

EARLY DETECTION METHODS OF HEARING IMPAIRMENT IN INFANCY

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Abstract

Early detection of hearing loss is considered to be very important for the development of hearing impaired infants. Several audiometrical methods can be used to detect hearing loss as early as possible. The aim of this paper is to give an overview of the most commonly used early detection methods.

1 Introduction

This paper is written within the scope of the research project 'The development of vocalisations of severely hearing impaired infants', supported by the Institute of the Deaf St. Michielsgestel and the Institute for Functional Research of Language and Language Use at the University of Amsterdam. The aim of this research project is to determine the influence of lack of auditive input on the development of vocalisations in the early childhood. For that purpose, we are interested in early detection of hearing impairment. To establish the hearing level, several methods can be used, which will be discussed below.

Based on the location of the impairment, hearing loss can be divided into two main groups. The term 'conductive hearing impairment' is used for hearing losses due to conditions affecting the external or middle ear. The term 'sensorineural hearing impairment' is applied to hearing losses, due to conditions affecting the cochlea and the eighth nerve (the nervus acusticus) up to the brainstem (Bamford and Saunders, 1985).

The most frequently occurring conductive hearing loss is caused by acute or chronic inflammation of the middle ear (otitis media). Studies carried out on preschool children suggest that conductive loss due to otitis media is very common in children younger than two years of age, and probably occurs most frequently between six and ten months of age (Lowe et al., 1963; Task Force, 1978). Estimates have been made of a prevalence rate of up to 60 percent in the first year of life (Klein, 1978).

Sensorineural hearing loss occurs less frequently than conductive hearing problems. According to Martin (1982) the prevalence rate of a sensorineural hearing loss of 50 dB or more is approximately one infant in every thousand new-borns. McCormick et al. (1984) report prevalence rates of 0.7 per 1000 for normal births and 7 per 1000 for babies admitted to a neonatal intensive care unit. In The Netherlands approximately 90 deaf infants (with a hearing loss of at least 90 dB) are born every year and approximately ten children become deaf in the first two years of life (Ipso Facto Rapport, 1991; Martin, 1982).

It is important to detect the hearing impairment as early as possible, as it is assumed that early intervention is necessary for the infant's total development. One of the goals of early assessment is to stimulate the residual hearing capacity, with hearing training and hearing aids. In paedo-audiology the first year is known to be the critical period for developing several auditory functions. With a prelingual hearing impairment, the absence of auditory stimulation can lead to loss of the ability of using residual hearing capacity for analytic listening on a central level (i.e. in the brain). It is assumed that an atrophy of the analytic brain mechanism for speech might occur, if the residual hearing is not stimulated. This atrophy means shrinking of these parts of the brain mechanism, which is an almost irreversible process (Crul, 1986).

Also, the early habilitation of hearing aids is one of the main goals of early intervention. Early use of hearing aids apparently has a large positive influence on perception of sounds and speech (Hoekstra, 1986).

Another important goal of early detection is the possibility to help the parents with the education of, and the communication with, the child as early as possible. According to Hoekstra (1986) the co-operation of the parents will be better if treatment is started early.

The North American Guidelines proposed in 1982 by the Joint Committee on Infant Hearing recommend screening of infants-at-risk at three months of age and completion of the diagnosis and initiation of habilitation by the age of six months. However, the reality differs from these guidelines. The findings of Stein et al. (1983) in their study of American hearing impaired infants, indicates that only 11 % of the infants were enrolled in therapy by six months of age. The median age for enrolment in a parent-infant program is one and a half year of age. The *Ipsa Facto Rapport* of the diagnostic process (1991) shows no better situation for Dutch children. In the last ten years no improvement has been detected.

2 Early detection methods

Several audiometrical methods are available for detecting a hearing problem in the first year of life. These methods can be divided into two groups; behavioural audiometry versus objective audiometry. Often, behavioural audiometry is used as screening. An auditory screening method is a quick test with the aim to trace hearing impaired children. When hearing impairment is suspected, usually a more objective test will be applied to confirm (or not) the hearing loss and to establish the hearing threshold. Subjective screening can be used on healthy infants, for example in a health centre. As well, a screening method can be limited to infants in a neonatal intensive care unit because of the higher risk of hearing loss.

2.1 Behavioural audiometry

Behavioural audiometry during the first months of life is based on behavioural responses to loud noises of normal hearing infants. For instance, the audropalpebral reflex (APR) implies a quick closing of the eyes or a tightening of the already closed lids at noises of approximately 90 dB. Also, arousal from sleep can be expected at noises of approximately 75 dB. After the first months these responses may be inhibited (Commission of the European Communities, 1990).

From the age of three to four months, rudimentary localisation responses to relative loud sounds can be observed. The term 'localisation response' means that the child looks for the place where the noise is coming from, by turning its head. At 9 to 13 months a direct localisation of sounds at 25 - 35 dB is possible (Northern & Downs,

1984). The test method based on this response is called the Ewing test (Ewing & Ewing, 1944). During the test the child sits on its parent's lap and its visual attention is attracted by a person in front of him or her, while another person produces sound stimuli behind the child. In The Netherlands a new test based on the Ewing test has been developed: the Compact Amsterdam Paedo Audiometric Screening Test (CAPAS). In this screening method digital sound stimuli and a microprocessor control of the test-protocol are used. The advantage of this method is an exact frequency and intensity definition of the stimuli which results in higher objectivity (Baart de la Faille, 1990).

Another method is the use of lists of criteria, the so called high-risk registers. These registers can be used for the detection of infants with a higher risk of hearing impairment, based on factors like low birth weight and low Apgar score. Riko et al. (1985) indicate that the high-risk register is a valuable, but imperfect, primary screening tool that should not be the sole early detection method. Feinmesser et al. (1982) describe a screening method used in Jerusalem, which combines hearing tests and a set of high-risk criteria. This study indicates that most of the children suffering from severe to profound hearing loss were detected before the age of one.

To provide a more objective procedure, the Crib-O-Gram is developed. The Crib-O-Gram is an automatic device that measures the movements of a neonate after exposure to a loud sound. Motion sensitive transducers, placed under the mattress in the crib, pick up the infant's activity. Fixed quantitative criteria are used to establish the presence of a response (Simmons & Russ, 1974; MacFarland et al., 1980). The detection rate of the Crib-O-Gram is 100 % in a well baby nursery and 91 % in a intensive care unit. One of the disadvantages is the high amount of false positives (i.e. the false detection of a hearing loss): 7% in a "well baby nursery" and 15 % in an intensive care unit (MacFarland et al., 1980).

2.2 Objective audiometry

Objective audiometry does not assume any active cooperation of the infant or its parents. The most frequently applied types of electric response audiometry are the Auditory Brainstem Response (ABR) and the ElectroCochleoGraphy (ECoG). These methods measure electric potentials.

2.2.1 ABR

In The Netherlands the most frequently applied electric reponse test is the ABR. To establish the hearing loss, electrodes are placed on the mastoid (the bone behind the auricle) and on the forehead of the infant, to measure electric potential activity between these points. The stimulus presented usually is a click. Beside potential activity, the latency time is measured, which means the time between stimulus and response. In normal ears, five response peaks on different latency times can be distinguished, descending from different places in the brain. The strongest peak is the fifth, which is descending from the brainstem. To establish the hearing threshold, clicks are presented on several intensity levels. The threshold is defined as the lowest stimulus intensity where peaks, especially the fifth, can be found (Rodenburg, 1984).

The ABR is relatively easy and quick to perform, because it requires no general anaesthesia. Especially for the infant below six months of age, it can easily be performed when it sleeps.

According to Hyde et al. (1984), the ABR can play an important role in clinical programs for early detection and quantification of hearing loss. In Canada, Durieux-Smith et al. (1991) have studied the prognostic validity of the ABR. For this purpose,

ABR results in infants of a neonatal intensive care unit are compared to pure-tone audiometry at three years of age. Of the ABR results, 89 % accurately predicted the hearing status at the age of three.

Some disadvantages can be mentioned. The usual stimulus is a click; this implies a limitation of the ABR. A click stimulus contains broad spectral information and does not provide frequency-specific measurements. The ABR responses correlate most closely with frequencies around the 2 kHz area, so high or low frequency hearing loss can be missed (Riko et al., 1985). This may explain the high amount of false negatives (14 %) in the study of Durieux-Smith et al (1991). If frequency-specific information is necessary for habilitation of hearing aids, another test must be added.

2.2.2 ECoG

The ECoG can provide frequency specific information, because of the use of tone pulses. An electrode is placed on the cochlea by a long needle, stuck through the tympanic membrane. The potential is relatively high, because the electrode is placed closely to the generator of the sound (a headphone) (Rodenburg, 1984). The higher potential makes the measurements of separate frequencies possible. Compared to the ABR, the ECoG is more invasive, because the infant requires general anaesthesia.

2.2.3 EOAE

The OtoAcoustic Emissions (OAE), first described by Kemp (1978), are generated by the motile activity of the unimpaired outer hair cells. An ear with a hearing loss exceeding 15-40 dB shows no OAE according to Kemp. Evoked OAE (opposed to spontaneous OAE) can be divided into four subclasses: emission with clicks (click evoked: CEOAE), emission with short pure tone pulses (transient evoked: TEOAE), emission with uninterrupted pure tones (stimulus-frequency evoked: SFOAE) and distortion product otoacoustic emission (DPOAE). The last category uses simultaneously applied two-tone stimuli. These two-tone stimuli (f_1 & f_2 , where f_2 is the higher frequency) evoke a third tone at a lower frequency ($2f_1 - f_2$) which, after amplification and spectral analysis, can be measured.

The use of click evoked OAE is evaluated in the last couple of years and the results are promising. For example, Stevens et al. (1990) have tested 723 neonates admitted to an intensive care unit by using EOAE and ABR. The ratio EOAE results / ABR results gives a sensitivity of 93 %; 29 infants failed the ABR and 27 of them also failed the EOAE test. The percentage infants that passed both tests (the selectivity) was 84 %. The mean test time was 12 minutes. Bonfils et al. (1988, 1990) have compared results obtained with EOAE with those of behavioural audiometry in 100 ears of infants. The false positive rate was lower than 2 %. These results suggest that the EOAE screening method might be considered as the primary screening method (Stevens et al., 1990). The disadvantage is the non-frequency specificity, caused by the use of clicks. Because of the use of continuous stimuli the DPOAE method has the ability to be frequency specific and is probably the most promising screening method at this moment (Lonsbury-Martin & Martin, 1990).

3 Conclusions and discussion

This paper gives an overview of the most common audiometry methods for early identification of hearing impairment. It appears that every method has its own advantages and disadvantages.

Table 1. Overview of the most common audiometry methods for early detection of hearing impairment.

Method	Main advantage	Main disadvantage
<i>Behavioural audiometry</i>		
<i>Observation during first months</i>	Easily applicable	Only high losses, moderate reliability
<i>Ewing</i>	Easily applicable	Only reliable from 9 to 13 months
<i>CAPAS</i>	Exact frequency & intensity of the stimuli is controlled	Only reliable from 9 to 13 months
<i>Crib-O-Gram</i>	High detection rate	High amount of false positives
<i>Objective audiometry</i>		
<i>ABR</i>	Reliable	No frequency-specific information
<i>ECoG</i>	Frequency-specific information,	General anaesthesia is necessary
<i>CEOAE</i>	Easily and quickly applicable, reliable	No frequency-specific information
<i>DPOAE</i>	Easily applicable, frequency-specific information	The reliability is not completely known yet (however promising)

Most authors (e.g. Bonfils et al., 1990; Feinmessenger et al. (1982)) suggest, that the best solution is a combination of several methods. An example of such a combined procedure is performed in the Academic Hospital Leiden (AZL). If hearing impairment is suspected by either the Ewing test, family history, or anxiety of the parents, a (second) behavioural test is applied. If the child fails this test, ABR and / or ECoG is used to confirm the hearing impairment and to establish the threshold. The suitability of the DPOAE test for early detection is studied at the AZL at present.

The most frequently used procedure may be influenced by the specific situation in a country. In The Netherlands many infants are born at home. This makes screening methods on new-borns difficult to apply. Most infants visit a health centre in the first year of life, where the Ewing test (or the CAPAS) is applied from 9 months of age onwards. If the infant failed the Ewing, two retests are performed before the child is sent to the family doctor. By the time the family doctor refers the child to a medical specialist, it may be one year of age. It is obvious that this does not approach the ideal situation as suggested by the North American Guidelines (Joint Committee on Infant Hearing, 1982). Recently developed early detection methods may lead to a solution of this problem in the near future.

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