The Aging Middle Ear: Acoustic Reflex Measures Using Wideband Energy Reflectance and Admittance

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ABSTRACT

Wideband changes in energy reflectance induced by the acoustic reflex were examined in 34 young-adult (M=21.5 years) and 23 elderly subjects (M=70.2 years). The group mean PTA (500, 1000 & 2000 Hz) was 6.5 dB HL for young group (SD=4.2 dB) and 18.5 dB HL for the elderly group (SD=10.1 dB). All subjects had normal 226 Hz tympanometry and middle-ear pressure within ±10 daPa. The reflex activator was a broadband noise presented through an ER-3A earphone. Energy reflectance was measured using filtered clicks (250-2000 Hz) as the probe stimulus presented through an ER-10C microphone system using the method of Keefe and Simmons (2003, J. Acoust. Soc. Am.) implemented in Matlab. Reflectance measurements of the reflex were made by subtracting measurements obtained in the presence of the contralateral activator noise from those obtained during a quiet baseline. Reflex threshold was defined as the lowest activator level for which pairs of reflex-induced shifts in reflectance were significantly cross-correlated. The mean contralateral reflex threshold for the noise activator for reflectance was 76.8 dB SPL for the young group and 79 dB SPL for the elderly group as calibrated in a Zwislocki coupler. At 4 dB above reflex threshold the maximum shift in reflectance occurred at approximately 600 Hz for both groups, but was 1.8 times larger for the young group (1.9% versus 3.4% shifts in reflectance) consistent with previous studies employing low-frequency probe tones with admittance measures. Contrary to a previous study reporting greater contralateral reflex magnitudes for young and elderly females for a noise activator, the trend in the present data was for a greater reflex magnitude for males for both age groups. The age differences in acoustic reflex magnitude reported in this study occurred over a frequency range for which the elderly, on average, have reduced energy reflectance at ambient pressure, suggesting the possible contribution of middle-ear mechanics to this effect. Work supported by the NIDCD grant DC04129

INTRODUCTION

We recently reported a difference between young and elderly subjects in wideband measures of energy reflectance (ER) at ambient pressure (Feeney & Sanford, 2003). The present study examines differences between young and elderly subjects on reflex amplitude and the growth of the reflex over a range of 8 dB above reflex threshold.

Previous studies that have employed a low-frequency probe tone have reported that elderly subjects have a reduced reflex amplitude compared to young subjects (Hall, 1982; Silman & Gelfand, 1981; Thompson, et al., 1980; Wilson, 1981).

The slope of the reflex amplitude growth function has also been reported to be more shallow in the elderly (Hall, 1982). Moreover, Hall (1982) found gender differences in reflex magnitude with females demonstrating a greater reflex magnitude than males over a 25 dB input-output range.

Current knowledge of age effects in acoustic reflex magnitude are based upon admittance measurements with a single low-frequency probe tone. The present study examined acoustic reflex magnitude for young and elderly subjects using a wideband ER system which permitted an examination of the acoustic reflex magnitude over a frequency range of 250 to 2000 Hz.

METHOD

Subjects

1. Negative history of middle-ear disorders
2. Tympanograms: single-peak shape, ± 10 daPa peak pressure
3. Groups:
   - Young: 34 subjects (16 F, 18 M) ages 19 to 23 yr (M=21.5 yr). PTA ≤15 dB HL Air-bone gaps ≤10 dB
   - Elderly: 23 adults (10 F, 13 M) ages 60 to 84 yr (M=70.2 yr). PTA ≤40 dB HL Air-bone gaps ≤10 dB.

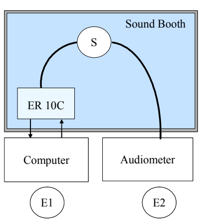
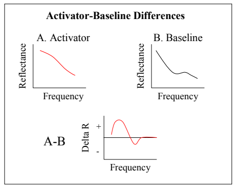


Figure 1 When the subject was seated quietly in the sound-treated booth, the first experimenter started ER data acquisition. On activator trials, contralateral white noise from the audiometer was presented by experimenter 2 during ER data acquisition. Baseline trials were obtained in quiet without the presentation of the activator.

Procedure

1. Obtained contralateral reflex thresholds for a white noise activator using a GSI-33 clinical admittance system with a 226 Hz probe tone. The noise source was white noise from a Madsen 622 audiometer with an ER-3A insert phone.
2. The ER measurement system was implemented in Matlab using a personal computer and a data acquisition card (Communication Automation & Control, Model 32C) based on a two-tube calibration technique described in Keefe and Simmons (2003).
3. Baseline reflectance measurement:
   - Experimenter 1 initiated the presentation of band-pass filtered clicks (250-2000 Hz, 55 dB SPL overall level) to the subject's right ear under computer control using the driver of an ER-10C microphone system.
   - When the subject was sitting quietly, the microphone response to 16 clicks was digitized, averaged and stored for data analysis.
4. Activator reflectance measurement:
   - Experimenter 1 initiated the presentation of band-pass filtered clicks (250-2000 Hz) in a free-run mode to assess subject noise levels.
   - When the subject was sitting quietly, Experimenter 2 presented the contralateral activator using the audiometer (Figure 1B). Experimenter 1 then initiated data collection. The responses to 16 clicks were then digitized, averaged and stored for data analysis.
5. The difference between baseline and activator responses was obtained to determine the magnitude of the shift induced by the reflex (Figure 2).
6. The reflex threshold was determined by examining the correlation between pairs of responses for each 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.



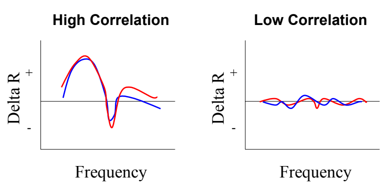


Figure 3. Illustration of the Correlation Method:

- The cross-correlation between ER (admittance) response shifts for activator-baseline differences for a given activator level has a length of 25, equal to the number of one-twelfth-octave frequency bins measured between 500 and 2000 Hz.
- The cross-correlation, *r*, was transformed to an approximately normal form using the Fisher's *Z* transformation, and tested for significance with an alpha level of 0.05 (Feeney & Keefe, 2001).
- The lowest activator level that resulted in a significant correlation between pairs of ER (admittance) responses was considered the reflex threshold.

RESULTS

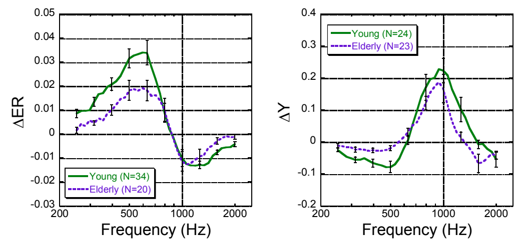
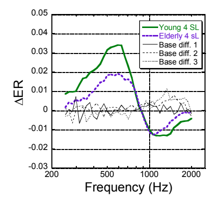


Figure 4. Group mean ΔER (Reflectance$_{activator}$ – Reflectance$_{baseline}$) and ΔY (|Y| $_{activator}$ – |Y| $_{baseline}$) for the young and elderly groups for a reflex activator at 4 dB above the reflex thresholds (SL). The error bars represent ±1 std. error. Note that for both ΔER and ΔY the shift from baseline is larger for the young group. Also note that the first zero crossing of the ΔER is the same for both groups. This suggests that the first resonance frequency of the middle ear is the same for both groups.



F-ratio for 4 dB SL Activator		
	ER	Admittance
Young	27.0	19.2
Elderly	10.3	9.1

Figure 5. Illustration of the method used to establish F-ratios by using variance from three baseline differences for 1 young subject (denominator) and group-mean data from reflex shifts (numerator) over a frequency range of 250 to 2000 Hz. The F-ratio was nearly 2.7 times larger for the young group for the ER measure, and around 2.1 times larger for the admittance measure.

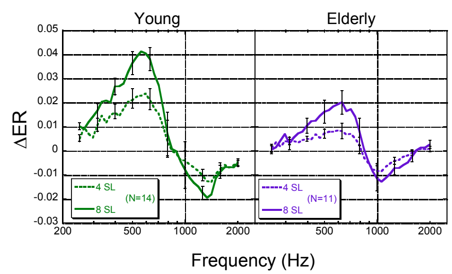


Figure 6. The group mean ΔER (Reflectance$_{activator}$ – Reflectance$_{baseline}$) for subgroups of 14 young and 11 elderly subjects with reflex responses at both 4 and 8 dB above reflex threshold (dB SL). The magnitude of the response for the young group is greater than that of the elderly group for both sensation levels.

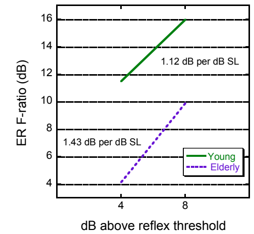


Figure 7. ER F-ratio in dB is plotted as a function of the level above reflex threshold (SL) for the young (N=14) and elderly (N=11) subjects from Figure 6. Note that in contrast to previous studies, a steeper slope is observed for the elderly function suggesting that the relative reflex amplitude grows more rapidly as a function of activator level for this group.

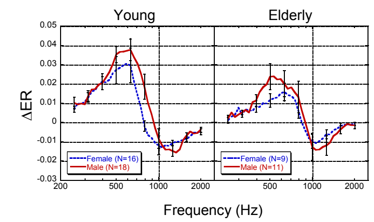


Figure 8. ΔER at 4 dB above reflex threshold for male and female subjects (compare with left side of Figure 4). Note that for both age groups the male subjects tend to have a larger shift in ER, and that the first zero crossing for ER is at a lower frequency for the females suggesting a lower first resonance frequency of the middle ear.

CONCLUSIONS

1. Consistent with previous studies that used a low-frequency probe tone to measure the acoustic reflex, the wideband magnitude of the contralateral acoustic reflex is greater for young than elderly subjects.
2. The reflex growth function from 4 to 8 dB above reflex threshold was relatively steeper for the elderly group when examined in terms of the dB shift in F-ratio.
3. The magnitude of the reflex shift at 4 dB SL was greater for males than females for both age groups. This is in contrast to Hall (1982) who reported larger shifts for females.

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