresholds (ARTs) ***(5)***. Reduced movement of the eardrum may be indicative of fluid in the middle ear or of ossicular dysfunction as seen in children with craniofacial abnormalities. Acoustic reflexes are involuntary contractions of the stapedius and tensor tympani muscles in response to loud noise ***(6)***. Conductive or sensorineural hearing loss will cause elevation of these thresholds. These

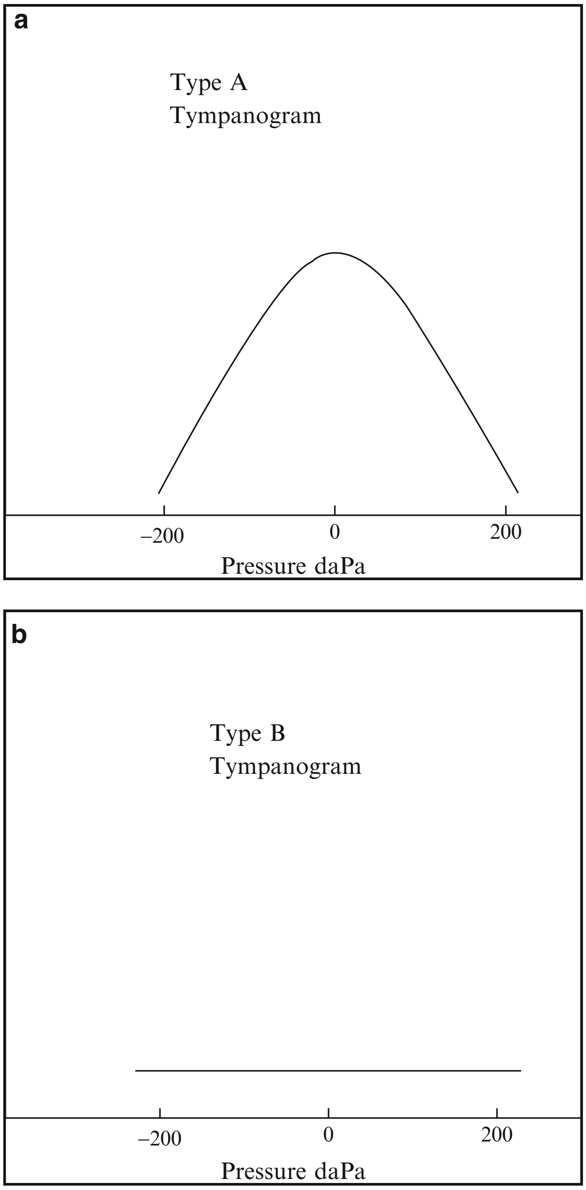

Fig. 1 Type A tympanograms indicate normal ear pressures. Type B tympanograms are seen with a tympanic membrane perforation, a patent tube (large ear canal volume), or with fluid in the middle ear cleft (small ear canal volume). Type C tympanograms are seen with eustachian tube dysfunction and a negative middle ear pressure

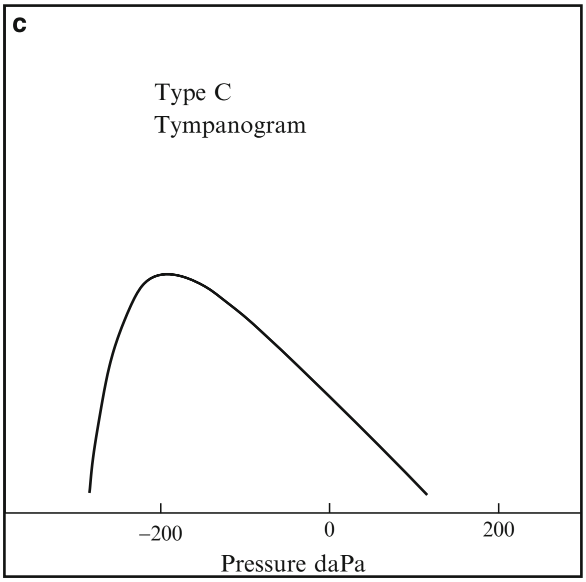

Fig. 1 (continued)

reflexes are usually absent if there is a moderate, severe, or profound hearing loss.

Air conduction and bone conduction testing. Stimuli may be presented to the test subject via circum-aural earphones, insert phones, or speakers. This method of stimulus delivery is known as air-conduction testing. The same stimuli may be presented through a bone vibrator usually placed on the mastoid of the test ear. This essentially directs the sound to the cochlea and bypasses the outer and middle ear systems by setting up vibrations in the skull, which are then transmitted into the fluids of the cochlea. Air and bone conduction testing establishes the presence of a conductive or sensorineural hearing loss.

Behavioral Audiologic Assessment

Visual response audiometry (VRA) ***(6)*** relies on the child's ability to localize to the side of the sound source. The child is placed in a sound booth, often seated on the caregiver's lap, with earphones placed in the ear canals. Speakers may be used in a sound field if the child would not tolerate earphones. The use of earphones provides ear-specific information. A stimulus, usually a pure tone, narrow band noise, or warble tone (at 500, 1,000, 2,000, 4,000, and 8,000 Hz), is presented to each ear individually at decreasing intensities, until a threshold is obtained. If the child localizes toward the sound, a visual reinforcer is given to maintain the child's responses. The reinforcement is given only if the child responds to the sound immediately following the sound stimulus ***(6)***.

Conditioned play audiometry (CPA) ***(6)*** requires the child to be conditioned to the stimulus and to provide a motor response. The response is a play task such as placing a block in a box or a peg in a board, once the stimulus has been heard. Verbal praise is provided as reinforcement to encourage the child to continue the responses. The play activity should be age-appropriate so as to maintain the child's interest but not be too demanding so as to detract from the response. Frequencies that are measured range from 250 to 8,000 Hz at decreasing intensities until a threshold is established.

Conventional audiometry ***(7)*** measures require the child to raise a hand or press a button when the stimulus is heard. Frequencies between 250 Hz and 8,000 Hz are assessed at decreasing intensities until a threshold is established at each frequency.

Speech audiometry is used to assess the child's ability to hear speech accurately. Speech stimuli may be used in any of the above behavioral measures rather than tones to obtain a *speech awareness threshold (SAT)*.

Speech reception thresholds (SRT) are established using phonetically balanced words at decreasing intensities. This test requires the child to be able to repeat the words or identify them in pictures.

Speech discrimination testing (SD) assesses the child's ability to comprehend words at suprathreshold levels. This test may require the child to repeat the words. Pointing to pictures may be used if the child has impaired speech production.

Test Batteries

Test batteries consisting of a number of assessment tools are used to make a diagnosis of a hearing loss and identify a probable site of lesion. No single tool can provide all of that information. Table 1 serves as a guide to determine which assessment tools are used at different ages.

It is not unusual to adapt a test battery to the needs and capabilities of the child (Table 1). AEPs and OAEs

Table 1 Age-appropriate assessment tools

Age	Assessment tool	Table key
Birth (screening)	Neonatal screening using AEP or OAE or both	DPOAE: distortion product otoacoustic emissions TEOAE: transient evoked otoacoustic emissions
Birth to 4 months (diagnostic)	DPOAE/TEOAE	AEP: auditory evoked potential
	AEP	VRA: visual response audiometry
	Tympanometry	SAT: speech awareness threshold CPA: conditioned play audiometry
4 to 18 months	VRA (air and bone conduction) SAT Tympanometry Acoustic reflexes	SD: speech discrimination
18 months to 5 years	CPA (air and bone conduction) SAT/SD Tympanometry Acoustic reflexes	
5 years and over	Conventional audiometry (air and bone conduction) Tympanometry SRT/SD Acoustic reflexes	

are often carried out in children at any age if accurate and reliable information cannot be obtained from behavioral tests. AEPs may require sedating the child in the clinic or operating room in order to obtain the information quickly and accurately. Hearing can then be classified into one of the following categories *(8)*:

1. *Normal hearing*. Air conduction thresholds are better than 15 dB at all frequencies.
2. *Slight hearing loss*. Any one or more thresholds are between 15 and 25 dB at any frequency.
3. *Mild hearing loss*. Any one or more thresholds are between 25 and 40 dB at any frequency.
4. *Moderate hearing loss*. Any one or more thresholds are between 40 and 60 dB at any frequency.
5. *Severe hearing loss*. Any one or more thresholds are between 60 and 80 dB at any frequency.
6. *Profound hearing loss*. Any one or more thresholds are 80 dB or more.

Information from these tests can also help identify the possible cause of hearing loss. A *conductive* hearing loss

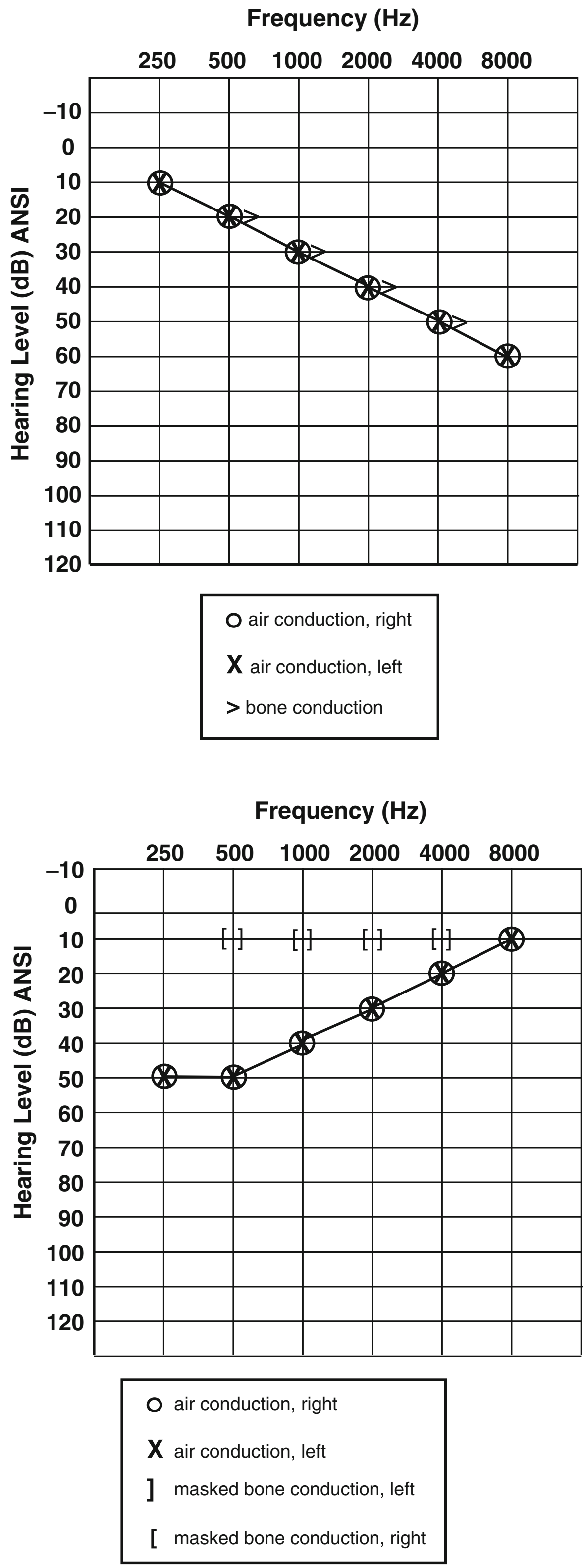

Fig. 2 (**a**) Conductive hearing loss; (**b**) sensorineural hearing loss

originates from the outer or middle ear. Atresia, cerumen impaction, otitis media, or ossicular discontinuity will result in a conductive hearing loss (Fig. 2). A *sensorineural* hearing loss originates from the cochlea or higher auditory pathways. Ototoxic medication or genetic-based hearing loss can give rise to a sensorineural hearing loss. A *mixed* hearing loss originates from the outer or middle ear and cochlea and may be seen in children with craniofacial anomalies that affect the embryologic development of the inner, middle, and outer ear.

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