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Introduction

During the first year of life a child has hearing abilities which, if activated sufficiently, play a decisive role in determining speech development. Auditory deprivation during this time diminishes these abilities and obstructs speech development and there is evidence to suggest that this process is irreversible (Ross, 1990).

For a congenital hearing-impaired child, stimulation of the residual hearing could form the basis for the development of auditory skills that will permit subsequent speech development (Fry, 1966; Wally et al., 1981; Eimas, 1982; Lindblom et al., 1986). The essential starting point in the management of hearing loss is early detection, fitting hearing aids and the participation in an appropriate rehabilitation programme. In this paper a general fitting procedure for very young children is presented and some technical aspects of hearing aids are discussed as far as they are of importance with regard to subjects with large hearing loss.

Fitting hearing aids should be focused on optimal speech recognition, even in children with very severe or profound hearing loss. When the MTS test (Erber et al., 1976) is used, it is possible for each child to optimize the gain and frequency response that gives the best possible prospects for speech recognition. Nevertheless, the abilities for speech perception may be limited (Vermeulen et al., 1995) and the effects of auditory training will be strongly affected by the hearing loss itself (van den Borne et al.). Indications are given about the possibilities and limitations in the use of conventional hearing aids in children with severe hearing loss.

Fitting Procedure for Young Children

As soon as hearing loss is detected, the procedure for fitting hearing aids is started. In general, there is no precise information available at that moment about the hearing loss and about the in situ characteristics of the hearing aids. With the help of a diagnostic loop in which stimulation of hearing, speech and language development as well as general behavioural observations play a part, it gradually becomes clear how a child is performing and whether or not readjustments of the hearing aids should be made (Fig. 1).

For the most part, the initial data about a possible hearing loss are limited because of the child's age. Usually one has to start with the responses obtained through behavioural observation audiometry. In most cases, especially when the hearing loss does not exceed 90-100 dBHL in the frequency range 2-4 kHz, brainstem evoked response audiometry (BERA) can be used to confirm the results of the observation audiometry.

The responses one gets through observation audiometry with very young children, and multi-handicapped or seriously deprived children, can be achieved at sound
levels substantially above the real auditory thresholds (McConnel et al., 1967). This is one of the uncertainties in the diagnostic data when fitting hearing aids in very young children.

Another aspect is deviation of the frequency responses of the hearing aids due to the small volumes of the child’s ear canals. It is common practice to make an initial selection of hearing aids based on technical information sheets referring to the 2 cc or IEC 711 Ear Simulator coupler. The dimensions of both couplers are based on adult ears, i.e. the volume of the ear canal. For children, this volume may be as little as 0.5 cc compared with about 2 cc in adults. As a consequence, for young children, insertion gain measurements may indicate a deviation with regard to the IEC 711 ear simulator data up to about +12 dB for the gain and the maximum output (Fig. 2). The deviation with regard to the 2 cc coupler is even larger.

These examples of uncertainties in diagnostic and technical data emphasize the need for incorporating diagnostics within a rehabilitation programme.

**Preselection of Hearing Aids**

Generally for severe hearing loss, body-type and behind-the-ear hearing aids (BTE) are applied. As a result of the technological improvements in BTEs, especially in terms of flexibility and maximum output levels, binaural amplification is possible in nearly all cases. Body-worn hearing aids can be considered in special cases, as for example in children with limited residual hearing or in combination with mental deprivation. Binaural hearing aids have several advantages, including binaural summation, elimination of the head shadow and binaural squelch, which can improve speech recognition (Mueller and Hawkins, 1990). Other important advantages that can be observed in young children are increased auditory localization abilities, spatial balance and ease of listening.
Saturated Sound Pressure Level

Selection of the maximum output or saturated sound pressure level (SSPL) needs special attention in young children as well as in children with large hearing loss. Typically, the audiologist adjusts the hearing aid output control so that the SSPL does not exceed the child’s loudness discomfort level. However, in the case of very limited residual hearing, the SSPL has to be high enough to provide adequate amplification without exceeding the saturation level frequently. On the other hand, one runs the risk of over-amplification. As already mentioned, for young children one has to be aware that the technical hearing aid specifications are reported relative to a 2 cc or 711 ear simulator. A hearing instrument with a maximum output of 130 dB SPL measured in a 2.0 cc coupler could create 142 dB SPL in an ear with 0.5 cc space between the tip of the earmold and the eardrum.

Gain

Since youngsters often cannot verbalize the perceived sound quality, selection of the appropriate gain to their hearing aids is difficult, and so a diagnostic loop in the fitting procedure is necessary. The use of prescriptive formulae may help to determine the target gain requirements relative to the patient’s auditory thresholds. There are several different prescriptive rules, but none of them provides the precise prediction of appropriate hearing aid performance (Snik et al., 1995). For an estimation of desired sensation levels, only the DSL prescriptive rule is available (Seewald, 1992). This method also takes into account the age-related differences in ear volume.

Another way to establish gain and output is to optimize speech recognition. The Monosyllable-Trochee-Spondee (MTS) test as described by Erber et al. (1976) might be of help in finding a gain and frequency response that is optimal for speech recognition. In a recent study of children with severe hearing loss in the range 70 to 120 dB (average hearing loss at 0.5, 1 and 2 kHz, called PTA) we determined optimal gain and frequency response using the MTS test. In this way it became clear that for children with severe hearing loss, most prescriptive rules underestimate...
the gain in the low frequencies. Compared with for instance the NAL rule (very popular in Europe), it became clear that for hearing loss exceeding 85 dB, the calculated gain was not sufficient for optimal speech recognition. The MTS test optimized gain is compared with the calculated NAL gain in Fig. 3. The need for an emphasized gain for this range of hearing loss occurs mainly in the 500 Hz region (Fig. 4) and less pronounced in the 1 KHz and 2 KHz regions (Fig. 5 and Fig. 6).

It was concluded that compared to the NAL prescription values, the gain at the frequency of 500 Hz has to be increased by an additional 9 dB when the hearing loss is in the range 85 to 105 dB PTA. For hearing loss greater than 105 dB, an additional gain of about 13 dB is on average the most optimal. In fact, the POGO rule gives the best estimate for the low frequencies in this range of hearing loss. This is not the case at frequencies 1 and 2 KHz, however, where the NAL rule gives a better estimate.

In children with severe or profound hearing loss, it is clear that amplification in the low frequency region is of great importance (Dyrlund, 1988; Von Wedel and Von Wedel, 1993). Byrne et al. (1990), too, proposed modifications to the NAL rule with an increase in the overall gain of about 10 dB and a decrease in the low frequency slope by 4 to 8 dB/octave for thresholds greater than 95 dB. This is in fair agreement with the presented results.

Nevertheless, prescription methods cannot take the place of behavioural evaluations by an experienced staff. This is clearly demonstrated by the large variations in the gain (Figs. 3–6). In preverbal profoundly deaf children, a fitting procedure as described before is of great importance.

Limitations of Conventional Hearing Aids

The benefits derived from hearing aids in terms of speech perception are a function of the hearing loss itself. For mild or moderate hearing loss it is clear that the use of hearing aids presupposes in general a good speech perception ability. For profound hearing loss without residual hearing, there will be no speech perception with hearing aids at all. Only the use of tactile sensory aids or cochlear implants may give support.

With the help of the MTS test, Vermeulen et al. (1995) demonstrated that with hearing aids the correct score on a segmental or supra-segmental level is an obvious function of the PTA. They collected data from severe and profoundly deaf children at an institute for the deaf using an oral approach, those at a school for hearing-impaired children and those in mainstreamed settings. From the scatterplot on the segmental score of the MTS test as a function of the PTA, it becomes evident that for a hearing loss less than about 90 dB there are good prospects for speech perception (Fig. 7). For a hearing loss exceeding about 110 dB there are hardly any possibilities for adequate speech perception with hearing aids. In the PTA interval from 90 to 110 dB, however, a large deviation in speech perception abilities is found. This means that there are children in that interval with adequate speech perception abilities as well as children without.

With respect to this large deviation the question about the effects of auditory training arises. It is of interest whether or not any positive effect of auditory training can be expected in particular for the children with low scores. Van den Borne et al. performed a study on the assessment of basal sound identification skills in preverbal profoundly deaf children with hearing aids or with cochlear implants. Part of their study was the effect of the training period on basal sound identification abilities. The basal sound identification test they used is a test on a symbolic non-verbal level. A number of tape-recorded everyday sounds differing in spectral and temporal characteristics were presented to the children. The test was scored in five levels as follows: Level 0 = no consistent identification; level 1 = 100% score in a 2 AFC set-up; level 2 = 100% score in a 3 AFC set-up; level 3 = at least 75% score in a 4 AFC set-up, and level 4 = at least 80% score in a 5 AFC set-up.

The children in Van den Borne et al.'s study were divided into three groups. A group of hearing aid users with PTA between 90 and 110 dB, a group with PTA exceeding 110 dB and a group of children with a cochlear implant and PTA exceeding 120 dB HL. The
results over time (Fig. 8) suggest that the children with PTA exceeding 110 dB with conventional hearing aids show no improvements at the sound identification test. This is in contrast to the hearing aid users with PTA between 90 and 110 dB and with the cochlear implant users.

Discussion and Conclusion

The procedure for fitting hearing aids in very young children involves a process of diagnostics and an appropriate rehabilitation programme. Because of limited initial data about the hearing loss of the children and the difficulties in getting an optimal prescription, every fitting has to incorporate a procedure verifying or validating the final fitting. Diagnostic observations and the ongoing rehabilitation programme can be used to obtain information regarding the child's hearing impairment and the effect of the hearing aids.

Especially in the case of children with severe or profound hearing loss, one has to ensure that the maximum output of the hearing aid allows optimal usage of the residual hearing. Also one has to be aware that most children with severe or profound hearing impairment require relatively more amplification in the low frequencies than would be appropriate for less impaired children with a similar audiogram configuration.

The ability to develop speech recognition is strongly affected by the hearing loss itself. The scores on the MTS test as a function of the PTA indicate limited speech perception ability for hearing loss exceeding 110 dB PTA. For children with similar hearing loss, the basal sound identification test shows no improvement over time. These findings should be interpreted with caution because in practice there is only a limited transfer between perception abilities for speech and non-speech sounds. There are also substantial deviations between the individual scores. Nevertheless, the data suggest that for most of the children with PTA exceeding 110 dB, speech recognition with hearing aids alone is almost impossible, but plays a supporting role in lipreading.

References


Ross M. Implications of delay in detection and management of deafness. The Volta Review 1990; 69–79.


