Evoked potential assessment of children with severe/profound hearing loss: a comparison of steady-state evoked potential (SSEP) and behavioural hearing threshold levels in subjects with absent click evoked auditory brainstem responses (ABR)

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SUMMARY

Steady-state evoked potential testing offers a means of obtaining accurate, frequency specific estimates of hearing threshold in subjects with even severe to total hearing losses. As such, the technique can play an important role in the pre-operative evaluation of young cochlear implant candidates.
INTRODUCTION

Despite recent technical advances and promising clinical results, paediatric cochlear implantation is currently restricted to patients with bilateral profound sensorineural hearing loss. As one and two year old children are now being considered for this procedure, the need for an assessment technique that can provide objective estimates of hearing levels in this range has increased.

Auditory Brainstem Response (ABR) testing is currently the most widely used method for objective hearing level estimation in young children (Picton et al. 1994). This test, which involves the recording of electrophysiological responses from the auditory pathway, does however have two major shortcomings in the assessment of ears with severe to total hearing loss. Firstly, maximum presentation levels are limited. Successful recording of the ABR requires a brief input such as an acoustic click to generate a sufficiently synchronised response from the auditory system. The brevity of the click (100μs) does however mean that behavioural thresholds for this stimulus are typically found at levels around 36dBSPL (peak) in normally hearing subjects. As maximum output levels for most clinical ABR systems are approximately 130dBSPL (peak), click-ABR testing is therefore restricted to corrected presentation levels of 5100dBnHL.

The second major limitation of click-ABR testing lies in the broad frequency spectrum of the stimulus. As the click contains acoustic energy across a wide frequency range, it can be difficult to accurately determine which cochlear regions are contributing to the response. A certain degree of frequency specificity arises from the mechanical properties of the cochlea, resulting in click-ABR thresholds that correlate most strongly with hearing levels in the 1000 Hz to 4000 Hz frequency range (Stapells, 1989). This relationship is fortuitous in the identification of ears with hearing problems as it is the high frequency sensitivity that is typically most effected in cases of sensorineural loss. It does however mean that ears with only low frequency residual hearing (corner audiograms) are likely to show no ABR at maximum presentation levels, and be indistinguishable from an ears that are anausic (Brockhouwer et al. 1990).

Steady-State Evoked Potential (SSEP) testing has recently become available as an objective hearing test option for young children. SSEPs are periodic scalp potentials that arise in response to regularly varying stimuli such as sinusoidal amplitude and frequency modulated tones (Richards & Clark, 1984). These tones are continuous, and as such do not suffer either the spectral distortion, or presentation level problems associated with short duration stimuli. SSEP assessment can therefore offer a means of obtaining frequency specific estimates of hearing levels in even the most profoundly deaf subjects (Rance et al. 1995).

This paper examines the relationship between behavioural hearing thresholds and steady-state evoked potential findings in a group of infants and young children for whom no ABR could be observed to click stimuli presented at 100dBnHL.

MATERIALS AND METHODS

Results from 105 infants and young children, aged 1-49 months at the time of the SSEP assessment (median age = 24 months) are included in this study. Behavioural hearing thresholds were established for each of these youngsters using the standard audiometric procedure and test techniques appropriate to the developmental level of the child. The hearing losses ranged from moderate to profound degree, and were sensorineural in nature.

The ABR and SSEP assessments were carried out with the children either in natural sleep (n=14), sedated with chloralhydrate (50mg/kg), (n=56), or under a general anaesthetic (halothane 1:1 nitrous oxide), (n=35).

ABRs were sought to 100μs acoustic click stimuli presented monaurally via Etymotic Research ER-3A tubephones at a maximum level of 100dBnHL (136dBSPL (peak)). Patients were only included in the study if no ABR could be identified in two trials of 2000 clicks presented at 100dBnHL.

SSEP testing was carried out using a custom built evoked potential system which employed an IBM-compatible XT-type microcomputer to generate stimuli and analyse responses in the manner described by Cohen et al. (1991). The presence or absence of a response was determined automatically using a detection criterion which looked for non-random phase behaviour.

The SSEP stimuli were 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz tones amplitude and frequency modulated at a rate of 90 Hz. These tones were presented via mu-metal shielded TDH-39 headphones that allowed maximum sound levels of 104dBHL for the 250 Hz carrier, and 120dBHL for the higher frequencies. To obtain SSEP thresholds the stimulus level was decreased in 10dB steps until the response could no longer be detected. It was then increased in 5dB steps until the potential was again identified. Threshold was defined as the minimum level at which the response was detected.

RESULTS AND CONCLUSIONS

The results of this study indicate that the click-evoked ABR technique is unable to quantify hearing losses in the severe to profound range. As expected, this test was particularly insensitive to the presence of low frequency hearing in our subjects. At 500 Hz for example, 78% of these ears which had shown no ABR at maximum levels, had some degree of residual hearing. Furthermore, even in the mid to high frequencies behavioural testing showed the presence of hearing in more than a quarter of the ears. Figure 1 shows the distribution of behavioural hearing thresholds obtained from the subjects at 1000 Hz and 4000 Hz (unfilled bars). These distributions are similar to those of the other audiometric frequencies, showing a significant number of ears with useful hearing, and some thresholds at levels as low as 60 - 65dBHL. At each of the test frequencies at least 10% of the ears with residual hearing in fact had behavioural thresholds within the moderate/severe hearing loss range (590dBHL). Clearly the absence of the ABR could not preclude the presence of hearing at even moderate levels in these subjects, the technique cannot safely be used to confirm cochlear implant candidature.

Findings for ears which in addition to showing no click-ABR also had no SSEP response at maximum presentation levels are also described in Figure 1 (filled bars). The absence of the SSEP at maximum levels in these cases was a reliable indicator of profound or total hearing loss. On the majority (82.5%), of occasions where no SSEP response could be obtained at a particular frequency, behavioural testing also showed no response at that frequency. Furthermore, for the few instances where a hearing threshold was obtained in the absence of an SSEP response, the behavioural level was always found within 15dB of the maximum SSEP level, and on 99.5% of
consistent with those obtained for the severely and profoundly deaf subjects in our previous study (Rance et al., 1995), and show that the SSEP technique can be used to make reliable hearing level predictions for ears with only minimal residual hearing.

In summary, the findings of this study indicate that the steady-state evoked potential technique is better able to accurately quantify and describe hearing losses in the severe to total range than the click-ABR procedure. Where the brevity of the ABR's acoustic click limits both its frequency specificity and its presentation level, the modulated tones used for SSEP testing allow frequency specific assessment at high stimulus levels. As a result, the SSEP technique can provide an important safeguard in the pre-operative evaluation of young cochlear implant candidates, potentially identifying children whose hearing is better than suggested by behavioural test results.

REFERENCES


occasions the threshold was in fact within 10dB. This small range of observed hearing thresholds suggests that a prospective cochlear implant candidate is very unlikely to have hearing at a useful level if the SSEP is absent at 120dBHL.

On occasions when an SSEP was obtained, the range of behavioural thresholds was also small. Overall, 82% of the SSEP thresholds were within 10dB of the subjects' hearing levels, and 95% were within 15dB. This close relationship was present across the frequency range, with mean SSEP/behavioural difference levels of approximately 5dB obtained for each of the stimulus tones. These results are
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