The application of Cortical Auditory Evoked Potential (CAEP) recordings in infant hearing aid fitting

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With the advent of new-born screening, methods are required for routinely evaluating the effectiveness and appropriateness of hearing aids fitted to infants only a few months old. The ability of a hearing aid to amplify speech to a sensation level high enough to be easily perceived can be directly tested by measuring the cortical potentials evoked by speech sounds. The sounds are presented via a loudspeaker at conversational levels while the infant wears hearing aids. Research at NAL has focused on the speech sounds /m/, /g/ and /t/, selected for their spectral emphasis in the low, mid and high-frequency regions respectively. Measurements on the cortical responses of babies with normal hearing has shown that cortical responses to these sounds can always be detected, provided the babies are awake, alert and not too physically active. Averaging of responses for one to two minutes, for stimuli presented once per second, is usually required. For clinical purposes, responses can be recorded with a single active electrode on the vertex, a reference electrode on either mastoid, and a ground electrode on the forehead.

The shape of cortical responses varies markedly with age: whereas adult cortical responses usually exhibit the well-known P1-N1-P2 response, with the three peaks at approximately 60, 100, and 180 ms after stimulus onset, infants exhibit a single positive peak centred about 200 ms after stimulus onset, and often a late negativity about 400 ms after stimulus onset. Latency of the positive peak decreases markedly within the first year of life, provided the child has had adequate exposure to sound during this period. Children who do not receive adequate stimulation with sound until many months or a few years after birth have latencies immediately after cochlear implantation closer to that of new-born babies (*Ponton* et al., 1996; *Sharma* et al., 2002). Latency decreases towards normal in the months and years following stimulation, so the latency of the cortical response provides a useful indicator of the stage of development of the auditory processing system. Latency does not decrease to normal values if the child first receives adequate stimulation after seven years of age, and may not decrease to normal if the first stimulation is after 3.5 years of age (*Sharma* et al., 2002).

The detailed shape and magnitude of the cortical response also varies from person to person, and from time to time within the same person, depending on the alertness or drowsiness of the person. This variation can make the identification of cortical responses more challenging than identifying the well-ordered peaks and troughs of an auditory brainstem response. To assist clinicians use cortical evaluation with infants, a statistical detection technique, based on the *Hotellings*-T^2 statistic, has been developed. Because the statistical technique has not been based on any *a priori* assumption about response shape, it is equally applicable to adult or infant responses. For both groups of people, the technique has been shown to be at least as accurate as expert human electrophysiologists in differentiating genuine cortical responses from random noise arising from other brain activity, muscle activity, and external electrical interference (*Golding* et al., unpubl.).

The recruitment that invariably accompanies sensorineural hearing loss helps make cortical evaluation possible within a time that is feasible within the clinic. The magnitude of the response increases with sensation level, rapidly so for people with hearing loss. The response magnitude for stimuli 10 dB above behavioural threshold for people with sensorineural loss is greater than for stimuli 30 dB above behavioural threshold for people with normal hearing. The detectability of cortical responses (i.e. distinguishing it from background electrical noise) varies directly with the magnitude of the response. Consequently, the responses arising from stimuli only 10 dB above threshold are readily detected for people with sensorineural loss. The other factor affecting detectability is residual noise in the averaged response, which is determined by the level of noise in each epoch and the number of epochs averaged to form the grand response. For proper clinical use of the cortical response, it is vital that the clinician be informed of the residual noise. With this knowledge, the clinician (or the test instrument) can determine whether a missing response is caused by the infant not perceiving the sound, or by the averaged waveform being excessively noisy.

The presence of cortical responses evoked by speech sounds at typical conversational levels is correlated to how well the infants function in real life, as subjectively rated by the child's parents (*Golding* et al., 2007). This should not be surprising as perception of speech is needed for good auditory functioning, and perceptible speech evokes a measureable cortical response provided residual brain noise has been reduced to a suitably low value by averaging. Cortical evaluation should not really be necessary if hearing thresholds have been accurately estimated, the hearing aid prescribed using a well-validated procedure, and the hearing aid adjusted to match the prescription. However, measurement error or outright mistakes can occur at any stage of the process, and it is reassuring to clinicians and parents alike to see cortical responses emerging while the infant is listening to speech sounds at normal conversational levels. An absence of cortical responses when the infant is not wearing his or her hearing aids can also provide graphic evidence to the parents of the importance of wearing the hearing aids.

In those cases where there is no cortical response, despite a satisfactorily low residual noise, careful attention to the appropriateness of the hearing aid fitting is warranted. In some cases, infants will require cochlear implants instead of, or in addition to, a hearing aid. Recent results at NAL (*Ching* et al., unpubl.) show the critical importance of implantation before the age of twelve months. Cortical evaluation while the infant is still wearing hearing aids will provide some additional information that is relevant to the decision of whether or when to implant. An additional use for cortical evaluation is measuring a child or inform person's thresholds. The method complements auditory brainstem response because it is best performed on awake people.

References

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