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Clinical Records

An improvement in hearing sensitivity following hearing-aid fitting in a child with an apparent sensorineural hearing impairment

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Abstract
This case describes an apparent improvement in hearing sensitivity in a young girl over a period of 12 months, after she was fitted with binaural hearing-aids. Discrepancies between objective and subjective test results are highlighted. Even if the underlying reason for the conflicting test results was due to poor listening skills or test error, this child behaved like a hearing-impaired child and her performance improved after hearing-aid use. The case also illustrates the application of earphone testing from six months of age. The importance of closely monitoring all children who are fitted with hearing-aids is highlighted.

Key words: Hearing loss; Hearing aids

Case history

A six-month-old girl was referred for hearing assessment in June 1991 due to parental concern from two months of age that she was generally unresponsive to sounds. However, it was reported that the girl responded to hand clapping, banging a drum, possibly her father's voice, and that she was also very visually alert. The mother had contracted German measles during the second trimester, otherwise, birth was normal and no concern was expressed about the girl's development by the parents or the referring senior community medical officer. The patient's general health was considered good and in particular, there was no report of URTI, otalgia or otorrhoea. There was a two and a half-year-old brother with normal hearing. It was reported that the maternal grandmother had undergone middle ear surgery. There was also a 21-year-old maternal aunt who was reported as having an apparent hearing loss although she has not sought help or advice. No abnormalities were detected on otoscopy.

The patient underwent comprehensive hearing assessment which consisted of both behavioural and objective tests. The traditional distraction test resulted in reliable results with good sound localization suggesting no significant asymmetry between the ears at the frequency tested. When there is an asymmetry present, the subject will turn to the side with the better hearing ear and this response bias is noted on the clinic worksheet. Past experience suggests that a response bias, particularly at high frequencies where localization skills are best due to the head shadow effect, is usually confirmed by auditory brain stem response (ABR) even when the asymmetry is as little as 10–15 dB. The minimum response levels obtained using frequency modulated tones (warbles) and the Manchester high frequency rattle revealed an apparent mild to moderate hearing loss with responses around 45 dB (A) at low frequencies and 65 dB (A) at high frequencies. The normal screening level is around 30 dB (A) across the frequency range. This is sufficient to be audible above the ambient noise level in the test room but should fail the cases where the hearing impairment may be sufficient to delay normal speech and language development. Tympanometry revealed normal middle ear function. It was concluded that the results were consistent with the parents' concern and that they revealed a bilateral hearing impairment which was probably sensorineural in origin. However, since the child fell asleep it was decided to carry out threshold estimation using auditory brainstem response (ABR) audiometry. The ABR threshold, using a broadband click stimulus, was judged to be 70 dB nHL on the right side and better than 30 dB nHL on the left side. (0 dB nHL is the behavioural threshold for the click stimulus in a normal adult population). The result from the right ear is consistent with the behavioural test but it now appeared that there was an asymmetry of greater than 40 dB, at least in the high frequency region with which the ABR click stimulus is best correlated.

The child returned one week later for repeat assessment. On this occasion, visual reinforcement audiometry (VRA) was used in preference to distraction testing although both techniques operate on similar principles. The essence of VRA is to reinforce an observable behavioural response (usually head turn) to frequency specific stimuli with a visual reward. The visual reward used in our clinic is an animated toy such as a rabbit which

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FIG. 1
Child being tested using VRA with insert earphones.

raises its ears and twitches its nose. This complex visual reward is a stronger reinforcer than the social praise used in distraction testing and will result in a greater number of head turns. This method of signal detection can be used in the six to 30 months age range. It has the advantage over conventional distraction testing since the stronger reward means that it is not always necessary to have a member of staff controlling the child's attention from in front. It can also be used in conjunction with headphones/insert earphones which allows each ear to be tested separately and to check for any asymmetry in hearing level. The test set-up for this procedure is illustrated in Figure 1. Conventional TDH 39 headphones are not easily retained on a baby's head but insert earphones can be held in place with an elastic headband. Responses were obtained at around 40 dB HL for low frequencies and 60 dB HL for high frequencies for each ear when tested separately using insert earphones. The insert earphones were calibrated for use with adult ear canals so it is possible that the sound pressure level generated in the smaller ear canal of the child was higher than that reported. As such, the degree of hearing impairment may be 5 dB or so greater than indicated. These findings are consistent with the previous behavioural test results but disagree with the asymmetry reported on ABR. Once again, tympanometry revealed results within normal limits. ABR testing was also repeated and this time repeatable responses were clearly visible at a screening level of 30 dB nHL bilaterally. The click ABR traces are shown in Figure 2. The filter settings and rapid click rate required for ABR threshold estimation tend to emphasize wave V at the expense of the earlier waves. In fact, the SN10 component that follows wave V is the dominant feature. These traces do not have the high resolution that is achieved with the recording parameters used in diagnostic ABR application. However, they are not atypical of the quality obtained for threshold assessment. The responses from each ear are very similar providing added confidence in the interpretation of the results. The latencies for wave V are around 6 ms which is within our normal range.

Although there was a discrepancy between the test results, the parents were adamant that the patient was hearing-impaired. It was decided to provide the girl with medium power, medium gain postaural hearing-aids binaurally and to monitor her closely. The hearing-aids were fitted within a month of the initial visit and the child was reviewed on a regular basis from one month post-fitting. Family support was offered by the peripatetic education staff but this was resisted by the parents.

There was no difficulty in getting the child to tolerate the hearing-aids and these are worn for most of the day. The parents have been delighted with the improvement in her responses to sound and in particular she is generally described as being more alert when the hearing-aids are being worn. Table I summarizes the results of the behavioural hearing tests which were carried out both before, and after, hearing-aid fitting. All results are for

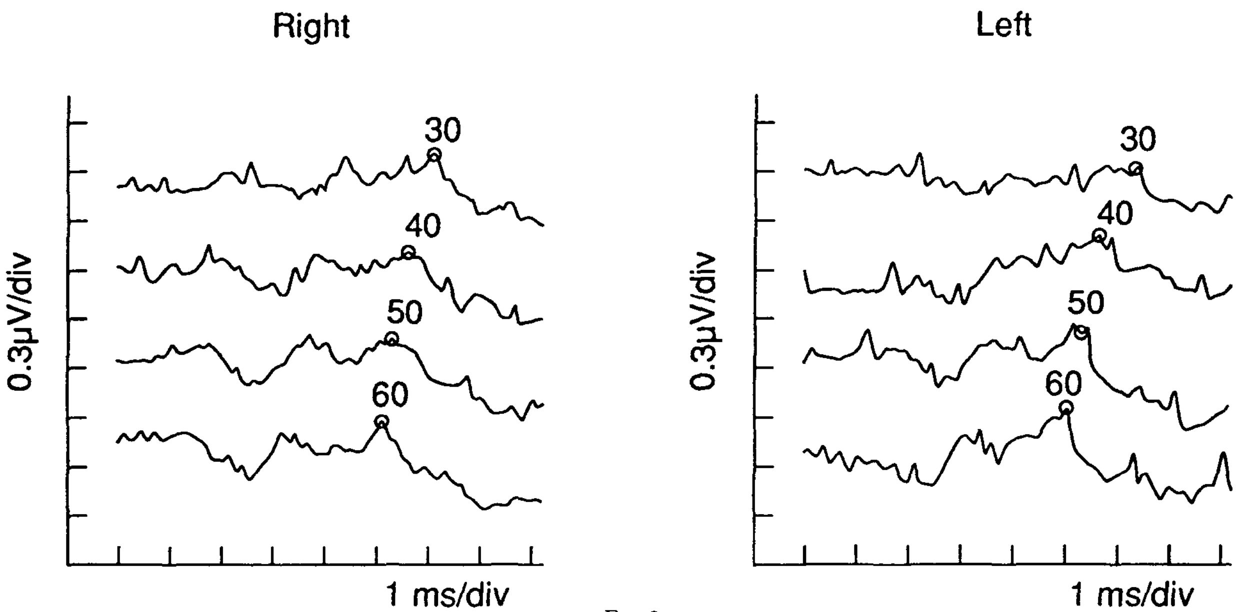

FIG. 2
ABR waveforms using a broadband click stimulus for different levels of signal presentation. Wave V has been indicated as has the stimulus level (dB nHL).

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TABLE I
SUMMARY OF BEHAVIOURAL TEST RESULTS. (THE RESULTS FROM SEPT 1991 (INC) ARE POST-HEARING-AID FITTING).

	500	1000	2000	4000	Hz
June 1991	45	45	nt	65	dB (A)
July 1991 R/L	40/40	nt	60/nt	60/60	dB HL
Sept 1991	55	40	50	60	dB (A)
Feb 1992	40	35	nt	40	dB (A)
Oct 1992	30	nt	nt	35	dB (A)
Oct 1992 R/L	nt	nt	nt	25/20	dB HL

VRA, except the occasion when the distraction test was used. In July 1991 and again in October 1992, insert earphones were used to test each ear separately. It should be noted that the soundfield results could be binaural and are measured in dB(A). However, since any errors of a few decibels will be in opposite directions (and hence cancel) this is probably not clinically significant. (A useful summary concerning the application of decibel scales in clinical audiology is given by Beynon, 1993). It can be seen from Table I that there is an improvement in the response levels, so that by the time the patient was reassessed with insert earphones in October 1992, the results were generally within normal limits. It is interesting to note that the hearing assessment in September 1991 and February 1992 was repeated with the hearing-aids *in situ* and that the results were recorded at around 30 dB(A) across the frequency range. This demonstrates that the minimum levels she would respond to were improved when wearing the hearing-aids. The child's aided responses could be even better than this but were possibly masked by the internal noise of the hearing-aid or by the ambient noise level in the test room which was around 30 dB(A). These aided results support the parents' view that the hearing-aids were providing obvious and measurable benefit. The family left the area around the beginning of 1993 when the girl was two years of age. At that time she enjoyed playing with toys and was able to bring a chair to a small table and sit herself down. She was able to understand simple instructions such as 'show me the duck' and joined in nursery rhymes.

Discussion

The early behavioural test results support the parents concern that this girl had a bilateral hearing loss. Numerous workers have demonstrated that parents' observations of their babies reactions to sound are generally very reliable indicators of the presence of hearing disorders (Latham and Haggard, 1980; Lilholdt *et al.*, 1980; Hitchings and Haggard, 1983). Wilson and Thompson (1984) have cited several authors who have shown that VRA warble tone soundfield responses for infants are within 10 dB of adult threshold values. There are fewer studies with hearing-impaired children who often exhibit poor listening skills, poor auditory attention and poor localization ability. The definition of threshold for such cases may be more problematic, although it appears that provided adequate time is allowed for suitable conditioning, VRA is just as successful with hearing-impaired children as with normal hearing subjects (Bamford and McSporran, 1994). The lack of evidence supporting a conductive hearing loss and the lack of developmental delay which could have influenced the test results, support the initial conclusions that this girl had a moderate, bilateral, high frequency, sensorineural hearing impairment. However, sensorineural hearing impairment observed behaviourally, may be a manifestation of a central auditory processing disorder or merely poor listening skills. What is a little unusual is that the parents were concerned from two months of age when the initial behavioural results were around 50 dB.

There are several important yet puzzling points to this case:

(1) The discrepancy between the successive ABR from the right ear;
(2) The discrepancy between the ABR and the behavioural tests;
(3) The general improvement in an apparent behaviourally observed sensorineural hearing impairment over a period of 12 months following hearing-aid fitting.

It is difficult to explain all of the above points. It is possible that the apparent discrepancy in the successive ABR traces was due to operator error and that no real change in the ABR thresholds occurred. Since the apparent changes occurred within one week this would seem an obvious explanation. The identification of a response in the averaged waveform is one of the most difficult tasks in ABR testing and is a potential source of gross error. The ABR results have been checked, but no errors could be found. Furthermore, unless the error is due to noise being wrongly interpreted as a response (by several reviewers), this would not explain why the ABR results were significantly better than the repeatable behavioural results which supported the parents' concern. Another explanation is that the ABR waveforms are correct and show an improvement as a result of auditory pathway maturation. The ABR waveform is affected systematically by maturation of the peripheral and brainstem pathways. However, this would not normally present as a difficulty in a normally developing six-month baby born at full term when the wave V should be clear and repeatable with a latency approaching adult values. The latency of wave V is usually within 0.5 ms of the adult values by around six months of age (Mason, 1994). Usually the ABR threshold is within 10 dB of the behavioural threshold (Mason, 1985) although this could be higher in children who do not necessarily respond at threshold level. It is known that during the early months of life, behavioural thresholds do not match physiological thresholds. It is not clear why this should be more marked at the high frequencies as in this case. However, the repeatability of the behavioural results prior to hearing-aid fitting and the subsequent improvement in aided results suggests that this is an unlikely explanation for the present case.

There are differences in the frequency content of the behavioural stimuli and the ABR click although most of the click ABR response correlates with the 2–4 kHz behavioural threshold (Coats and Martin, 1977). There have been many reports in the literature about the 'effectiveness' of test sounds for behavioural hearing tests in children. The primary stimuli used in this clinic are frequency modulated tones (warbles). These generally overcome the problems of standing waves which occur with pure tones in a soundfield environment. The traditional stimuli for testing children in the developmental age range of six to 18 months was to use frequency-specific voice sounds. McCormick carried out a questionnaire study in 1986 comparing responses to warbles and other test sounds. He found that 75 per cent of respondents reported that babies were just as or more responsive to warbles compared with other sounds.

An alternative explanation might be that the behavioural test assesses the whole auditory system including peripheral detection and central processing whereas the ABR provides information about neural pathways up to brainstem level. This raises the possibility that the girl has a problem at a higher level which accounted for both the initial high frequency hearing loss (which alerted the parents) and the improvement after using the hearing-aids. As far as we are aware, there are no reports of this in the literature although a small number of children have been seen in our clinic with an apparent improvement in sensorineural hearing levels after hearing-aid fitting (Cafarelli Dees and Munro, 1995). Again, an organic central auditory processing disorder is thought to be unlikely as the child's unaided responses improved with time and/or with amplification, and there were not any other developmental delays. It is also impossible to know if the apparent improvement would have occurred without hearing-aid fitting although anecdotal evidence supports the notion that hearing-aids can be used in children with mild learning disability to help focus their attention better. However, these cases have not demonstrated any carry-over when the hearing-aids are not worn, as in this case.

There are reports in the literature of 'sensory overloading'. Northern and Downs (1991) have cited several studies (Deutsch, 1964; Clark and Richards, 1966; Goldman and Saunders, 1969; Nober, 1973) which have apparently shown that children raised in noisy environments do not respond in competing noise environments as well as their peers from quiet homes. It is not clear if this could be an explanation for this girls' results especially since concern was raised by the parents at such a young age. In any case, the hearing tests were not carried out in a noisy environment.

For whatever reasons, this case highlights important differences between behavioural tests and ABR. The implications for management are important and the need for closely monitoring all children who are fitted with hearing-aids is stressed. Even if the underlying reason for the conflicting test results was due to poor listening skills or even test error, this child behaved like a hearing-impaired child and her performance improved after hearing-aid use. There are other reasons why regular follow-up is required such as increasing the limited test information that is available due to the child's age, the high incidence of fluctuating middle ear disease (Haggard and Hughes, 1991) and the high occurrence with which hearing-aids are found to be faulty at paediatric hearing-aid review clinics (Munro and Martin, 1991). This case also illustrates the application of earphone testing in infant behavioural hearing assessments when VRA facilities are available.

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