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MIDDLE LATENCY RESPONSE TO A 500-Hz TONE PIP IN NORMAL-HEARING AND IN HEARING-IMPAIRED SUBJECTS

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ABSTRACT

Middle latency response to a 500-Hz tone pip in normal-hearing and in hearing-impaired subjects. Barajas, J. J., Exposito, M., Fernandez, R. and Martin, L. J. (Tenerife, Canary Islands, Spain).

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Measurement of middle latency responses (MLR) appears to be one of the most useful ways of determining low-frequency auditory threshold. It is known that analog filtering can drastically affect MLR and since most laboratories use different recording characteristics, we carried out these measurements with a number of filter configurations. Ten subjects with normal hearing sensitivity were tested. The stimuli were 500-Hz tone pips (alternating in polarity) with a 4-ms rise–fall time and a plateau of 2 ms, presented at the rate of 9.3/s. The MLR were recorded with filter settings of 10–100, 10–250, 10–1 500, 10–3 000, 30–100 and 30–250 Hz at 12 dB per octave roll-off with a time base of 100 ms. MLR threshold was found between 8.0 and 11.5 dB nHL. The Wilcoxon statistical test showed that mean MLR thresholds did not differ significantly at the various bandpass configurations. An additional objective of this study was to compare hearing sensitivity based on MLR threshold to tone pips at 500 Hz and behavioural results obtained by conventional pure-tone audiometry. Although the correlation coefficient between the behavioural and electrophysiological measurements was statistically significant ($r=0.85$), further studies are required in order to determine the real magnitude of the predicted errors obtained, before this electrophysiological measure can be applied clinically.

INTRODUCTION

Determination of auditory thresholds is one of the important applications of evoked response audiometry. The auditory brainstem response (ABR) to click stimuli has been found to correlate well with the high-frequency behavioural threshold (Jerger & Mauldin, 1978). Of the various approaches used to accurately estimate low-frequency thresholds, middle latency response (MLR) appear as one of the most useful (Thornton et al., 1977; McFarland et al., 1977; Kavanagh et al., 1984). Previous studies have shown that MLR waveforms can be substantially affected by analog filtering (Scherg, 1982; Suzuki et al., 1984; Kavanagh et al., 1984). In this context, Scherg (1982) has demonstrated in adults that steep high-pass analog filter slopes can distort the MLR waveform.

In a recent study, Kavanagh et al. (1984) compared ABR and MLR thresholds, using a 500-Hz tone pip. They found the MLR threshold at 10 dB nHL. However, the results that they obtained using steep filter roll-off slopes and different filter band-pass settings do not necessarily apply to MLR threshold determination recorded with filters with shallower roll-off. Since analog filters with shallower slopes are very common in many clinical set-ups and since most laboratories studying MLR have used different recording characteristics, data comparison between laboratories is difficult.

The purpose of this study was twofold:

(I) to observe, in normal-hearing subjects, MLR thresholds with 500-Hz tone pips, using shallow filters and a number of filter band-pass configurations.

(II) to compare the 500-Hz thresholds obtained by conventional psychoacoustic methods with the thresholds obtained by MLR to 500-Hz tone pips in patients with different degrees of hearing loss. In this comparison, we used the filter band-pass settings from experiment I that showed a better MLR response definition.

METHODS

Subjects

Ten normal-hearing subjects, 9 men and 1 woman ranging in age from 14 to 34 years, were examined in experiment I. Only one ear selected at random was tested per subject. Ten subjects passed pure-tone screening at 15 dB HL (ISO, 1964) for the octave frequencies from 250 to 8000 Hz. Tympanograms were normal in amplitude and shape. None of these 10 subjects reported any otological or neurological disease.

Fifty-six ears from 32 individuals ranging in age from 7

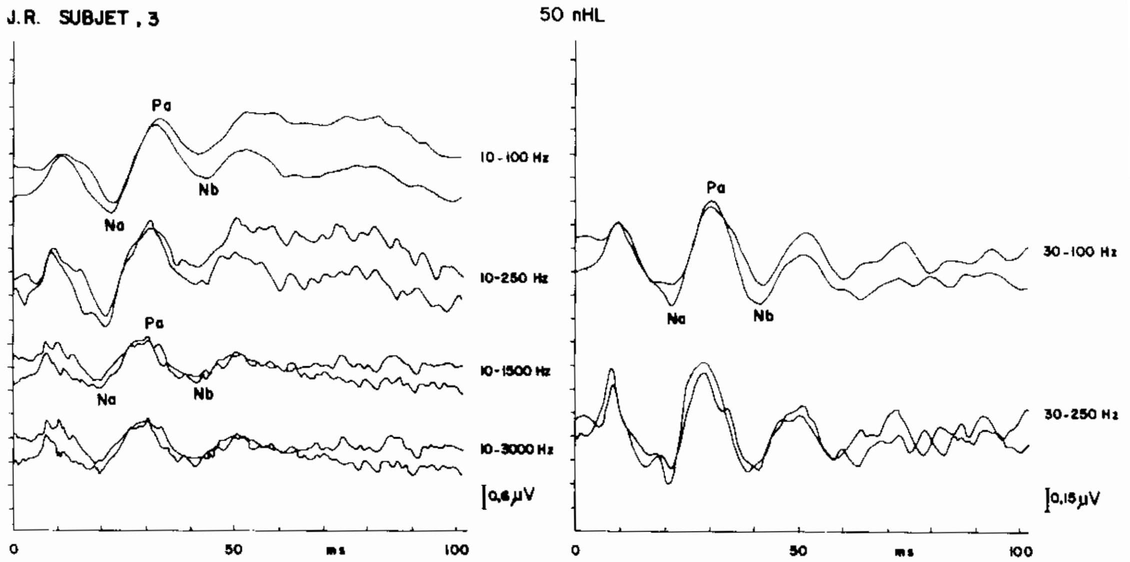

Fig. 1. Effect of the bandpass of recording filters on the 500 Hz MLR in an adult with normal hearing at 50 dB nHL.

to 80 (mean 44) years were the subjects for experiment II. All of these patients had a sensorineural (cochlear) hearing loss in at least one ear, according to psychoacoustic methods used. In these ears, the threshold results obtained by conventional audiometry at 500 Hz were compared with the MLR threshold obtained by 500-Hz tone pips.

Stimuli

In Experiment I, tone pips of 500 Hz were generated by a pure-tone oscillator and then directed to an earphone (TDH 39). The stimuli for Experiment I had 4 ms rise–fall times and 2 ms plateaus, while the stimuli for experiment II had 2 ms rise–fall times and 1 ms plateaus. The stimuli were alternated in polarity and presented monoaurally at a rate of 9.3/s. To establish an intensity reference for the tone pip, the earphones were calibrated biologically. Biologic calibration was obtained by testing 15 normal-hearing subjects between 18 and 29 years old. These subjects passed a 15 dB HL (ISO, 1964) screening test and had normal tympanograms and acoustic reflexes. Thresholds were obtained for these normal subjects with both types of 500-Hz tone pips and the intensity of the mean threshold for each stimulus was specified as 0 dB nHL in this study.

Recording procedure

Conventional 500-Hz pure-tone threshold was obtained from each ear separately by means of an ordinary audiometer and THD 39 earphone, calibrated according to ISO (1964) standards. In order to obtain a clear response, the subject lay, completely relaxed, on a bed in an electrically shielded room. MLR recordings were obtained under sedation using Diazepam. Electrical activity was recorded as the potential difference between an electrode on the ipsilateral mastoid (voltage negative) and a scalp vertex electrode (voltage positive) with the ground on the forehead.

In Experiment I the band-pass filter was set at 10–100, 10–250, 10–1 500, 10–3 000, 30–100 and 30–250 Hz. Filtering was carried out with two-pole Butterworth filters with standard phase characteristics and 12 dB/octave roll-off. The onset of the test stimulus was synchronized with the beginning of the signal averager which continued for 100 ms (analysis time). In Experiment II, a 10–250 band-pass filter with standard phase characteristics and a 12 dB/octave roll-off were used, since experiment I showed that restricted filter setting facilitates MLR identification and improves good correlation to behavioural audiometry threshold. The responses to 1 500 stimuli were directed to a physiologic amplifier and then to a signal averager (Nicolet Compact IV).

Response identification and latency measurements

All peaks were identified and labelled according to conventional nomenclature (Picton et al. 1974). The presence or absence of evoked potentials was based upon the following guidelines. (*a*) A maximum negative peak Na between the latency of 18 and 31 ms, a maximum positive peak Pa between the latencies 33 and 54 ms, and a maximum negative peak Nb between the latencies 33 and 54 ms. (*b*) At threshold level, the identification and labelling of waves was done by comparing their latency with easily identifiable waveforms recorded from the same subject at higher stimulus intensity. (*c*) Clearly visible and replicable waves in two out of two recordings or in three out of four recordings determined 'blind' by three independent observers.

The latency values of Na, Pa and Nb were taken at each threshold level. The threshold values obtained were statistically evaluated by means of the non-parametric Wil-

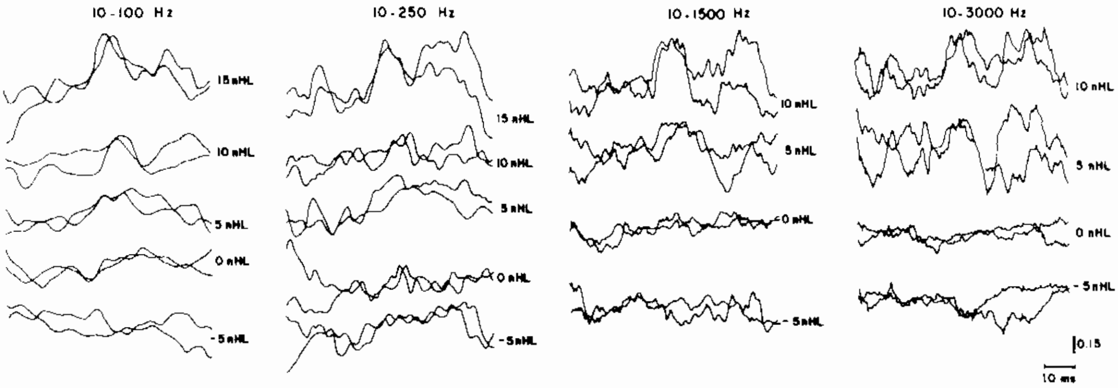

Fig. 2. Results of threshold measurement with 500 Hz MLR on an adult with normal hearing using different bandpass configurations of recording filters. Stimulus intensities are listed in dB nHL.

coxon signed rank test. In experiment II, a regression equation and correlation coefficient were used in order to compare the 500-Hz threshold obtained by pure-tone audiometry and 500-Hz threshold derived from MLR.

RESULTS

Experiment I

A typical evoked response to a 50-dB nHL 500-Hz tone pip is shown in Fig. 1. At this stimulus level, easily identifiable responses were obtained for all filter settings used and waves Na, Pa and Nb appeared as the most consistent components. As the stimulus intensity was lowered, all subjects showed an increase in wave latencies and a decrease in wave amplitudes. Fig. 2 shows a typical response from one subject at different band-pass filters at threshold level. At this stimulus level, only waves Na and Pa can be identified, whatever the band-pass configuration. Varying the recording of the MLR from 10–100 to 10–3 000 had a negligible effect on the response threshold. Table I shows the MLR (waves Na, Pa and Nb) thresholds (range: 8 to 11.5 dB nHL). The Wilcoxon test showed that mean MLR threshold values were not significantly different at the various filter band-pass configurations used in this study.

The standard deviation for the latency of Na, Pa and Nb was not significantly related to the stimulus intensity, although there was a tendency to greater inter-subject variability (larger standard deviation) at threshold level. In addition, variability increased with the latency of the components. The variability of amplitude between subjects was greater than latency, and no statistical evaluation was carried out. As with latency variability, amplitude variability increased with the latency of the component.

Experiment II

In Fig. 3, representative MLR recordings are presented. Fig. 4 shows the threshold of MLR to the 500-Hz tone pips in each patient vs behavioural threshold at 500 Hz. This figure also shows the scattergram, correlation coefficient, standard error and regression equation for 500 Hz behavioural threshold vs 500 Hz MLR threshold. From this figure, the following points can be established. First, the high correlation coefficients indicate a strong positive relationship between thresholds for 500 Hz MLR tone pips and their corresponding pure-tone behavioural thresholds. Second, the slope of the linear regression equation is close to unity, and third, since the scatter may be represented statistically by the standard error of estimation (SE) of behavioural threshold from electrophysio-

Table 1. *Middle latency response threshold to a 500 Hz tone pip for the different bandpass filters*

Waveforms	Bandpass of recording filters (Hz)	Threshold (dB nHL) $N=10$ Mean	SD
MLR Na, Pa, Nb	10–100	11	6.99
	10–250	11.5	7.09
	10–1 500	10	6.24
	10–3 000	10.5	5.99
	30–100	8.5	4.12
	30–250	8.0	3.50

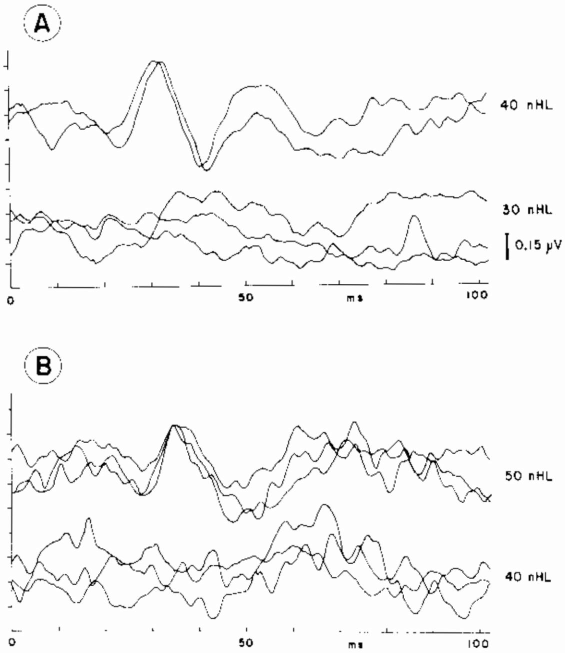

Fig. 3. Results of threshold measurements with 500 Hz MLR in two subjects. Case A presented a subject with a 500 Hz pure tone threshold of 40 dB with an audiometric slope 1000–500 Hz of 25 dB. Case B presented a subject with a 500 Hz pure tone threshold of 50 dB with an audiometric slope 1000–500 Hz of 0 dB. Stimulus intensities listed in dB nHL.

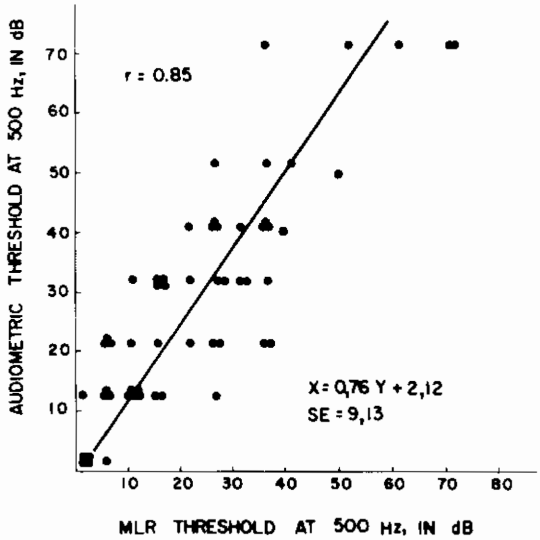

Fig. 4. Scatter plot of threshold of the MLR to a 500 Hz tone pip as a function of behavioral pure tone threshold at that frequency in 56 ears.

logic threshold, the small SE obtained in this study may indicate a minor error in predicting behavioural threshold for MLR at 500 Hz tone pips.

DISCUSSION

Experiment I

Present results show that MLR waves Na, Pa and Nb were the only components consistently recorded in all subjects for all the filter band-pass configuration and stimulus levels. These findings are in agreement with previous results by Scherg & Volk (1983) and Özdamar & Kraus (1983). The comparison of our results with other works in which a different type of stimulus was used (Musiek & Geurkink, 1981; Özdamar & Kraus, 1983), support the idea that in agreement with Maurizi et al. (1984), the morphology of the MLR remains unaffected by the frequency content of the stimulus.

In addition, our study shows that wave Pa is the most prominent and consistent MLR wave near threshold, whatever the type of stimulation, thus agreeing with earlier works (Musiek & Geurkink, 1981; Özdamar & Kraus, 1983; Maurizi et al., 1984). Our results show that the different MLR band-pass configurations had little effect upon the response threshold. However, our study, in agreement with Kavanagh et al. (1984), shows that more, even clearer, recordings were obtained when the high-frequency energy was eliminated from the response, thus allowing a more accurate MLR peak identification and latency measurement and also that in the evaluation of the low-frequency hearing threshold, the recording filter's low-frequency cut-off should be about 15 Hz and the high frequency cut-off should be 100 Hz or higher. In addition, high pass filter setting of 15 Hz may enhance the Na, Pa, detectability in children as have been reported by Suzuki et al., 1984 and Kraus et al., 1985. The similarity between the two studies is of interest, since filters with different roll-offs were used. The shallower filter slopes used in our study may have important clinical implications, since Scherg (1982) demonstrated that steep high-pass filter slopes can introduce non-physiological peaks into the MLR latency range and enhance the later components (i.e. Pb, Pc). Thus, shallow filter slope used in our work may account for the virtual absence of MLR activity beyond Pa, as reported by Kraus et al. (1985).

Our research shows that the latency and amplitude of the MLR Na, Pa and Nb components behave in an obscure fashion as the stimulus intensities decrease. The MLR components show even more clearly that variability does not necessarily increase at threshold levels. These results are in agreement with those obtained by Maurizi et al. (1984) and support the idea that a just-detectable wave Pa is a more significant measure of the auditory threshold than is the exact latency of this component. Components Na and Pa of MLR were unaffected by sedation with Diazepam. This is consistent with the findings of Mendel & Hosick (1975), Harker et al. (1977) and Özdamar & Kraus (1983), thereby justifying the use of sedatives, at least in adults.

In conclusion, important information can be obtained from the MLR threshold, and when filters with shallow roll-off are used, restricted band-pass filter settings make the MLR easier to read, while the correlations to behavioural threshold remain good.

Experiment II

The second experiment indicates that the MLR at 500-Hz tone pips is a sensitive measure of auditory threshold. Our data support previous results (Özdamar & Kraus, 1983) in the sense that MLR Na and Pa appear to be the most robust components near the auditory threshold.

The positive correlations between the auditory threshold obtained by conventional auditory and electrophysiological response indicate that as the 500-Hz threshold obtained by conventional audiometry increases, the threshold obtained by 500 Hz MLR also increases.

Since the principal purpose of tone-pip stimuli is to estimate sensitivity in the low-frequency region of the audiogram, the high correlation found at 500 Hz between MLR threshold vs. thresholds obtained by conventional audiometry is especially interesting. Moreover, the small SE indicates the possibility of accurate prediction of behavioural threshold from MLR with 500-Hz tone pips. In order to investigate this possibility, the major source of the SE to 500-Hz tone pips was analysed. To do this, we reviewed the individual data. A provisional finding from this review (since our data have a limited number of ears with a >1 000–500 Hz slope audiogram) is that the MLR to 500 Hz behaves in an unpredictable manner, regardless of the audiogram contour. From this review, we can also add that in 47 (84%) instances, the differences were ±15 dB between the audiogram threshold and the MLR to 500 Hz tone pips.

In conclusion, the present data reveal that MLR under sedation can be a good predictor of behavioural hearing at low frequencies. However, further studies are required in order to investigate the actual magnitude of the SE of this regression line before these electrophysiological measures can be reliably used as predictors of the 500-Hz tone audiogram in children.

REFERENCES

Harker, L. A., Hosick, E., Voots, R. J. & Mendel, M. I. 1977. Influence of succinylcholine on middle component auditory evoked potentials. *Arch Otolaryngol 103*, 133–7.

International Organization for Standardization. Standard Reference Zero for the Calibration of Pure Tone Audiometers. *ISO Recommendation R 389*, New York: American National Standards Institute, 1964.

Jerger, J. & Mauldin, L. 1978. Prediction of sensorineural hearing level from the brainstem evoked response. *Arch Otorhinolaryngol 104*, 456–61.

Kavanagh, K. T., Harker, L. A. & Tyler, R. 1984. Auditory brainstem and middle latency responses. I. Effects of response filtering and waveform identification. II. Threshold responses to a 500 Hz tone pip. *Ann Otol Rhinol Laryngol*, Suppl. *108*, 2–12.

Kraus, N., Read, N. L., Smith, D. I., Stein, L. K. & Cartee, C. 1985. Auditory middle latency responses in children, effects of age and diagnostic category. *Electroenceph Clin Neurophysiol 62 (5)*, 343–51.

Maurizi, M., Ottaviani, F., Paludetti, G., Rosignoli, M., Almadori, G. & Tassoni, A. 1984. Middle latency auditory components in response to clicks and low and middle frequency tone pips 0.5–1 kHz. *Audiology 23*, 569–80.

McFarland, W. H., Vivion, M. & Goldstein, R. 1977. Middle components of AER to tone pips in normal-hearing and hearing-impaired subjects. *J Speech Hear Res 20*, 781–98.

Mendel, M. I. & Hosick, E. C. 1975. Effects of the secobarbital on the early components of the auditory evoked potentials. *Rev Laryngol 96*, 178–84.

Musiek, F. E. & Geurkink, N. A. 1981. Auditory brainstem and middle latency evoked response sensitivity near threshold. *Ann Otol 90*, 236–40.

Özdamar, O. & Kraus, N. 1983. Auditory middle-latency response in humans. *Audiology 22*, 34–49.

Picton, T. W., Hillyard, S. A., Krausz, H. I. & Galambos, R. 1974. Human auditory evoked potentials. I. Evaluation of the components. *Electroenceph Clin Neurophysiol 36*, 179–90.

Scherg, M. 1982. Distortion of the middle latency auditory response produced by analog filtering. *Scand Audiol 11*, 57–60.

Scherg, M. & Volk, S. A. 1983. Frequency specificity of simultaneously recorded early and middle latency auditory evoked potentials. *Electroenceph Clin Neurophysiol 56,* 443–52.

Suzuki, T., Hirabayashi, M. & Kobayasi, K. 1984. Effects of analog and digital filtering on auditory middle latency responses in adults and young children. *Ann Otol Rhinol Laryngol 93,* 267–70.

Thornton, A. R., Mendel, M. I. & Anderson, C. V. 1977. Effects of stimulus frequency and intensity on the middle components of the averaged auditory electroencephalic response. *J Speech Hear Res 20,* 81–94.

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