

## Air-bone gap estimated with multiple auditory steady-state response in young children with otitis media with effusion

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### ABSTRACT

**Objective:** Multiple auditory steady-state responses (ASSRs) to air- and bone-conduction stimuli were recorded in young children with otitis media with effusion (OME). After treatment for OME, differences between pre-treatment bone-conduction ASSR levels and post-treatment conditioned orientation reflex (COR) or air-conduction ASSR levels were examined, and compared with ASSR-estimated air-bone gap (ABG) before treatment.

**Methods:** Navigator Pro with Master was used to assess the threshold of air- and bone-conduction ASSR in both ears at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. For bone-conduction ASSR, RadioEar B-71 bone-vibrator placed on the mastoid was used with white-noise masking on the contralateral ear.

**Results:** After ventilation tube placement, the thresholds of COR got closer to those of pre-treatment bone-conduction ASSR in young children with OME. Moreover, post-treatment air-conduction ASSR thresholds also got closer to those of pre-treatment bone-conduction ASSR. The differences between pre-treatment bone-conduction ASSR thresholds and post-treatment COR or air-conduction ASSR thresholds became much smaller than ASSR-estimated ABG before treatment.

**Conclusion:** These findings suggest that bone-conduction ASSR can assess the normal or near normal cochlear sensitivity in young children with conductive hearing loss. It is also suggested that ASSR-estimated ABG can be used clinically to predict their accurate ABG.

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## 1. Introduction

The auditory evoked potential is required to estimate hearing thresholds for individuals who cannot respond reliably to behavior testing such as infants, young children and emotionally disturbed or cognitively impaired patients. The auditory brainstem response (ABR) is currently used clinically for threshold assessment in infants and young children. However, the ability of ABR to click tone to detect an auditory response is limited at high frequencies. Although ABR to tone-pips of 500 Hz or 1000 Hz is used to overcome the limitation, its error of prediction was reported especially in patients with steeply sloping audiograms [1].

The auditory steady-state responses (ASSR) evoked by auditory stimuli that are sinusoidally modulated in amplitude at rate between 80 and 110 Hz are used to evaluate auditory thresholds objectively [2]. ASSR can be simultaneously recorded for multiple

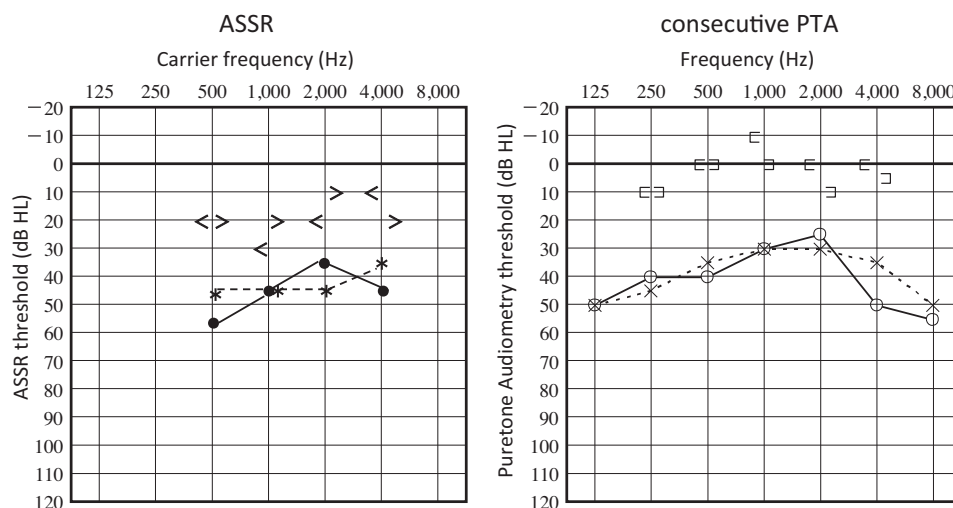
carrier frequencies in both ears. ASSR with multiple simultaneous stimulation technique (multiple ASSR) to air-conduction stimuli have been found to provide accurate prediction of hearing thresholds at 500, 1000, 2000 and 4000 Hz. The ASSR thresholds at 1000 Hz, 2000 Hz and 4000 Hz are elevated by less than 10 dB, compared to behavioral thresholds, but those at 500 Hz are elevated by a bit more than 10 dB than those at higher frequencies.

In order to distinguish between sensorineural and conductive hearing loss, the ASSR thresholds to bone-conduction stimuli must be evaluated, as it is routinely done in behavioral audiometry. It was reported that multiple ASSR are recorded in response to the stimuli directly through a bone conduction transducer positioned either on the forehead [3,4] or on one of the mastoids [5] in adults. Moreover, air-bone gap (ABG) estimated with multiple ASSR to air- and bone-conduction stimuli was reported to be strongly correlated with that measured using pure-tone audiometry in adults with simulated conductive hearing loss [6].

In the present study, we recorded multiple ASSR to air- and bone-conduction stimuli and assessed ASSR-based ABG in young children with otitis media with effusion (OME). To prove a reasonably accurate prediction of ABG with ASSR in young children with conductive hearing loss, differences between pre-treatment

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**Fig. 1.** Air- and bone-conduction thresholds with multiple ASSR and air- and bone-conduction ones with the consecutive pure-tone audiometry in case 3 of a 6-year and 11-month child with ossicular malformation found on CT. ●: air-conduction ASSR of right ear, \*: air-conduction ASSR of left ear, <: bone-conduction ASSR of right ear, >: bone-conduction ASSR of the left ear.

bone-conduction ASSR levels and post-treatment COR or air-conduction ASSR levels were examined, and compared with ASSR-estimated ABG before treatment

## 2. Subjects and methods

### 2.1. Subjects

Nine children with conductive hearing loss were enrolled in the present study. In three children, the bone-conduction ASSR thresholds were assessed and then the bone-conduction levels on peep-show or pure-tone audiometry were assessed on the same day. The subgroup included a 3-year and 6-month infant with first and second brachial syndrome, a 5-year and 1-month child with malleus malformation and another child aged 6 years and 11 months with ossicular malformation found on CT. Also, four children had OME and their bone-conduction ASSR thresholds were assessed from the age of 4 months to 1 years and 3 months. After the treatment with ventilation tube placement or myringotomy, the air-conduction levels on conditioned orientation reflex (COR) audiometry were assessed from the age of 6 months to 2 years and 7 months. Finally, in two children with OME, the bone-conduction ASSR thresholds were assessed at the age of 2 months. After myringotomy, the air-conduction ASSR thresholds were assessed at the age of 3 months and 4 months. This study was approved by the Committee for Medical Ethics of Tokushima University Hospital.

### 2.2. Methods

Navigator Pro with Master (Multiple Auditory STEady-state Response) was used to assess the threshold of air-conduction ASSR in both ears at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz simultaneously [7]. Also the bone-conduction ASSR threshold in both ears at the same frequencies was also assessed alternatively with RadioEar B-71 bone-vibrator which was placed on the mastoid with elastic band [8]. White-noise masking of 50 dB HL was used on the contralateral ear. Bone-conducted stimuli were calibrated in air-equivalent dB SPL based on American National Standards Institute and International Standards Organization. Stimuli of air- and bone-conduction were amplitude-modulated tone. The carrier frequencies and modulation frequencies were as follows: 500 Hz/82 Hz, 1000 Hz/84 Hz, 2000 Hz/87 Hz and 4000 Hz/89 Hz to the

left ear, and 500 Hz/91 Hz, 1000 Hz/94 Hz, 2000 Hz/96 Hz and 4000 Hz/99 Hz to the right ear [9]. Air-conduction stimuli of 80–0 dB HL and bone-conduction stimuli of 50–0 dB HL were used.

## 3. Results

Multiple ASSR to bone-conduction stimuli were recorded in three young children with conductive hearing loss: case 1 with first and second brachial syndrome, case 2 with malleus malformation and case 3 with ossicular malformation found on CT (Fig. 1). The ASSR thresholds to bone-conduction stimuli were 15.8 dB at 500 Hz, 21.7 dB at 1000 Hz, 13.3 dB at 2000 Hz and 10.8 dB at 4000 Hz above consecutive behavioral bone-conduction thresholds (cases 1 and 2 on peep-show audiometry and case 3 on pure-tone audiometry) (Table 1).

The bone-conduction ASSR thresholds were lower than those of air-conduction in the four young children with bilateral OME. ASSR-estimated ABG in the ear with better air-conduction levels was 20–40 dB ( $32.5 \pm 9.6$  dB) at 500 Hz, 10–30 dB ( $22.5 \pm 9.6$  dB) at 1000 Hz, 0–10 dB ( $7.5 \pm 5.0$  dB) at 2000 Hz and 0–20 dB ( $n = 3$  and 50 dB,  $n = 1$ ) ( $22.5 \pm 20.6$  dB) at 4000 Hz. Three were treated with bilateral ventilation tube placement and one with bilateral myringotomy, and the air-conduction thresholds of the better hearing ear were assessed with COR audiometry. Accordingly, the differences between pre-treatment bone-conduction ASSR thresholds and post-treatment COR thresholds were 2.5 dB at 500 Hz, 5.0 dB at 1000 Hz, –1.9 dB at 2000 Hz and 2.5 dB at 4000 Hz, and were much smaller than ASSR-estimated ABG before treatment (Table 2). For example, in case 5 with bilateral OME, post-treatment of air-conduction level of

**Table 1**

Differences of bone-conduction levels between ASSR and consecutive behavior audiometry in children with suspected conductive hearing loss.

		500 Hz	1000 Hz	2000 Hz	4000 Hz
Case 1	R	20 dB	20 dB	20 dB	20 dB
	L	20 dB	20 dB	20 dB	10 dB
Case 2	R	10 dB	20 dB	10 dB	5 dB
	L	5 dB	15 dB	10 dB	5 dB
Case 3	R	20 dB	40 dB	20 dB	10 dB
	L	20 dB	20 dB	0 dB	15 dB
Average		$15.8 \pm 6.6$ dB	$21.7 \pm 6.8$ dB	$13.3 \pm 8.2$ dB	$10.8 \pm 5.8$ dB

Data represent bone-conduction ASSR levels minus those of behavior audiometry. Average indicates mean  $\pm$  S.D.

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