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GREATER DISPARITY BETWEEN AUDITORY STEADY-STATE RESPONSES AND PURE-TONE AUDIOMETRY IN PATIENTS WITH ACOUSTIC NEUROMA

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Abstract

Objective : The purpose of this study was to investigate whether auditory steady-state responses would reveal characteristics indicative of acoustic neuroma in patients.

Methods : Subjects were 42 unilateral acoustic neuroma patients with an average age of 55.0 (±13.6) years. The control group consisted of 19 idiopathic sensorineural hearing loss patients with an average age of 42.3 years (±18.8 years). Carrier frequencies used to obtain auditory steady-state response were 500, 1,000, 2,000 and 4,000 Hz, respectively. The measured auditory steady-state responses thresholds were compared with hearing levels of the pure tone audiogram.

Results : The auditory steady-state response threshold was somewhat greater (6 to 12 dB) than the pure-tone threshold that has been reported. Even higher thresholds were found in the acoustic neuroma group. In fact, when the subtracted values obtained by auditory steady-state responses threshold minus pure tone audiogram threshold of each frequency in each case were compared between the two groups, the acoustic neuroma group showed significantly greater values in all frequency regions. On the other hand, no differences were found in the values between the control and intact ear side.

Conclusion : The presence of acoustic neuroma may lower the auditory steady-state responses threshold. This might reflect that the tumor could jitter in creating a auditory steady-state responses.

Key words : Auditory Steady-State Response, Pure-Tone Audiometry, Acoustic Neuroma, Thresholds

Introduction

Acoustic neuromas (AN), also termed vestibular schwannomas, are generally slow growing, benign extra-axial intracranial tumors, most commonly arising from the vestibular portion of the eighth cranial nerve[1]. The majority of patients present with sporadic (unilateral) lesions in the fifth decade of life while approximately 5% of patients develop neurofibromatosis type 2, most commonly presenting with bilateral AN at a younger age. Presenting symptoms commonly include asymmetric high frequency sensorineural hearing loss (SNHL), tinnitus and deteriorating speech discrimination[2-5]. The mechanism by which the hearing disorder is caused by the tumor has not yet been fully elucidated. It has been reported that auditory brain response (ABR) and vestibular evoked myogenic potential (VEMP) are highly sensitive in detecting AN[6-8], although their physiological sig-

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nificance is somewhat different. As an alternative audiological test battery, the auditory steady-state response (ASSR), which is a newly developed frequency specific objective measuring method of hearing acuity, may be of some value although its significance is not fully understood[4], especially in patients with AN. It has been shown that ASSR is essentially an auditory response evoked by continuous tones modulated in amplitude, and sometimes in frequency, at specific rates or modulation frequencies, and its main application is to estimate the frequency-specific hearing threshold[9-11]. ASSRs are generated throughout the auditory nervous system, with cortical regions contributing more than brainstem generators to responses at lower modulation frequencies[12]. The objective of this study was to investigate whether or not ASSR could reveal characteristics indicative of AN in patients.

Materials and methods

This study is in accordance with the Declaration of Helsinki and was approved by our institutional review board and was conducted at the Ear, Nose and Throat (ENT) clinic of the Akita University Hospital.

Forty-two patients with unilateral AN were enrolled for the present study. They were 27 females and 15 males with an average age of 55.0 (±13.6) years. The control group consisted of 19 patients (9 females, 10 males) with idiopathic SNHL. Their average age was 42.3 years (±18.8) years. To guarantee an adequate condition for the auditory assessment, all patients underwent thorough an ENT evaluation. The audiological measurement tests (subjective and objective) were done by an audiologist. The pure-tone audiometry (PTA), which is a standard subjective examination to obtain frequency specific hearing acuity, was done in both ears by a Rion Co. Ltd. AA-75 audiometer (Tokyo, Japan), using TDH-39 phones. The test was taken in a soundproof cabin measuring the following frequencies : 125, 250, 500, 1,000, 2,000, 4,000 and 8,000 Hz, and using a down 10 dB/up 5 dB paradigm.

The ASSR, in both ears, was tested with Navigator Pro by Bio-Logic System Corp (Illinoi, USA), monitoring the electrical stimulus with the MASTER program software. The carrier frequencies of stimuli were 500, 1,000, 2,000 and 4,000 Hz with the frequency modulated at a rate, on the right ear of 84.375, 89.062, 93.750 and 98.437 Hz and on the left ear of 82.031, 86.719, 91.406 and 96.094 Hz. The patient was placed on a bed in a supine position in natural sleep or relaxed in a cabin acoustically treated and electrically isolated. The exponential modulation sounds were given through earphones and the surface electrodes were placed at the vertex (active electrode), at the nape of the neck (reference) and on the forehead (ground). Most of the patients took about an hour to complete the test.

Student's *t*-test was used to analyze all data obtained of the PTA and ASSR thresholds from the control patient group and AN patient group. P value <0.05※ and <0.01※※ were considered to be statistically significant.

Results

We could not obtain ASSRs in a few cases in the control group, most of whom had severe hearing loss, and they could not be counted as data. We obtained 30 to 33 responses at each frequency region from 38 ears. Among 42 AN patients, eight cases had severe hearing loss at the lesion side ear, most of which showed no ASSR. In addition, some cases with AN had highly unstable ASSR in several frequency regions, especially on the lesion side, being the threshold of this specific frequency not included on the data. As a result, 23 to 30 ASSR thresholds were detected in each frequency region from the AN group. On the other hand, ASSR was obtained from 40 to 41 ears from the intact side of patients in the AN group. No ASSR was obtained in a few frequency lesions in cases that had severe hearing loss on the intact side as well.

All the AN cases were diagnosed in the outpatient clinic at Akita University Hospital. Twenty-one cases were less than 2 cm from the porus acoustics and had no brainstem compression. However, 7 cases ranging from 2 to 4×2.6 cm had a slight brainstem compression. The largest case showed slight dizzy feeling with no significant change regarding ASSR threshold when compared with the small tumor cases.

In the control group, the ASSR threshold was some-

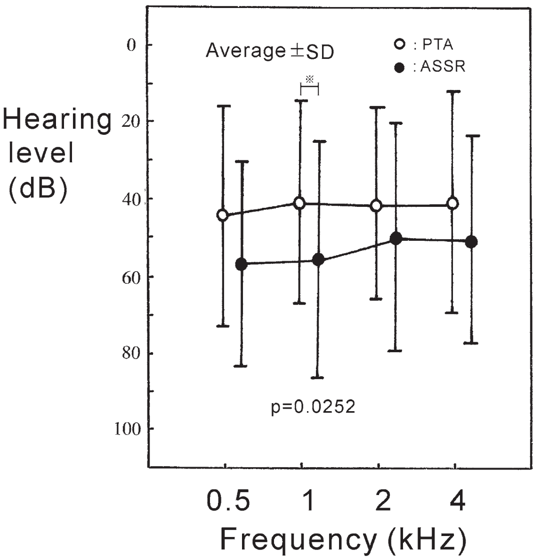

Fig. 1. PTA and ASSR hearing levels in the control patient group (n=19, 38 ears). The ASSR threshold was somewhat greater than the PTA threshold.
PTA — Pure-tone audiometry
ASSR — Auditory steady-state response

what reduced compared to the PTA threshold, showing mostly no significant difference between the ASSR threshold and the PTA threshold. The ASSR threshold was on average 6 to 12 dB lower when compared with the PTA threshold at each frequency (Fig. 1).

When compared with the AN patient group, a significantly lower threshold was obtained at each frequency region from 0.5 kHz to 4 kHz (Fig. 2).

When we compared the difference between the PTA threshold and the ASSR threshold of all frequency regions in each case, a significantly greater difference was found in the AN patient group (Fig. 3), as well. The same tendency was obtained in the comparison between the lesion and intact ear sides of AN cases.

On the other hand, no such difference was found between those of the control and intact ears of patients in the AN group (Fig. 4).

ABR was measured for 34 of 42 AN patients and classification of the results is shown on Table 1. This test was not performed in seven patients, who were either

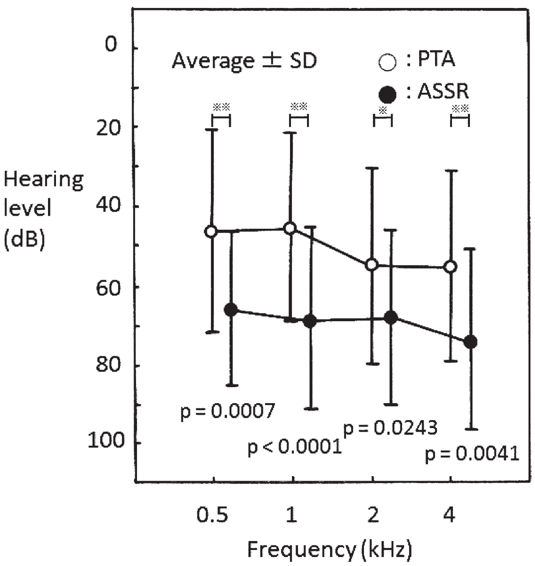

Fig. 2. Pure-tone hearing levels and ASSR threshold on the lesion side ear of AN patient group (n=42, 42 ears). Significantly greater thresholds were found in all frequency regions.
PTA — Pure-tone audiometry
ASSR — Auditory steady-state response

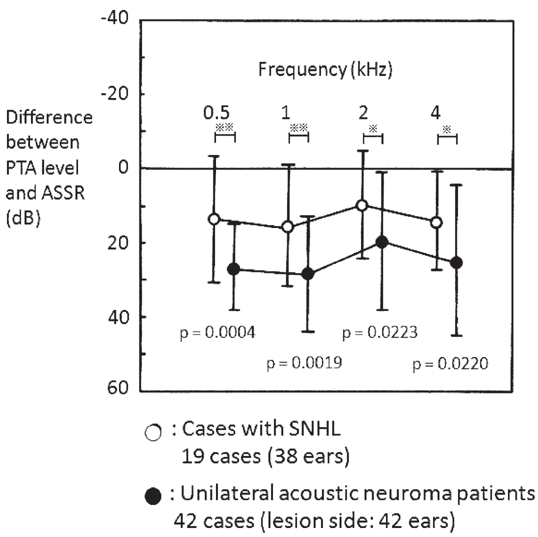

Fig. 3. The difference between pure-tone hearing level and ASSR threshold in the control patient group (open circles) and AN patient group on the lesion side ears (filled circles), showing that these differences were also significant, indicating much greater threshold in cases with AN than in control cases with SNHL.
PTA — Pure-tone audiometry
ASSR — Auditory steady-state response
SNHL — Sensorineural hearing loss

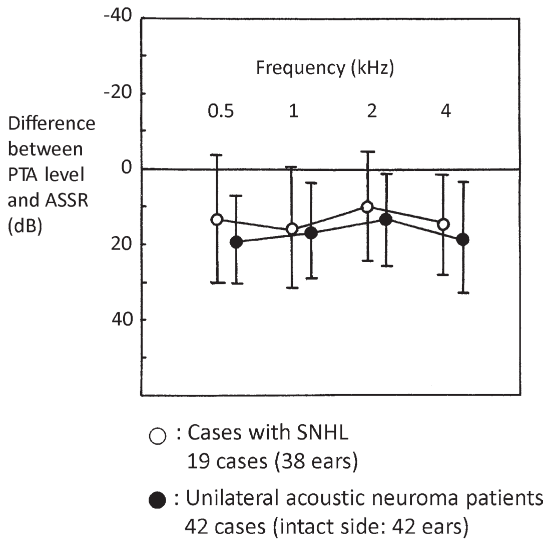

Fig. 4. The difference between pure tone hearing level and ASSR threshold in the control patient group (open circles) and AN patient group of intact ear (filled circles). No differences were found.
PTA — Pure-tone audiometry
ASSR — Auditory steady-state response
SNHL — Sensorineural hearing loss

Table 1. Type of ABR in AN cases. Various types were found, although "wave V only" was the most commonly occurring type.

Type of response	No. of patients (n=34)
Normal	7
Wave I only	1
Wave I-V elongation	4
Wave V only	21
No response	1

deaf or who had profound hearing loss, and one patient dropped out of the study. Those ABR results were shown for reference (Table 1). No certain tendency between ASSR thresholds and types of ABRs was found, although "wave V only" was the most common type of response.

Discussion

ASSR was recently introduced as an objective method to measure hearing levels and many reports have demonstrated its usefulness as an objective method to measure frequency-specific hearing levels. However, the relationship between ASSR findings and causes of hearing disorders has not yet been fully studied. In AN cases, ASSR measures may help to identify unique traits associated with a particular hearing disorder, suggesting inner ear lesion, retrocochlear lesion, or both.

One important key to suspect an acoustic neuroma might be threshold differences between both ears in pure-tone average from 1.0 kHz to 8.0 kHz that exceed 15 dB or 20 dB maximize identification of persons with these tumors while minimizing false-positive diagnosis of persons with cochlear losses[13]. This could be of value as a screening test. However, it will be important to obtain some other audiophysiological findings which are indicative of AN. From this point of view, one should pay attention to obtain the findings which might suggest retrocochlear lesion such as temporal threshold shift (Jerger type III), reflex decay in stapedial reflex, decreased speech discrimination and/or normal otoacoustic emission (OAE) with decreased pure-tone threshold. ASSR measurements, as a novel test battery, could provide a means of identifying a retrolabyrinthine pathology, since it has been recognized that ASSR could contribute to evaluate hearing ability and quality to examine the underlying disorder[14].

The ASSR neural generators might activate the whole auditory nervous system through modulated tone, in two major peaks, 40 and 80 Hz[11]. Some studies indicate that 40-Hz ASSRs are generated in the auditory cortex, having good responses in adults while awake, with responses decreasing in amplitude and increasing in threshold during sleep. It has been reported that 80-Hz ASSRs are generated in the inferior colliculus, having good responses in children during sleep, with no responses while awake[15-17]. This suggests that the 80-Hz ASSR, which was employed in our measuring system, is a useful audiometric device to determine the pure-tone hearing threshold in a frequency-specific manner in children during sleep[18].

Comparison of the 80-Hz ASSR and tone burst ABR in adults showed that both techniques are comparable for estimating the behavioral thresholds in hearing loss patients[19].

The SNHL patients had better results when the ASSR threshold and PT threshold in normal and SNHL patients were correlated and compared. This was likely due to the physiologic recruitment that is present in cochlear hearing loss. Longer recording periods produce smaller differences between behavioral and physiological thresholds[11,20].

In a recent study where ABR was compared with ASSR, it was shown that ASSR had several distinctive features, being uniquely suitable for objective evaluation of frequency-specific thresholds. The conclusion of the study was that ASSR is a more reliable test for the accurate prediction of auditory thresholds than ABR, and also, that it is a powerful and impersonal tool for objective assessment of hearing-impaired adult patients[21]. Also, it has been reported that the comparison between 80-Hz ASSR and tone burst ABR in adults are scarce, but that both techniques can be used to estimate the behavioral thresholds in hearing loss patients[19]. The main differences between frequency-specific ASSR and ABR measures are that[9-11] : 1) ASSR uses a repeated sound stimulus and a high repetition rate and ABR uses a brief sound stimulus with a relatively low repetition rate ; 2) ASSR can be used bilaterally and simultaneously from 0.5 to 4.0 kHz and ABR can be used only unilaterally from 1.000 to 4.000 Hz ; 3) ASSR is an objective examination and ABR depends on the examiner's subjective assessment ; and 4) ASSR uses pure tones, detecting from moderate to profound sensory hearing loss and ABR uses tone bursts or clicks and is able to detect from mild to moderate sensory hearing loss. In our series, we have not been able to ascertain the relationship between ABR and ASSR.

Our present results have clearly shown that there is a significantly greater difference between the PTA threshold and ASSR threshold in AN patients. Although further study will be necessary, these findings suggest that the tumor might enhance intrinsic jitter for neural synchrony for the responses, and have the potential to reveal other aspects of retrocochlear pathology.

Conclusion

Our present findings illustrate a greater disparity between ASSR threshold and PTA hearing level and may imply some retrocochlear pathology such as AN.

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Conflict of interest

None.

References

1) Menner, A.L. (2003) *A pocket guide to the ear*. Thieme flexibook, New York, pp. 86 ; 108-9 ; 128.

2) Ho, S.Y. and Kveton, J.F. (2002) Acoustic neuroma : assessment and management. *Otolaryngol. Clin. North Am.*, **35** (2), 393-404.

3) Baloh, R.W. and Honrubia, V. (2001) *Clinical neurophysiology of the vestibular system*. Oxford University press (3rd ed.), New York, pp. 311-314.

4) Keith, R.W. (2002) Clinical tests. In Seiden, A.M., Tami, T.A., Pensak, M.L., Cotton, R.T. and Gluckman, J.L. (eds.) *Otolaryngology : the essentials*. Thieme, New York, pp. 22-23.

5) Kesser, B.W. and Friedman, R.A. (2002) Functional disorders. In Seiden, A.M., Tami, T.A., Pensak, M.L., Cotton, R.T. and Gluckman, J.L. (eds.) *Otolaryngology : the essentials*. Thieme, New York, pp. 36-41.

6) Harner, S.G. (2001) The intracanalicular acoustic neuroma. In Pensak, M.L. (ed.) *Controversies in Otolaryngology*. Thieme, New York, pp. 276-278.

7) Murofushi, T., Matsuzaki, M. and Mizuno, M. (1998) Vestibular Evoked Myogenic Potentials in patients with acoustic neuroma. *Arch. Otolaryngol. Head Neck Surg.*, **124**, 509-512.

8) Angunsri, N., Omi, E., Itasaka, Y. and Ishikawa, K. (2010) Vestibular evoked myogenic potential in acoustic neuroma. *Otol. Jpn.*, **20** (5), 151-155.

9) Hall, J.W. (2007) *New handbook of auditory evoked responses*. Pearson education, Boston, pp. 258-312.

10) Hall, J.W. *The role of auditory steady-state response (ASSR) in audiology today*. Serial in the internet available at : http://www.otoemissions.org/FTP/powerpoint_pres/The_Role_of%20ASSR_in_Audiology.pdf. Accessed October 16, 2010.

11) Hall, J.W. and Swanepoel, D.W. (2010) *Objective assessment of hearing*. Plural publishing, San Diego, pp. 105-134.

12) Picton, T.W., John, M.S., Dimitrijevic, A. and Purcell, D. (2003) Human auditory steady-state responses. *International Journal of Audiology*, **42**, 177-219.

13) Schlauch, R.S. and Nelson, P. (2009) Puretone evaluation. In Katz, J., Medwetsky, L., Burkard, R. and Hood, L. (eds.) *Handbook of clinical audiology*. Lippincott Williams & Wilkins (6th ed.), Philadelphia, pp. 30-49.

14) Duarte, J.L., Alvarenga, K.F., Garcia, T.M., Costa Filho, O.A. and Lins, O.G. (2008) Auditory steady-state response in the auditory evaluation : clinical application. *Pró-Fono R. Atual. Cient.*, **20**(2), 105-110.

15) Aoyagi, M., Kiren, T., Furuse, H., *et al.* (1994) Pure-tone threshold prediction by 80-Hz amplitude-modulation following response. *Acta Otolaryngol. (Stockh.)*, Suppl. **511**, 7-14.

16) Aoyagi, M., Suzuki, Y., Yokota, M., Furuse, H., Watanabe, T. and Ito, T. (1999) Reliability of 80-Hz amplitude-modulation-following response detected by phase coherence. *Audio Neurootol.*, **4**, 28-37.

17) Kuwada, S., Batra, R. and Maher, V.L. (1986) Scalp potentials of normal and hearing-impaired subjects in response to sinusoidally amplitude-modulated tone. *Hear Res.*, **21**(2), 179-192.

18) Aoyagi, M. (2003, March) *Reliability and frequency specificity of 80-Hz amplitude modulation following response.* Lecture presented at the Cuban Neuroscience Center, Havana, Cuba.

19) Stapells, D.R. (2008) The 80-Hz auditory steady-state response compared with other auditory evoked potentials. In Rance, G. (ed.) *The auditory steady-state response : generation, recording, and clinical application.* Plural publishing, Portland, pp. 149-160.

20) Picton, T.W., Dimitrijevic, A., Perez-Abalo, M.C. and Roon, P.V. (2005) Estimating audiometric thresholds using auditory steady-state responses. *J. Am. Acad. Audiol.*, **16**, 140-156.

21) Lin, Y.H., Ho, H.C. and Wu, H.P. (2009) Comparison of auditory steady-state responses and auditory brainstem responses in audiometric assessment of adults with sensorineural hearing loss. *Auris Nasus Larynx*, **36**(2), 140-145.