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WIDEBAND MEASUREMENTS OF THE ACOUSTIC STAPEDIUS REFLEX IN HUMAN INFANTS

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ABSTRACT

Wideband changes in energy reflectance induced by the contralateral acoustic stapedius reflex were examined in 8 six-week-old infants and in 3 young adults using wideband shifts in admittance and energy reflectance (YR). The probe signal consisted of 40-ms electrical chirps with a bandwidth from 0.2 to 10 kHz. The overall level of the chirps was set at 65 dB SPL for adult testing and 55 dB SPL for infant testing as calibrated in a Zwislocki occluded ear simulator. The reflex activator presented to the contralateral ear was a band-pass noise from 2.5 to 11 kHz presented at a maximum overall level of 90 dB SPL measured in the ear canal. An experimental run consisted of the presentation of five baseline-activator pairs by varying the activator level from 90 to 70 dB SPL in 5 dB steps. Two such runs were completed for adults and infants unless the subject's state precluded additional measurements.

Reflex-induced YR shifts were then obtained by subtracting measurements obtained during a quiet baseline from those obtained in the presence of a contralateral activator noise. Reflexes were detected by calculating a cross-correlation between one-twelfth-octave measurements of YR for the highest activator level and responses to lower levels. The reflex-induced shifts in YR for the infant ears were similar in pattern to adult responses, but were shifted higher in frequency by around .5 kHz. Infant reflexes were more successfully detected when the cross-correlation was calculated from 1 to 8 kHz, whereas adult reflexes were more successfully detected for a cross-correlation from .25 to 2 kHz. This wideband acoustic reflex method may be useful in capturing the most robust frequency region for acoustic reflex detection across postnatal middle-ear development.

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INTRODUCTION

A method has been developed that uses a wideband probe stimulus for measuring the acoustic reflex by examining changes in admittance and energy reflectance (YR) of the middle ear (Feeney & Keefe, 1999, 2001). This method has been shown to provide a sensitive measurement of the contralateral acoustic reflex threshold in adults, which is about 12 dB lower than those obtained using a single 226 Hz probe tone (Feeney, Keefe, & Marryott, 2003).

Infant acoustic reflex measurements have been shown to be sensitive to probe frequency, being absent for a traditional 226 Hz probe tone (Keith, 1973), but present for higher probe frequencies, with reflex threshold decreasing with increasing probe frequency (Hirsh et al.,1992; Weatherby & Bennett, 1980; Bennett & Weatherby, 1982). The results of these studies suggest that the pattern of immittance shift with the acoustic reflex may change with development. The use of a wideband probe stimulus should allow for reflex-induced shifts in middle ear characteristics to be monitored at the most sensitive frequencies for a given age as the reflex response changes with development. This would allow us to study the development of the acoustic reflex independent of the biasing effects of a fixed probe frequency.

In the present study, a wideband contralateral acoustic reflex method was applied in young infants. Data from young adults were obtained for comparison using the same reflectance system and reflex activator.

METHOD

Subjects

1. Eight 6-week-old infants 3 boys and 5 girls with normal birth history and negative family history of hearing impairment.
   a. Pass distortion product otoacoustic emission screening (f_2 frequencies of 2, 3 and 4 kHz with a primary frequency ratio of 1.22, L1 and L2 = 65 and 55 dB SPL, respectively. DPOAE levels ≥0 dB SPL and an emission-to-noise-floor ratio of ≥6 dB (Gorga et al, 1999; Prieve, 2002).
   b. Pass 1000 Hz tympanogram (peak within 100 daPa of ambient pressure and with peak-compensated static acoustic admittance (Peak Ytm) greater than 0.6 mmhos at 1000 Hz using a +200 daPa reference (Margolis et al, 2003).
2. Three young adults with negative history of middle-ear disorders, normal hearing and single-peaked tympanograms with ± 10 daPa peak pressure.

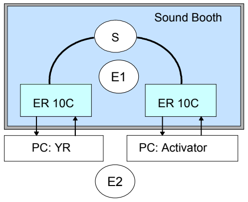


Figure 1. When the subject was quiet, experimenter 2 started YR data acquisition. Baseline trials were obtained in quiet without the presentation of the activator. On activator trials, contralateral band-pass noise (2.5-11 kHz) was presented using the second ER-10C.

Instrumentation and Stimuli

YR data collection using a method developed by Keefe et al. (1993).

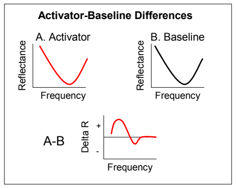
- Two ER-10C microphone systems were used to record YR responses and generate a band-pass noise for the contralateral activator stimulus under computer control (Figure 1).

1. YR probe stimulus was an electrical chirp with a bandwidth of 0.2 to 10 kHz at a level of 55 dB SPL for infants and 65 dB SPL for adults measured in a Zwislocki coupler.
2. Band-pass noise from 2.5 to 10 kHz calibrated in the ear canal of each subject with a maximum level of 90 dB SPL. In situ calibration of the contralateral activator stimulus was obtained for both infants and adults.

Procedure

1. Baseline YR measurement:
   a. Experimenter 2 initiated the presentation of the probe (chirps) to the subject's ear under computer control using the driver of an ER-10C microphone system. Experimenter 1 held the probe in the infant's ear and monitored the infant status (Figure 1).
2. Activator reflectance measurement:
   a. YR response was measured in one ear during the presentation of the contralateral activator noise.
   b. Activator levels varied from 90 to 70 dB SPL in 5 dB steps.
   c. Two runs were completed for each subject, time and subject state permitting.
3. The difference between baseline and activator responses was obtained to determine the magnitude of the shift induced by the reflex (Figure 2).
4. The reflex was detected by examining the correlation between the YR shifts for a given activator level and that of the highest activator level (Figure 3).

Figure 2 Illustration of the method used to calculate the wideband acoustic reflex response. Graph A is the ER response in the activator condition (contralateral activator present) and Graph B is the ER response in the baseline condition (contralateral activator absent). A – B is the difference between these responses shown in the lower panel as Delta R, the change in ER in the presence of the activator.



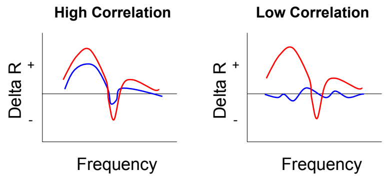
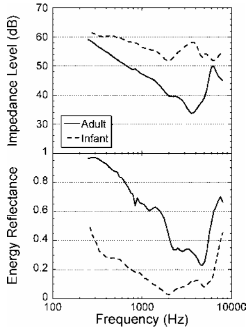


Figure 3. Illustration of the Correlation Method for ER shifts.

- Cross-correlations between YR response shifts for the highest activator condition (90 or 85 dB SPL) and a given activator level were calculated across bandwidths of 250 – 2000 Hz, 250 – 4000 Hz, and 250 – 8000 Hz, 500 – 8000 Hz and 1000 to 8000 Hz.

RESULTS

Figure 4. The upper panel shows the mean one-twelfth-octave impedance level in dB for the 3 adults (solid line) and 5 infants (dashed line). The lower panel shows the mean energy reflectance for the same subjects. The error bars represent ±1 SE. Three infants had large negative equivalent volume measurements in the low frequencies suggesting a leaky probe fit. Data from these 3 infants were not used to evaluate acoustic reflex responses.



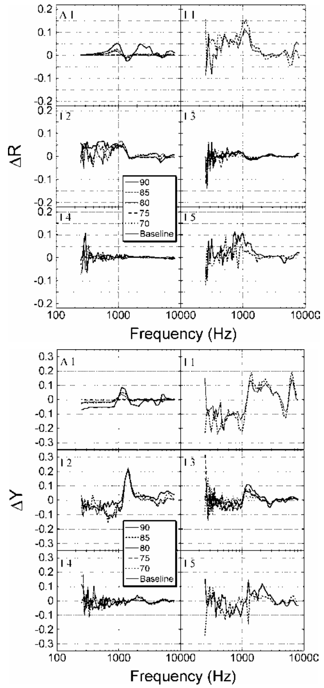


Figure 5. Wideband acoustic reflex responses for 1 adult and 5 infants for ER (top panel) and admittance (bottom). Two adults had absent reflexes for the 90 dB SPL activator condition and were not evaluated further.

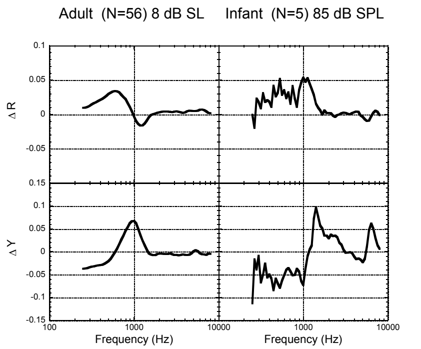


Figure 6. Mean shifts in energy reflectance (upper panels) and admittance (lower panels) induced by the acoustic reflex for a group of young adults (left panels) and the 5 infants (right panels) in the present study. The contralateral activator was either a 1000 Hz or 2000 Hz tone for the adults (N=56 ears) at 8 dB above reflex threshold measured with the reflectance method. ($\Delta R = \text{Reflectance}_{\text{activator}} - \text{Reflectance}_{\text{baseline}}$; $\Delta Y = [|Y|_{\text{activator}} - |Y|_{\text{baseline}}] / |Y|_{\text{baseline}}$).

CONCLUSIONS

1. The overall patterns of reflex-induced YR shifts in infants are similar to those of adults.
2. However, compared to adult data, the mean positive peak of the YR shift was at a higher frequency in the infants, suggesting a higher middle-ear resonance frequency for infants. This may be affected by the ear canal admittance for YR measurements. However, ER shift should be independent of probe position in the ear canal (Stinson et al, 1982).
3. Correlation analysis for the infant data showed the 1000 to 8000 Hz bandwidth as the frequency region most often resulting in the detection of a reflex response compared to 250 to 2000 Hz in adults.
4. The results are promising for the investigation of acoustic reflex development.
5. An ipsilateral wideband reflex paradigm should be investigated as a supplement to newborn hearing screening for the evaluation of middle ear and brainstem function.

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