LEFT-RIGHT DIFFERENCE IN HIGH FREQUENCY SENSITIVITY: APPLICATION FOR UNILATERAL COCHLEAR DISORDER EVALUATION

YUKA URATANI, TADASHI NISHIMURA, NARI OHARA, TOSHIAKI YAMANAKA and HIROSHI HOSOI
Department of Otolaryngology and Head & Neck surgery, Nara Medical University
Received November 18, 2013

Abstract : High-frequency audiometry has the potential to detect hearing impairment at its early stage. However, several problems prevent the clinical application of high-frequency audiometry. In this study, the dispersion and left-right difference in the high-frequency sensitivity were investigated in normal hearing volunteers. In our results, the difference between the left and right ears varied only slightly among individuals or age groups, while dispersion of hearing threshold values became marked with an increase in frequency. The results suggest that the measurement of left-right difference in high-frequency sensitivity may be useful for the evaluation of unilateral impairment. To investigate this usefulness, the left-right differences were measured in the patients complaining of unilateral cochlear symptom with normal hearing. Considering the results of normal hearing, we determined that abnormal left-right difference in high-frequency sensitivity was over 20 dB. In 12 patients with unilateral tinnitus, 7 showed left-right differences, and 6 had tinnitus in the ear with increased thresholds. Our results suggested a relationship between tinnitus with normal hearing and hearing impairment in the high-frequency range.

Key words : high frequency audiometry, high frequency sound, tinnitus

INTRODUCTION

The frequency range used in routine audiometry is 125 Hz-8 kHz, and other frequencies are not clinically used at present. However, humans can perceive frequencies from 16 Hz to 24 kHz as sounds[1], and if the sound was presented by bone conduction, human ear can hear ultrasound at the frequency range below 100 kHz[2, 3, 4, 5]. Therefore, there are frequencies not measured by a conventional audiometry. This is because the frequencies necessary in daily life have been generally considered to be present mainly in the conversation speech range (250 Hz-2 kHz), and an upper limit of 4 kHz has been regarded as adequate. On the other hand, previous studies have shown that a decrease in hearing due to aging or hearing impairment caused by ototoxic medications often starts in the high-frequency range[5, 6, 7, 8]. Therefore, measurement of the hearing threshold in the high-frequency range ($\geq$ 8 kHz) may be useful for

the early detection of these disorders.

Despite the usefulness, several problems prevent the clinical application of high-frequency audiometry. One of them is that the normal sensitivity in high-frequency range has not yet been determined. As previous studies reported, high-frequency sensitivity is strongly dependent on age[8, 9]. To evaluate hearing impairment in the high-frequency range, it is necessary to consider the normal range of high-frequency sensitivity influenced by aging. In this study, the accuracy of high-frequency audiometry was evaluated. The dispersion of hearing threshold values in the high frequency range was investigated in normal hearing volunteers. Furthermore, if left-right difference of sensitivity in high-frequency range is as small as that of conventional frequency range, unilateral hearing impairment may be easily evaluated by comparison of both ears sensitivity. In this study, left-right difference in high frequency range was evaluated in normal hearing volunteers. To investigate the usefulness of high-frequency audiometry for the detection of unilateral impairment, the left-right differences were measured in the patients complaining of unilateral cochlear symptom with normal hearing. Considering the left-right difference in normal hearing volunteers, the relationship between abnormal left-right difference and cochlear symptom were evaluated.

MATERIALS AND METHODS

The subjects consisted of 34 normal hearing volunteers and 15 patients aged 26-67 years who showed a hearing threshold of < 30 dB HL at all frequencies from 125 Hz to 8 kHz in standard pure-tone audiometry. The 15 patients consisted of 10 with unilateral tinnitus, 3 with a feeling of fullness in the ear, 2 with both tinnitus and a feeling of fullness in the ear. The standard audiometry was performed with a conventional audiometer (AA-78, Rion Co., Tokyo, Japan).

The high frequency hearing thresholds were measured at 1-kHz steps from 8 to 18 kHz. As test sounds, tone bursts with duration of 300 ms were presented at 2 Hz. The threshold was measured by a 5-dB step increment method. Stimuli were generated using a function generator (WF1946; NF Electronic Instruments Co., Yokohama, Japan) and presented using a condenser type headphone (SR-303; STAX, Miyoshi-machi, Japan). Sound pressure was adjusted using a programmable attenuator (PA5; Tucker-Davis Technologies, Gainesville, FL, USA). The headphone is calibrated with a Head and Torso Simulator (Type 4128C; Brüel & Kjær, Nærum, Denmark).

At first, dispersion of hearing threshold values in the high-frequency range was evaluated in 16 normal volunteers aged 20-29 years. At the next step, left-right differences in hearing thresholds according to age were evaluated in 9 normal volunteers aged 10-19 years, 16 aged 20-29 years, and 9 aged 30-39 years. The mean values were calculated, and used for the evaluations. The maximum output sound pressure was 100 dB SPL, and the sound pressure at the time of scale-out was regarded as 105 dB SPL. Considering the results of left-right differences in normal volunteers, the normal ranges of left-right differences were determined. To evaluate the usefulness of high-frequency audiometry, the relationship between the left-right differences and cochlear symptom in the 15 patients were investigated.

RESULTS

Fig. 1 shows high-frequency sensitivities in 16 volunteers aged 20-29 years. The hearing threshold increased with an increase in frequency. In standard pure-tone audiometry, there were only slight individual differences. However, in the frequency of 9-18 kHz, dispersion of hearing threshold values became marked with an increase in frequency. Fig. 2 shows left-right difference in high-frequency sensitivity according to age group. The left-right differences were < 10 dB at most frequencies and were independent of age. Table 1 shows the symptom of 15 patients with normal hearing and the observed over 20 dB left-right difference in high-frequency sensitivity. Over 20 dB left-right differences were found in 9 patients, and 7 patients had the cochlear symptoms in the ear with an increased threshold. Furthermore, in the 12 patients with unilateral tinnitus, abnormal left-right differences were found in 7 patients, and 6 patients had unilateral tinnitus in the ear with an increased threshold.

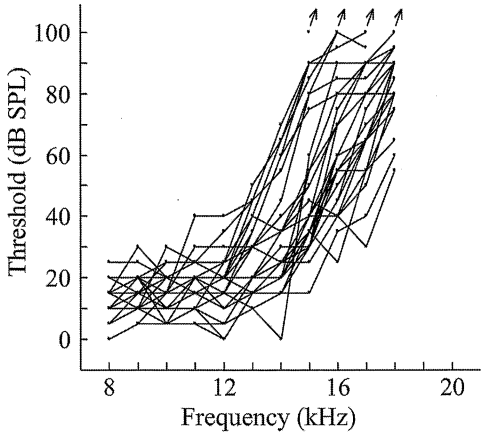

Fig. 1 : High-frequency sensitivities in 16 volunteers (32 ears) aged 20-29 years
Arrows indicate scale out.

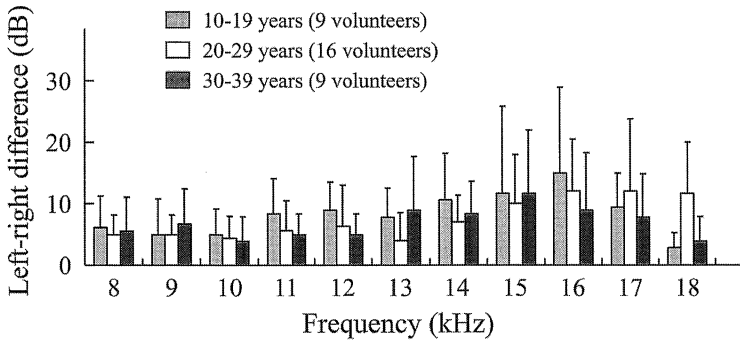

Fig. 2 : Right-left differences in high-frequency sensitivity according to age group
Vertical bars indicate standard deviation.

Patient	Age	Sex	Symptom	Left-right difference (≥ 20 dB) in high-frequency sensitivity
1	26	F	L tinnitus	25-30 dB difference at 13-15 kHz (L > R)
2	30	M	L tinnitus	25 dB difference at 14/15 kHz (L > R)
3	43	F	L tinnitus	No difference
4	47	F	L tinnitus	40-55 dB difference at 10-12 kHz (R > L)
5	48	M	L tinnitus	20-40 dB difference at 9-12 kHz (L > R)
6	50	F	R tinnitus	20 dB difference at 11 kHz (R > L)
7	52	M	L tinnitus	25 dB difference at 12 kHz (L > R)
8	54	F	L tinnitus	No difference
9	60	F	R tinnitus	No difference
10	64	F	L tinnitus	20 dB difference at 11 kHz (L > R)
11	65	F	L tinnitus+ Fullness	No difference
12	67	F	L tinnitus+ Fullness	No difference
13	48	F	L Fullness	25-dB difference at 11 kHz (L > R)
14	49	F	L Fullness	25-dB difference at 9 kHz (R > L)
15	66	F	L Fullness	No difference

Table 1 : Characteristics of 15 patients and left-right differences in high-frequency sensitivity

DISCUSSION

Based on the results of this study, the normal range of the hearing threshold appears to be difficult to determine and cannot be a parameter for sensitive early diagnosis. However, the difference between the left and right ears was < 15 dB independent of frequency and age. Therefore, the evaluation of the left-right difference may allow the early detection of unilateral hearing impairment.

Considering our results, we determined that the normal range of the left-right differences is ≤ 15 dB and an over 20 dB left-right difference is abnormal. In the 15 patients, 9 showed a left-right difference of ≥ 20 dB in the hearing threshold in the high-frequency range. In the 12 patients with unilateral tinnitus, 7 showed a left-right difference in the hearing threshold in the high-frequency range, and 6 had tinnitus in the ear with an increased threshold, that is, abnormal threshold shifts at the high-frequency range were frequently observed at the ipsilateral ear. Thus, these results suggested a relationship between tinnitus with normal hearing and hearing impairment in the high-frequency range.

Contrary to our results, Barnea et al.[10] reported that high-frequency audiometry showed no significant differences between the subjects with and without tinnitus. However, a large individual difference was found in high-frequency sensitivity, which indicates the difficulty in detecting small hearing threshold shifts in high-frequency range. In this study, abnormal high-frequency sensitivity was determined by the left-right difference. Our method may support the finer detection of threshold shifts in high-frequency sensitivity. Therefore, a relationship between tinnitus and abnormal high-frequency sensitivity was found in our results.

Table 2 shows the pitch and loudness in 8 tinnitus patients. The upper 4 patients had abnormal high-frequency sensitivity at tinnitus ear, and the lower 4 had no left-right difference. For 2 of the 4 patients with tinnitus in the ipsilateral ear, the pitch was 10 kHz, ranging at high frequency. On the other hand, for 3 of the 4 patients without left-right difference, the pitch was

under 0.5 kHz. Although the number of subject is small, it is therefore supposed that low pitch tinnitus is independent of high frequency sensitivity. If the subjects are specified in patients with high pitch tinnitus, the relationship between left-right difference in high-frequency sensitivity and tinnitus may be emphasized.

Patient	Symptom	Pitch, Loudness at pitch frequency
2	L tinnitus	250 Hz, 35 dB/ 500 Hz, 40dB/ 4 kHz, 30 dB
5	L tinnitus	125 Hz , 30-40 dB/ 10 kHz, 45 dB
6	R tinnitus	6 kHz, 22dB
7	L tinnitus	10 kHz, 35 dB
3	L tinnitus	250 Hz, 56 dB/ 500 Hz, 52 dB
4	L tinnitus	4 kHz, 22 dB/ 6 kHz, 26 dB
8	L tinnitus	125 Hz, 35 dB
9	R tinnitus	250 Hz, 40 dB

Table 2 : Pitch and loudness in 8 tinnitus patients

High-frequency audiometry may be useful for evaluating hearing impairment that could not be detected by conventional audiometry. Although the assessment of bilateral impairment is difficult at present, evaluation of unilateral impairment may be easy by comparison with the normal side. At present, to diagnosis a bilateral hearing impairment in the high-frequency range at its early stage, it is necessary to follow up high frequency sensitivity and detect an increase in thresholds.

CONCLUSIONS

High-frequency audiometry that allows examination of hearing function not evaluated by standard pure-tone audiometry, may allow a more detailed assessment of hearing. However, clinically, the hearing threshold in the high-frequency range markedly varies among individuals, and the evaluation of mild impairment appeared to be difficult. On the other hand, the difference between the left and right ears varied only slightly among individuals or age groups. Therefore, at least, high-frequency audiometry may be useful for evaluating unilateral impairment.

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