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The Audiologic Assessment of the Young Pediatric Patient: The Clinic

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INTRODUCTION

Due to the increasing number of newborn hearing screening programs, infants are being referred for audiologic assessment and diagnosed with hearing loss at very young ages. Early diagnosis of hearing loss necessitates early initiation of habilitation including the fitting of amplification. Providing appropriate amplification is dependent on having a reliable definition of the child's hearing loss. The assessment process is therefore tantamount to the habilitation and hearing aid fitting process.

Unlike most adults whose hearing loss can be defined in one clinic visit, children often require repeated visits before the configuration and degree of hearing loss is defined. Audiologic assessment in children is often a challenging, time-intensive and ongoing process, particularly when assessing the very young infant. Infants and young children do not possess the breadth of responses that adults do, requiring modifications of behavioral audiologic techniques. In addition, there is sometimes the need for electrophysiologic tests to provide a baseline estimate of auditory function until complete behavioral audiologic findings can be obtained. However, complete behavioral audiologic information is **not** necessary before the hearing aid fitting and early intervention processes can begin. Valuable time should not be wasted waiting for complete information. Rather, the amplification process should be initiated with refinements and adjustments of the hearing aid fitting occurring as more and more precise information is obtained.

Both behavioral and electrophysiologic tests are used in the audiologic assessment of the very young pediatric patient. Behavioral tests usually are thought of as subjective and the electrophysiologic tests are thought of as objective because of their reliance or non-reliance on patient participation, respectively. At very young ages, the electrophysiologic test findings often predominate in the decision making about the management of the child with a hearing loss, but for older children it is generally the behavioral audiologic findings on which management decisions are made. These two types of tests, however, provide information on different aspects of the child's auditory function, and cannot serve as perfect substitutes for each other.

What follows are brief descriptions of the behavioral and electrophysiologic tests that are appropriate for the young pediatric patient. It should be highlighted that behavioral audiologic testing of the young child can yield reliable results if proper procedures are followed during the test session.

BEHAVIORAL AUDIOLOGIC ASSESSMENT

Behavioral Observation Audiometry

When an infant is less than 5–6 months developmental age, behavioral observation audiometry (BOA) is used. In this method, observations are made of the infant's behavioral changes in response to auditory stimuli. Consequently, it is important to observe the child for a period of time to obtain a baseline of his/her behavior. Responses to auditory stimuli that are easily and often observed are reflexive behaviors such as eye blinks, eye widening or startle responses. The major limitation of this technique is the wide range of intensities over which individual infants will respond. Other limitations are that there is a large tendency for the infant's responses to habituate quickly, and observer bias can influence the BOA results (Ling et al, 1970; Gans and Flexer, 1982).

BOA findings are referred to as minimal response levels (MRL), which are an indication of the infant's responsivity to sound. MRLs vary as a function of the stimulus, the developmental age of the infant and the infant's state. Responses to speech stimuli are often more apparent and occur at lower intensity levels than do responses to pure tone stimuli (Hoversten and Moncur, 1969; Thompson and Thompson, 1972). Age and signal intensity has an inverse relationship. Generally for normal hearing infants, the younger the child, the higher the signal intensity that is needed to elicit an observable response (Thompson and Weber, 1974; Nozza and Wilson, 1984; Olsho et al, 1988; Schneider et al, 1986). Infants need to be in an alert and relaxed state. If they are too active, too fussy, or too tired, MRLs will be high or responses may not be observable.

BOA provides information about the type of auditory response the child makes and about the auditory development of the child. Knowing the type of auditory response that a child makes provides a basis for knowing what responses to look for once amplification is introduced. However, the presence of overt responses to auditory stimuli cannot be used to predict speech and language development.

Visual Reinforcement Audiometry

Suzuki and Ogiba (1961) first described an operant conditioning technique called Conditioned Orientation Reflex (COR). Liden and Kankkunen (1969) introduced the term Visual Reinforcement Audiometry (VRA), and introduced variations of the COR technique. The VRA term has taken on a more generic meaning from the original description of the technique and often now refers to any technique in which a visual reinforcer is used. Many of the procedures as they are used clinically today are the result of the work from the University of Seattle by Wesley Wilson and colleagues (Moore et al, 1977; Wilson and Moore, 1978; Nozza and Wilson, 1984; Thompson and Wilson, 1984; Wilson and Thompson, 1984; Thompson and Folsom, 1984; 1985).

VRA is the preferred behavioral technique for children over 5-6 months of age. VRA allows for a head turn response to sound to be maintained through the use of a visual reinforcer. Most visual reinforcers are animated toys that should be kept behind darkened plexiglass and only visible during periods of activation. Keeping the animated toy out of sight helps to maintain the child's interest.

With VRA, an infant seated either in a high chair or on a parent's lap, is facing forward with a loudspeaker situated at 45 or 90 degrees from the infant. When auditory stimuli are presented through the loudspeaker, the child's natural tendency to search for the sound source is reinforced by activation of an animated toy. The visual reinforcer serves to maintain the head-turn response. The main difference between COR and VRA is that COR requires the ability to detect the sound and to localize it, and VRA uses a head turn response after the signal is detected but does not require localization of the sound. However, Primus (1992) did find that infants perform better when there was consistency between the sound source and reinforcer location.

Several studies have attempted to identify factors that will increase the number of responses during a test session. One variable that has produced consistent findings is the number of reinforcers. The use of additional reinforcers that are randomly chosen is effective for increasing the attention of infants approximately one year of age (Primus and Thompson, 1985; Thompson et al, 1992).

Using VRA, hearing threshold levels can be obtained either in the sound field, under earphones or through a bone conduction transducer (Wilson and Moore, 1978; Diefendorf, 1988; Widen, 1990). Children are more tolerant of insert earphones, and their lightweight makes them an excellent choice for earphones. However, when using earphones or a bone conduction transducer, children may not respond initially with a head turn response. Rather the child may need to be taught to look for the reinforcer. This is accomplished by presenting the auditory stimulus and turning on the visual reinforcer shortly after the auditory stimulus is presented. If conditioning was achieved in the soundfield prior to introducing earphones, the child readily remembers what to do.

It is possible to obtain a four-frequency, soundfield audiogram, speech awareness or speech recognition threshold and some indication of symmetry in one test visit. Most children will not complete an ear specific, four frequency, and speech threshold audiogram in just one visit; two visits are usually required. To maximize obtaining information during a clinic visit, the order of stimuli presentation should be prioritized to provide information about the degree and configuration of the hearing loss. A good starting point for conditioning is to use speech stimuli because children often find this interesting and respond naturally with a head turn response. Warbled pure tones follow the speech stimuli to obtain frequency specific information in the soundfield. Alternating a high and low frequency while starting with a higher frequency will yield an audiogram that provides information necessary to predict the contour of the hearing loss. For example, 2000 Hz would be the starting frequency followed by 500, 4000, and then 1000 Hz. If the child stops responding before all of the frequencies have been tested, the contour of the hearing loss can be derived from the partial results.

The number of reversals (i.e., change from decreasing to increasing or increasing to decreasing stimulus levels) that are reasonable clinically are 4 to 5. Starting close to anticipated threshold (inferred from the speech threshold) and bracketing is recommended. Some children do require reconditioning when going from frequency to frequency. Therefore, it may be necessary to present stimuli above anticipated threshold to remind the infant what to do.

Use of control trials is the best way to reduce subjectivity and ensure valid findings. Control trials are trials with no signal present. These silent intervals allow for observation of the child during a specified period to determine if random head turns or other responses occur without a stimulus present. These observation periods help reduce the number of false-positive results.

The child's maturational or developmental level does not influence the threshold level (Wilson and Moore, 1978; Olsho et al, 1987; Nozza, 1995). That is, a decrease in threshold level is not observed with an increase in age as long as conditioning is achieved. VRA not only allows for assessment of threshold, but also provides information on the intactness of the auditory pathway and the child's ability to react to auditory stimulation.

Play Audiometry

Play audiometry is a term used to describe a technique in which a game is used to obtain threshold information. Play audiometry can be used starting at approximately 24 months of age but is better at 2 ½ to 3 years of age. Play audiometry involves conditioning the child to respond to sound using an activity such as placing a peg in a pegboard, placing blocks in a container, stacking rings on a stick or placing puzzle pieces into a puzzle. Conditioning usually occurs after four or five guided responses or demonstrations. Often a social reinforcer, such as clapping hands or praising the child is used to help to establish the conditioning. Using this technique, frequency specific and ear specific information can be obtained to both air and bone conduction stimulation. For very young children or children who have difficulty staying on task, the sequence of frequencies should be presented to optimize obtaining information necessary to predict the contour and degree of hearing loss. Furthermore, complete testing of one ear need not be done before the opposite ear is tested. That is, it may be best to get partial frequency information from both ears rather than complete information from one ear.

Conventional Audiometry

Conventional audiometry can be used by the time the child is 5 to 6 years of age. The response made is typically the same that is used for adults such as conditioning the child to raise their hand in response to the sound. As with all behavioral test techniques, the chronological age is not the determinant of technique, rather it is the developmental level of the child.

Summary of Behavioral Audiologic Assessment

To summarize, behavioral audiologic findings can yield reliable results but care must be taken to eliminate false positive responses. Using control trials to observe the child's responses during times of no stimulus can reduce false-positive results. Furthermore, awareness of parental cueing (often unintentionally) or patterning of presentation cues or examiner bias can help to reduce subjectivity and error. Another option to reduce subjectivity and one that is now commercially available is a computer controlled system. This commercially available system (Intelligent Hearing Systems) allows the examiners to be in the room with the child to help control the child's behavior state during signal presentation. In addition, this system uses control trials and has a limited time window in which the examiner decides if a response is present, thus helping to ensure that the child's responses are a result of the stimuli presented and not random responses.

Because of a child's very young age, the presence of other impairments, or inconsistencies in test findings, behavioral audiometric techniques may not provide sufficient information on the contour, type and/or degree of hearing loss. Parents and clinicians often seek electrophysiologic information to further define sensitivity or to substantiate behavioral findings. The electrophysiologic tests are more objective because of the lack of patient (child) participation in the evaluation. The physiologic evaluations that are most common in the pediatric population are the auditory brain stem response (ABR) and otoacoustic emissions (OAEs).

ELECTROPHYSIOLOGIC ASSESSMENT

ABR

The benefits of using ABR to construct the audiogram far outweigh the limitations. The major limitation is the choice of stimuli that can be used to elicit a response. Synchronous neural firing of multiple neurons is essential to record an auditory brainstem response. A rapid or abrupt onset stimulus such as a click that stimulates a broad area of the basilar membrane generates synchronous neural discharge in a large number of neurons. The auditory brainstem response to click stimuli will provide an overall assessment of the integrity of the auditory pathway and provide a basis on which to start investigating thresholds at specific frequencies.

Frequency Specific Information

The click stimulus contains energy in a broad frequency range. Responses to click stimuli correlate best with audiometric findings in the 2000-4000 Hz frequency range (Møller and Blegvad, 1976; Coats and Martin, 1977). The use of this stimulus solely can either underestimate or miss a hearing loss at a particular frequency or frequencies depending on the degree and configuration of the hearing loss. While the use of age-appropriate latency-intensity functions together with the threshold search will help to identify impairments, exact quantification of the impairment at each frequency cannot be done using the click stimulus. Frequency specific or tonal stimuli need to be used. The stimulus commonly used to obtain frequency specific information is a brief duration tone burst.

The trade off in becoming tonal by increasing the rise time of the stimulus is to reduce the synchronous neural discharge. The aim is to achieve a balance of tonality with enough synchronous neural firing to elicit a response. It is necessary to maintain a fast enough rise time to elicit a response yet reduce the acoustic splatter to frequencies above and below the nominal frequency of the stimulus. Producing a frequency specific stimulus without significant contribution from other frequencies can be achieved by using gating functions or stimulus shaping envelopes such as Blackman functions (Gorga and Thornton, 1989). While producing a stimulus that does not have contributions from other frequencies is important, it will not ensure a place specific region of excitation on the basilar membrane. Physiologically, there is an upward spread of excitation on the basilar membrane as the intensity level of the stimulus is increased beyond 70 dB SPL (Pickles, 1988). Spread of energy to frequencies with better hearing will result in an underestimation of threshold level.

The alternative to using tone bursts is to combine either the click or tone burst stimulus with masking to ensure more place specific activation of the basilar membrane. One approach is to use high pass masking that is introduced ipsilaterally with the stimulus. This technique may be useful for providing information at 500 Hz but not for the mid or high frequencies because of the inability to adequately eliminate the contribution from lower frequencies. Contributions from lower frequencies will underestimate the threshold, especially in cases of sloping high frequency hearing loss with better thresholds in the low frequencies.

High pass masking also has been used in a technique called derived responses by Don et al (1979). This method involves the subtraction of waveforms that have been obtained in the presence of high pass maskers of various cutoff frequencies. For example, an ABR is obtained without masking and then with an 8000 Hz high pass masker. Subtraction of these responses will yield a response that provides information for 8000 Hz. This ABR response would then have subtracted from it a response produced in the presence of a 4000 Hz high pass masker. This would have a resultant waveform that contains information for only 4000 Hz. These derived responses were found by Don et al (1979) to be predictive of pure tone thresholds and to provide frequency specific information. The drawback to this procedure is the length of time needed to obtain sufficient information from the patient as well as time off line to do the waveform subtraction. Additionally, this procedure cannot be performed with all test systems.

Another method for obtaining frequency specific information is the use of a notched or band rejection noise in combination with a click or tonal stimuli. Notched noise is broad band noise that has a portion of the frequencies removed. If a tonal stimulus is being presented with notched noise, the notch will correspond to the frequency of the tonal stimulus. Several advantages to this method are that it requires the same amount of time that clicks or tonal stimuli do and much less time than derived responses. Second, as compared to high pass masking, this procedure prevents contribution from frequencies lower and higher than the nominal frequency. The results of notched noise with click stimuli have been mixed, with some concern that the low frequencies of the masker can leak into the notched region and somewhat reduce the amplitude of the waveform (Pratt and Bleich, 1982; Pratt et al, 1984; Stapells et al, 1985). There may be technical limitations to this method as well. While several newer commercially available evoked potential systems have notched noise as an option, older equipment does not, and the older equipment may not allow for an external noise source to be used.

Predicting the Audiogram

Prediction of the audiogram using the ABR is possible if proper testing conditions and parameters are used. Responses to both air and bone conducted stimuli should be obtained to click stimuli at a minimum. While there are intensity output limitations in bone conduction testing, it often helps to confirm the type of auditory impairment. Threshold levels between air and bone conduction stimuli in individuals with normal hearing and in individuals with sensorineural hearing loss should agree closely. There will be latency differences with longer latencies to bone conduction stimulation (Mauldin and Jerger, 1979; Yang et al, 1987) except when testing very young infants, latencies actually may be shorter by bone conduction than by air conduction (Hooks and Weber, 1984; Stuart et al, 1990). Threshold differences of greater than 15 dB with better bone conduction threshold than air conduction threshold is indicative of conductive involvement. To obtain valid results, the tester must assure adequate headband pressure (Yang et al, 1987) and proper placement of the bone vibrator on the mastoid.

A practical consideration in bone conduction testing is the electrode placement. Electrodes cannot be placed on the mastoid when bone conduction testing is being done because of the small area of the mastoid in children and the electromagnetic interference that can occur when the electrode is close to the bone vibrator. Moving the electrode off of the mastoid to the earlobe or in front of the tragus in very young infants is necessary. Use of insert earphones permits placement of the bone vibrator and masking earphone on a small child's head. Bone conduction testing does require the use of masking, although there appears to be more interaural attenuation in young children than adults (Stuart et al, 1990).

The correspondence between behavioral thresholds and ABR thresholds is good, particularly for click stimuli where thresholds are often within 10–15 dB of each other (Gorga et al, 1985; Kileny and Magathan, 1987; Fjermedal and Laukli, 1989). There are larger differences between ABR and behavioral thresholds for the tonal stimuli, particularly in the lower frequencies. Gorga and colleagues (1988) reported that ABR and behavioral thresholds at 500, 1000, 2000 and 4000 Hz differ by approximately 30 dB, 20 dB, 15 dB and 10 dB respectively, with ABR thresholds being worse. Data from our own clinic agree well with this, although our 2000 Hz agreement is closer than our 4000 Hz showing differences of 10 dB and 15 dB, respectively. Similar, although slightly better findings for tones in notched noise are reported by Stapells et al (1995).

The ABR is affected not only by stimuli type but also stimuli intensity, repetition rate and polarity. There is an inverse relationship between wave latencies and stimuli intensity. The higher the intensity, the shorter the latencies. Furthermore, waveform morphology is affected by signal intensity. Typically, wave V, being the most robust is the only wave present at intensity levels close to threshold. The early waves are generally only clearly seen at supra threshold levels. Repetition rate affects both latency and response morphology. As repetition rate increases, response latencies increase, particularly for the later waves and response morphology degrades especially for the early waves (I-III). Polarity of the stimuli will affect the latencies with responses to rarefaction clicks occurring at shorter latencies than to condensation clicks. While alternating the polarity of the stimuli can at times reduce stimulus artifact, important information can be lost if only alternating polarity is used (Berlin et al, 1998).

Recording parameters that affect the ABR are filter settings and transducer type. Filter settings should be narrow enough to eliminate unwanted noise but broad enough to allow for good waveform definition (e.g., 30-3000 Hz). Wave latencies are affected by using analog filtering, but with newer equipment employing digital filters, this is less of a concern. The type of transducer (air versus bone conduction transducer) has already been discussed, but latency changes also will be observed when using circum-aural or supra-aural compared to insert earphones. Absolute wave latencies to insert earphones are recorded later because of the added travel time through the tubing. Many commercial pieces of equipment automatically correct for the use of insert earphones.

Patient parameters also affect the ABR. These parameters include age, gender, body temperature and hearing loss. The morphology of the response from preterm and term infants typically does not show good definition of all waves but rather only waves I, III and V are clearly visible. In addition, in some very young infants, wave I amplitude may be the same as or larger than wave V amplitude. Both absolute and interwave latencies decrease with increasing age with wave I reaching adult values by three months of age. Wave III reaches adult-like values next, and last, wave V by approximately two years of age. Gender impacts interwave latencies in adults with females generally showing shorter interwave latencies. These differences are not clearly evident in children until at least eight to ten years of age (McClelland and McCrea, 1979; O'Donovan et al, 1980).

Body temperature is known to affect interwave latencies with longer latencies being observed as core body temperature is decreased. A commonly applied correction is for every degree decrease in body temperature below normal, there is a 0.2 msec increase in interwave latency (Hall, 1992). The opposite of this is true as well with shorter interwave latencies as body temperature increases.

The ABR is affected by hearing loss. Conductive hearing loss prolongs the absolute latencies and the response disappears at elevated intensity levels (i.e., above 20 dB). In general, with sensorineural hearing losses of flat configuration, the response latencies are normal but the response disappears at elevated intensity levels. With sensorineural hearing losses of downward sloping configurations, the latencies are normal at suprathreshold levels but become continually prolonged as intensity is decreased to threshold. Plotting the age appropriate latency-intensity function, together with bone conduction information, helps to determine the type of impairment. Knowledge of all of these variables is essential to ensure accurate interpretation of the findings.

Suggested Sequence of Testing

The goal of evoked potential testing, in particular the ABR, is to predict the audiogram sufficiently so that if a sensory impairment is present, amplification can be fit. The optimal time to conduct an ABR on a child is during sleep, but there is always an uncertainty as to how long a child will sleep even when sedation is used. Therefore, there should be a prioritization of the sequence of the frequencies used during testing. Since the ABR to click stimuli provides the best response and provides information in the 2000-4000 Hz frequency range, it is reasonable to start with this stimulus. The click stimulus would then be followed by a low frequency stimulus, such as a 250 or 500 Hz tone burst (with or without the use of ipsilateral high-pass or notched noise masker depending on test equipment). Following this, more frequency specific testing (4000 and 1000 Hz tone burst) and bone conduction testing should be completed. While this is a guideline on the sequence of testing, each child's findings must be viewed and decisions made on-line to maximize obtaining information about the type, degree and contour of hearing loss. That is, if the findings to click stimuli suggest that an impairment has a relatively flat contour, then testing by bone conduction might follow the click with low frequency testing last. Whereas, if the click results imply a sloping configuration (based on the latency intensity functions and thresholds obtained), then testing using a low and then a high frequency stimulus would follow the click with testing by bone conduction last. If behavioral findings have suggested the degree and configuration of hearing loss, and the ABR is being done to substantiate these findings, then the click stimuli could be bypassed with only responses to tonal stimuli recorded.

The ABR does not measure hearing in the true meaning of the word. Instead it measures the integrity of a portion of the auditory system through approximately the level of the midbrain. While agreement exists between behavioral thresholds and ABR thresholds, there are instances where they will not agree. There are cases of normal ABR yet no ability to recognize or use sound to hear. Conversely, the absence of an identifiable waveform on an ABR test does not necessarily equate to thresholds in the severe to profound range or to no hearing. First the ABR equipment is more limited in output than most audiometers used to test behavioral thresholds. Consequently, an absent ABR should not have an interpretation of no residual hearing. Secondly, the ABR will be affected by the neurologic status of the child. If the auditory system is damaged and neurons cannot fire synchronously, or if there are disruptions of the auditory pathway due to an insult, there will be no identifiable ABR waveform or a partial waveform with later waves absent, even though the end organ of hearing, the cochlea, may be functioning normally. With the availability of technology to monitor otoacoustic emissions from the cochlea, discrepancies between behavioral audiologic findings and ABR are being resolved. Behavioral audiologic findings showing better responsivity to sound than can be predicted by the ABR are being substantiated by the presence of OAEs.

Otoacoustic Emissions

Otoacoustic Emissions (OAEs) are sounds generated by the cochlea that can be recorded in the ear canal. More specifically, OAEs are thought to be by-products of normal cochlear function, in particular the outer hair cells. OAEs are present in ears that have normal hearing and relatively normal middle ears. While OAEs cannot provide exact threshold information and are best suited as a screening tool to determine presence or absence of hearing loss, they can help in identifying the site of lesion of the hearing loss.

OAEs are classified according to whether a stimulus is used to elicit them. Spontaneous Otoacoustic Emissions (SOAEs) are recorded when no stimulus is present and Evoked Otoacoustic Emissions (EOAEs) are recorded following a stimulus. EOAEs are subcategorized depending on the type of stimulus used to evoke them. Presently, the two clinically useful EOAEs are Transient (TEOAEs), which are recorded following a brief acoustic stimulus (click), and Distortion Product (DPOAEs), which are recorded following two simultaneously presented pure tones.

TEOAE

The click produces a broadband stimulus and therefore a response from a wide range of frequencies. While the click stimulus used to elicit the response is not frequency specific, TEOAEs, unlike the ABR, can be analyzed in frequency bands. A stimulus level of 80-84 dB SPL is optimal for eliciting TEOAEs. The response amplitude is recorded over a 20-msec time window following the stimulus. The higher frequencies are recorded in time first because they originate closer to the base of the cochlea and have shorter latencies. The lower frequencies come from more apical portions of the cochlea and consequently have longer latencies and are recorded next. Presence or absence of a response is determined by evaluating the response amplitude relative to the noise floor and the response reproducibility of the waveform (two waveforms are generated for each test), assuming that the stimulus is maintained at a proper intensity level. At least 3 dB signal to noise is needed in a minimum of three frequency bands in order for a response to be considered present. Furthermore, agreement between the waveforms (response reproducibility) is needed to be greater than 50% in these frequency bands. In general, the TEOAE response amplitude is higher in children than in adults, making it easier to obtain a response from a young child.

DPOAE

DPOAEs are recorded following the simultaneous presentation of two pure tones that are related in frequency. The interaction of the tones produces a third tone (not present in the original signal) emitted from the cochlea. Distortion products are by-products of a normal non-linear system, in this case the outer hair cells. DPOAEs allow for more frequency specific stimulation of the cochlea as compared to the click stimuli used to elicit TEOAEs. The intensity level of the two stimuli are either equal or the lower frequency stimuli has a higher intensity by approximately 10-15 dB. DPOAEs are plotted on a DP gram with response amplitude as a function of frequency. Absolute amplitude of the response or amplitude relative to the noise level determines the presence or absence of a response. Response amplitude of approximately 10 dB is needed, although this is somewhat equipment specific. Like TEOAEs, the amplitude of DPOAEs is larger in children than adults. The differences between these OAEs is that TEOAEs, in general, provide less high frequency information than DPOAEs.

OAEs and Hearing Loss

OAEs are sensitive to hearing losses and can be absent with as little as a 20-30 dB HL hearing loss. The absence of an OAE must be viewed within the context of the condition of the middle ear since both the stimulus and the response pass through the middle ear. Therefore, the absence of an OAE is diagnostically significant for sensory hearing loss only when middle ear function is relatively normal.

The application of TEOAEs and DPOAEs has been focused primarily on screening to assess presence or absence of hearing loss, particularly in the neonatal, very young and the difficult-to-test populations. Audiogram threshold prediction at this time is not possible using OAEs. However, recent research by Gorga et al (1997) showed that DPOAEs can be used to make predictions within one category of degree of hearing loss up to 40-60 dB of hearing loss.

OAEs are becoming an important clinical tool for evaluating hearing in young children to help with decision-making on how to best proceed with obtaining more information regarding thresholds and site of lesions information. Since OAEs are pre-neural events generated in the cochlea and the ABR is a neural event, sensory impairment can be differentiated from neural hearing impairment.

Middle Ear Status

An accurate picture of a child's hearing can be obtained by combining the results of OAEs, ABR and behavioral audiologic findings but the evaluation is not complete if middle ear status has not been evaluated. Acoustic immittance testing helps to differentiate and/or substantiate other test findings.

In children less than 7 months of age, tympanometry has not been found to be the best predictor of middle ear status when a low frequency probe tone has been used (Paradise et al, 1976). Rousch et al (1995) found that infants and young children (6-18 months of age) show lower static admittance values and wider tympanometric widths than older children when a low frequency probe tone is used. Acoustic immittance findings with higher frequency probe tones have yielded more promising results for infants less than six months of age (Marchant et al, 1986). At Children's Hospital of Pittsburgh, we routinely conduct tympanometry using a 1000 Hz probe tone in children less than 6 months of age. We have found that using a 1000 Hz probe tone for tympanometry in very young children has a higher correlation with ABR, OAE and at times otoscopic findings, although formal study of this is needed to confirm our impressions. That is, the presence of a peak on a 1000 Hz tympanogram is often associated with normal OAE, ABR and otoscopic findings, whereas no identifiable peak is often seen with abnormal ABR, OAE, and otoscopic findings. Further study regarding tympanometric findings in infants is needed and currently underway at this facility.

Tympanometric data in pediatric populations are summarized by Nozza in this issue and can be found in Koebsell and Margolis (1986); Margolis and Heller (1987); Roush et al (1995); Nozza et al (1992); and Nozza et al (1997).

SUMMARY

Audiologic information is necessary in order to start the habilitative process. However, audiologic assessment in the pediatric population does not end with the audiogram. Rather, it ends with the family's ability to mobilize after the diagnosis is made. When a child comes to the clinic, they always bring along a family. Audiologists are faced not only with the challenges of obtaining accurate audiologic information, they have the added issue of dealing with the families and their acceptance and readiness to advance into habilitation once a hearing loss is identified. Therefore, it is not only the audiologist's skill in obtaining accurate audiologic information that is important, but also their ability to counsel and effectively communicate with the child's family. There is a certain urgency with which one likes to move when dealing with children with hearing loss so that habilitation can be initiated in a timely manner to maximize the child's potential of developing speech and language. In our haste, we often forget the parents and their need to accept the hearing loss. Without acceptance, the habilitative process can be stalled. We may blame the family for lack of follow through because we forget that this inability to mobilize is not intentional but a consequence of their inability to deal with the diagnosis. The majority of families are doing the best they can, given their circumstances, and should not be blamed for their inability to proceed but encouraged to deal with their feelings (Luterman 1984; 1987). For those families who do accept the hearing loss, yet do not follow through with recommendation, other stresses in their lives may have precedent. Effective communication and counseling will help to identify the issues and needs of the family so that habilitation can be initiated and follow through can be achieved in this ongoing process. The audiologic assessment of the young pediatric patient in the clinic, therefore, intertwines the scientific knowledge with the very real element of the child and the emotions and needs of the child's family.

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