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ABSTRACT

This paper provides guidelines for neonatal audiologic screening. Hearing tests that measure behavioral responses, and those that measure physiological changes of body function in response to a stimulus, are discussed. The paper is intended to rectify inadequate means of identifying and testing infants considered as high risks for hearing loss. The information presented indicates the existence of viable methods of determining the hearing acuity of an infant. Discussion emphasizes that early identification of hearing problems is of paramount importance for the prevention of unnecessary delays in a child's ability to communicate and interact with the world. Specific strategies for early identification are offered. (RH)

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Neonatal Audiologic
Screening and Test Procedures

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Abstract

The early identification of hearing loss is imperative in order to prevent cognitive, social and language disabilities in young children. This fact necessitated the establishment of guidelines and procedures to aid in rectifying inadequate means of identifying and testing infants considered as high risks for hearing loss. Along with presenting behavioral and objective tests for hearing, physiological considerations concerning an infant's hearing mechanism are also presented.

Neonatal Audiologic Screening
and Test Procedures

It is a well known fact that as a result of any degree of hearing loss, from mild to profound, children are adversely affected in terms of language, cognitive and social skills. In light of this fact, it would seem to necessitate the early identification of hearing deficits in young children in order to prevent impairment in other parameters or areas of development. Along with this consideration, there are other factors to examine when looking at early identification. For one, it is helpful in the prognosis of the hearing deficit. Another, is that if children with a hearing loss are not identified at birth, it could be several years before they are tested and rehabilitation efforts are begun (Gerber, 1971). This, of course, would mean an even further delay in development and would cause the prognosis to be less favorable.

In 1971, at the Conference for Newborn Hearing Screening, several recommendations were made concerning the early identification of newborn infants and the procedures for doing so. They are as follows:

- I. A high risk population can and should be identified by prenatal history and postnatal physical assessment of the infant. As a first step a registry should contain the following groups:

Prenatal High Risk Procedure

1. All infants with a family history of childhood deafness in some member of the immediate family, i.e., father, mother and sibling.

2. All infants whose mothers have had rubella documented or strongly suspected during any period of pregnancy.
3. All infants with a family history of congenital malformations of the external ear, cleft lip or palate.
4. All infants with a family history of deafness in other relatives, with onset in childhood

Postnatal

5. All infants found to have structural abnormality of the external ear, cleft lip or palate including bifid uvula.
6. All infants having bilirubin values of 20 mg/100 mg or more, who had exchange transfusions are at high risk of bilirubin encephalopathy.
7. All infants under 1,500 grams.
8. All infants with abnormal otoscopic findings (p. 11-12).

In the 3rd edition of Hearing in Children, Northern and Downs stated that in 1982, the Joint Committee, represented by the Academy of Otolaryngology - Head and Neck, the Academy of Pediatrics and American Nurse's Association and the American Speech-Language-Hearing Association proposed a new position statement concerning guidelines for identifying hearing impaired infants. Along with the physiological risk criteria used for identification, which has been cited previously, they included screening guidelines and diagnostic evaluation procedures. They include:

- B. Screening. The hearing of infants who manifest any item on the list criteria should be screened under the supervision of an

audiologist, preferably prior to 3 months of age, but not later than 6 months after birth. The initial screening should include the observation of behavioral or electrophysiological response to sound. If consistent electrophysiological or behavioral responses are detected at appropriate sound levels, then the screening process will be considered complete except in those cases where there is a possibility of a progressive hearing loss, e.g. delayed onset, degenerative disease, or intrauterine infections. If results of an initial screening of an infant manifesting any risk criteria are equivocal, then the infant should be referred for audiological diagnosis testing.

II. Diagnosis

The Committee recommends that a diagnostic evaluation of an infant under six months of age include:

- A. General Physical Examination and History Including
 1. Examination of the head and neck
 2. Otoscopy or otomicroscopy
 3. Identification of relevant physical abnormalities
 4. Laboratory tests such as urinalysis and TORCH (toxoplasmosis, rubella, cytomegalovirus, herpes, syphilis).
- B. Comprehensive Audiological Evaluation
 1. Behavioral history
 2. Behavioral observation and audiometry
 3. Testing of auditory evoked potentials if indicated

After the age of 6 months the following are also recommended.

1. Communication skill evaluation
2. Acoustic immittance measures
3. Selected tests of development

For infants of any age, the Committee suggests the following when indicated:

1. Audiograms of parents and siblings
2. Thyroid function tests
3. Polytomography of middle and inner ears
4. Electrocardiograms
5. Chromosomal study
6. Tests for mucopolysaccharidosis
7. Ophthalmological assessment
8. Vestibular tests (p. 235).

The incidence of hearing loss in newborns ranges according to different studies. Gerber (1971) in his synopsis of the Conference for Newborn Hearing Screening, stated that on the average "the incidence of congenital deafness ranges from one in 1,000 to one in 2,000" (p. 17). Also, as cited by Northern and Downs (1978), "...the incidents of moderate to profound hearing loss in the at risk infant group is 2.5 - 5.0%" (p. 234). As a result of figures such as these, it was determined that a hospital setting was the most appropriate setting in which to do audiologic screening of infants, most especially those who are considered "high risk." As defined by Northern and Downs (1978):

Screening is the process of applying to large numbers of individuals certain rapid, simple measure, that will identify those individuals with a high probability of disorders in the function tested. A criterion measurement point is always involved, below or above which the individual are suspect. Screening is not intended as a diagnostic procedure, it merely surveys large populations of asymptomatic individuals in order to identify those who are suspected of having the disorder and who require more elaborate diagnostic procedures (p 193)

Tests given to newborn infants usually are considered to be just screening devices. Due to the fact that infants have limited means of responding to auditory tests, the initial screening procedures should not be considered the last step in the identification process, especially with high risk infants. There should always be follow up tests if there are any questions concerning the infant's hearing capabilities. Frisina (1973) made the observation that as an audiologist,

We need to be concerned with only 2 sets of variables: the first is the specification of the stimulus and the way in which it is presented; second is the identification and measure of the response. The technology for producing a well-defined stimulus is available but at this time generating and maintaining comparable precise human response leaves something to be desired (p. 158).

Although information about infant auditory response is somewhat limited, in recent years there has been an accumulation of new information in this area. By applying this information about what type

of stimulus an infant is capable of responding to, the audiologist can make more accurate judgments. According to Frisina (1973), auditory research has found the following to be true.

1. The cochlea seems functional by about the 20th week of intrauterine life.
2. Basic mechanisms for coding intensity and frequency appear to be operating by the 28th or 30th week of gestation.
3. Mechanisms governing attentive behavior may not be functional until some weeks later.
4. Functionally differentiated channels for processing acoustic information according to the frequency and organization of a stimulus envelope probably are present at birth (p 276).

Bradford (1975) made the statement that the newborn "comes with much potential (particularly relative to hearing, inasmuch as the cochlea, at least, is quite fully developed by 26-28 weeks of term), but can rarely put all this to use" (p. 178). He also made the point that hearing is largely controlled by the brain - not the ear - and that as the brain develops, the newborn's ability to hear improves. This leads again to the assertion that even though a high risk infant may pass a hearing screening, further monitoring is necessary as the child gets older in order to eliminate any doubts concerning his or her hearing acuity.

Hearing tests vary according to the age of the patient. Tests for children can be divided into three categories according to Fulton, Lloyd and Hoyt (1975):

Some tests are effective for children 2 to 4 years who are willing and able to respond. They are really devices to increase the child's motivation and keep him interested in the test. Tests of the second class depend on unconsciousness, inborn reflex responses to sound, such as startle movements, eye blinks, or changes in respiration or heart rate. The third class takes advantage of the electrical responses of the brain or auditory nerve or the "electrodermal" response of the sweat glands (p. 242-243)

Each test involves the elicitation and measurement of an auditory response. An auditory response, as defined by Rose (1971), ...may be represented as merely a change in a child's prestimulus activity level. In more sophisticated form, an auditory response is a change in prestimulus behavioral, or electrophysiologic activity meeting definite criteria, i.e., poststimulus activity of a required latency relative to stimulus onset; activity of required latency and magnitude revealed by the swing of a pen on an electrophysiologic recording, a specific type of poststimulus muscular activity occurring at a definite time after stimulus onset; and correct speech production of a spoken stimulus word (p. 249).

As Rose points out, the criteria for auditory responses from neonates would of course, be more primitive than responses required from an older child.

The following paragraphs will discuss those tests that measure behavioral type of responses and also those that measure physiological

changes of body functioning in response to a stimulus. Most newborns who are considered high risk will undergo specific hearing evaluation in the hospital setting, so these tests will be introduced first.

The arousal test is Hospital Administered tests recommended for use in identifying infants at high risk in the hospital setting. It is a relatively simple test to administer. The infant is placed in a room that is quieter than 60 dB SPL noise level. Testing should not start unless the infant is in the light sleep stage. Deep sleep will negatively influence the test results. A signal of 90 dB SPL is recommended along with a high frequency, narrow band noise with an available white noise source of 90 dB SPL. Criteria for presentation of the signal also is given along with criteria for responses. Response criteria is very specific. If the baby opens his or her eyes, moves his/her whole body, or has a strong and immediate eye blink followed by body movement or eye opening, this is considered passing criteria. If the baby fails the set criteria for passing the test, referrals are made for more extensive hearing evaluations. One drawback to this test is that it is not very efficient in identifying infants with mild to moderate losses; but, on the other hand, it is a good test for identifying babies with severe to profound losses while they are still in the nursery (Northern and Downs, 1978).

Another test that can be administered in a hospital setting is the Crib-o-gram.

The Crib-o-gram "is an automated device that measures the movement of a neonate immediately before and after the presentation of a calibrated acoustic stimulus" (McFarland, Simmons and Jones, 1980, p 501) It is a more complex procedure in that more information is given about the degree and type of hearing loss and the results are recorded on a strip chart to be analyzed after the test. Those children who are found to have a hearing loss are scheduled for behavioral type testing at about 7 months of age. This delay is due to the fact that at 7 months, they are able to localize and respond to this type of testing. According to McFarland et al.,

The Crib-o-gram appears to be an effective neonatal hearing screening test. The current 91% detection rate and 15% false positive rate in the Intensive Care Nursery indicate that it is detecting most hearing impaired infants with minimal error.

The discovery of an incidence of hearing impairment of 1 in 56 in our Intensive Care Nursery is quite disturbing. It does indicate that neonatal hearing screening should be mandatory in the Intensive Care Nursery (p. 502).

The auditory response cradle is another automatic newborn screening device. Described by Northern and Downs (1978), this system monitors four separate behavioral responses after the infant has been stimulated auditorily. The responses and instrumentation are as follows:

Trunk and limb movements are monitored by a pressure sensitive mattress; the headjerk component of the startle reflex is monitored by a transducer embedded in the foam of a headrest

which is pivoted on low friction bearings to detect head turn reactions, infant respiratory pattern is sensed by a transducer fitted in a plastic belt which is placed around the upper abdomen of the baby (p. 249)

Test stimulus is "a high pass noise of 85 dB SIL (band width from 2,600 to 4,500 Hz" (p. 249), and is presented through ear probes. It is reported that this test is helpful in identifying babies with moderate to severe hearing impairment along with those who have serous otitis media.

Other clinical measures in addition to these tests, there are other behavioral and objective tests that can be done either in a hospital or clinical setting. Again, as stated by Rose (1971),

Auditory responses produced through the behavioral response systems are characterized by some neuromuscular activity of the child under test. This activity occurs after auditory stimulation and can be visually observed or audibly heard by the audiologist. These response systems can produce muscular responses to stimuli other than the auditory stimulus, if such stimuli are of sufficient magnitude and importance to the child. Thus, they are nonspecific auditory response systems (p. 243)

In contrast, an objective test "is one which defines a patient's hearing ability without the patient's active participation or cooperation" (Northern and Downs, 1978, p. 149)

Orienting tests are behavioral tests. The most common orienting test is one which incorporates specified noisemakers as the auditory stimulus. The child being tested is placed in a sound treated room and

various noisemakers are selected which have been proven to be effective for eliciting responses. They include a squeeze toy, rattle and rattle that can be made to fit the recommended frequency and intensity levels. The child is placed in the mother's lap and the tester proceeds to introduce the various noisemakers out of sight of the child. The age of the child will determine how he or she will respond. For example, the 0 to 4 month old infant will be expected to either wake up, if asleep, blink his/her eyes or widen his/her eyes. From 4 to 7 months, the child will attempt to move its head to the source of the sound. The older the infant, the more accurate he or she will be in trying to localize to the sound. Criteria for passing the test fluctuates according to who is conducting the test. Of course, if the infant does not respond at all, or if he/she does not respond to either high or low frequency noises, he or she should be referred for further testing (Northern and Downs, 1978).

Objective tests include those that monitor an infant's heart rate, cortical responses, autonomic nervous system and the auditory system in the brainstem. Each test has advantages and disadvantages as will be pointed out.

First, brainstem evoked response audiometry (BSER) measures the "responses generated in the nuclei of the auditory system in the brainstem" (Davis and Silverman, p. 254). When stimuli are presented, responses in the form of wave patterns are recorded. Northern and Downs (1978) reported that "filtered clicks and tonal bursts for frequencies between 2000 Hz and 8000 Hz are successful in evoking the BSER" (p. 179). The BSER can be used with any population. It has started to be an

accepted procedure for patients who have inconsistent auditory test results such as infants and other difficult to test children. It only requires that the children either be sedated or sleeping in order to achieve maximum muscular relaxation. Along with rechecking hearing in children, the BSER is used by neurologists to localize midbrain and brainstem tumors and brainstem circulation (Northern and Downs, 1978).

A second objective test for evaluating hearing is electrodermal audiometry which measures an electrodermal response (EDR). This test records the responses of the autonomic nervous system which are monitored through changes in electrical properties of the sweatglands in the skin. Rose (1971) described this process.

"Centers for the regulation of the autonomic nervous system have been found at many levels of the central nervous system. Therefore, an auditory sensation of sufficient magnitude and importance to a child will indirectly cause an alteration of sweat gland activity by first exciting the auditory system, which in turn excites the central nervous system, which activates the autonomic nervous system, which finally increases or decreases sweat gland activity by way of its sympathetic nerve fibers" (p. 244).

This test involves classical conditioning in that an electric shock sometimes is paired with the auditory stimulus in order to condition hard to test patients to respond to auditory stimuli. This technique does have its drawbacks. As stated by Northern and Downs (1978), "Anyone who has ever attempted to entice a youngster into a sound treated booth, when the child's previous exposure to having his or her hearing tested was

with the EDR audiometric procedure, can appreciate our feelings toward this testing technique" (p. 73) Davis and Silverman (1978) also pointed out that this test is not really appropriate for those who usually have erratic responses, such as young children; and, EDR readings often are hard to decipher when making judgments about responses.

Electroencephalic testing, or cortical ERA, is yet another objective test. It involves the measurement of electrical responses in the cortex when a stimulus is presented. Northern and Downs (1978) stated "the cortical evoked response results from generalized electrical activity on the cortex due to the presentation of various sensory stimuli including light, vibrotactile stimuli, and sound" (p. 176). Although this test procedure was thought at one time to be an effective tool for evaluating hearing, it proved to be impractical because of cost, technical problems, and the fact that test results were influenced too much by other variables including electrode placement, nature of acoustic stimulus, physiologic state of the patient, age of the patient and nonspecific response criteria. Another disadvantage to the test is that young children and other difficult to test patients are included in the group of patients who are most difficult to get precise audiological information on. Therefore, results for cortical ERA testing usually cannot be used to cross check the standard audiometry tests (Northern and Downs, 1978).

Lastly, the electrocardiac response system (EDR) has been used as a testing device to measure an infant's heart rate in response to auditory stimuli. There does seem to be a discrepancy in opinion as to whether or

not the EKR is an effective procedure. According to Eisenberg (1976), many researchers have attempted to use cardiac measures to study infant audition. But, for different reasons, each has concluded that other procedures are more reliable. Among other things, they found that an infant's heart rate during the first 2 months is very unstable when compared to older children and adults; and, there is difficulty defining thresholds with this procedure. In contrast, Northern and Downs (1978) concluded that "heart rate change is a sensitive measure of auditory function, and is within clinical feasibility" (p. 175). Again, other researchers have indicated a direct correlation between auditory stimulus and heart rate response patterns. They also listed the advantages of using the heart rate technique instead of cortical measurement. The advantages include "it is technically simpler, electrode placement is not so critical, a superior signal to noise ratio exists, and fewer stimulus presentations were needed to obtain a response. The heart rate procedure was less time consuming, more reliable, and less expensive to perform" (p. 175).

As can be seen from the information presented, there are viable methods of determining the hearing acuity of an infant. These include both objective and behavioral methods. Although some of them lead to inconclusive results, others can be used to cross check the accuracy of other audiological tests done. Also, from the information presented, it should be clearly evident that early identification is of paramount importance in order to prevent unnecessary delays in a child's ability to

communicate and interact with his or her world. Specific strategies have been recommended to accomplish this goal. Screening of infants in the hospital setting is a start toward increasing a child's chance to develop as normally as possible. Further research is underway to find more accurate means of testing the neonate's hearing acuity.

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