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# Preoperative Characteristics of Auditory Brainstem Response in Acoustic Neuroma with Useful Hearing: Importance as a Preliminary Investigation for Intraoperative Monitoring

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**Abstract**

**We classified the results of preoperative auditory brainstem response (ABR) in 121 patients with useful hearing and considered the utility of preoperative ABR as a preliminary assessment for intraoperative monitoring. Wave V was confirmed in 113 patients and was not confirmed in 8 patients. Intraoperative ABR could not detect wave V in these 8 patients. The 8 patients without wave V were classified into two groups (*flat* and *wave I only*), and the reason why wave V could not be detected may have differed between the groups. Because high-frequency hearing was impaired in *flat* patients, an alternative to click stimulation may be more effective. Monitoring cochlear nerve action potential (CNAP) may be useful because CNAP could be detected in 4 of 5 *wave I only* patients. Useful hearing was preserved after surgery in 1 patient in the *flat* group and 2 patients in *wave I only* group. Among patients with wave V, the mean interaural latency difference of wave V was 0.88 ms in Class A (n = 57) and 1.26 ms in Class B (n = 56). Because the latency of wave V is already prolonged before surgery, to estimate delay in wave V latency during surgery probably underestimates cochlear nerve damage. Recording intraoperative ABR is indispensable to avoid cochlear nerve damage and to provide information for surgical decisions. Confirming the condition of ABR before surgery helps to solve certain problems, such as choosing to monitor the interaural latency difference of wave V, CNAP, or alternative sound-evoked ABR.**

Keywords: auditory brainstem response, acoustic neuroma, cochlear nerve damage, wave V, hearing preservation

## Introduction

Auditory brainstem response (ABR) was helpful in identifying acoustic neuroma before the development of magnetic resonance imaging (MRI).[1,2] However, the reliability of diagnosis was not very high,[3–6] and there are typically fewer opportunities to perform ABR before surgery. ABR recently became more important for use in intraoperative monitoring. Intraoperative ABR is important to avoid cochlear nerve damage, and it can provide critical information for making decisions to prioritize total removal or hearing preservation. Because radiosurgery for acoustic neuroma is effective, reduction of tumor volume while preserving useful hearing following radiosurgery may be a better choice than total tumor removal without hearing preservation. Thus, recording ABR during surgery is indispensable, and we should be prepared to use ABR for patients with useful hearing. To monitor and estimate intraoperative cochlear nerve damage, the condition of ABR before surgery should be investigated. Here, we present the findings of preoperative ABR in our patients and discuss the problem using ABR for intraoperative monitoring. As there have been many studies concerning wave V on ABR,[7–11] we classified our patients according to whether wave V was present.

## Materials and Methods

We received approval from the Nagoya City University

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Medical School investigational review board to collect pertinent data from medical records.

### I. Patients

This retrospective study identified 121 patients (63 females, 58 males; age range, 22–70 years; mean age, 48.7 years) with useful hearing who underwent surgery for unilateral acoustic neuroma between 2004 and 2012 at Nagoya City University Medical School Hospital. Hearing was estimated by pure tone average and speech discrimination testing before surgery and the results were evaluated according to the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) classification.[12] Classes A and B are considered to represent useful hearing. Tumor size was classified according to Koos grade[13] (Grade I, 35 patients; Grade II, 38 patients; Grade III, 40 patients; and Grade IV, 8 patients).

### II. ABR

ABR was recorded with a Neuropack (Nihon Kohden, Tokyo) about 1 week before surgery. Monaural stimulation with alternate clicks was delivered at a rate of 13 Hz with an intensity level 90 dB through a headphone. Responses of 2,000 sweeps were averaged. Simultaneously applied white noise at intensities of 50 dB was used to mask the contralateral ear.

### III. Statistical analyses

Statistical analysis was performed using R-2.14.0 (R Foundation, Vienna, Austria). Analysis of differences was performed using the Mann-Whitney U test. Statistical significance was set at $p < 0.05$.

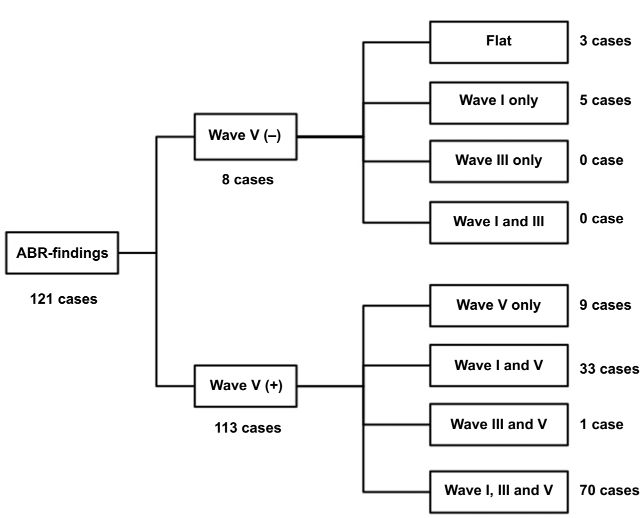


**Fig. 1 Scheme of the classification in preoperative auditory brainstem response (ABR).**

## Results

Figure 1 presents classification of the ABR characteristics. Wave V was confirmed in 113 patients and was not confirmed in 8 patients. Intraoperative ABR detected wave V in 111 patients before tumor resection. Intraoperative ABR could not detect wave V in all 8 patients without wave V on preoperative ABR. Eight patients without wave V were classified into two groups, *flat* and *wave I only*. There were no apparent waves in the ABR of 3 patients, and these were classified in *flat*. In 5 patients there was only wave I in the ABR. The audiograms were different between the *flat* and *wave I only* groups. The mean hearing threshold (MHT) at 125, 250, 500, 1,000, 2,000, 4,000, and 8,000 Hz is shown in Fig. 2. High-frequency hearing above 2,000 Hz was impaired in the *flat* group. Among the patients with wave V, wave I could not be detected in 10 (9 patients, *wave V only*; 1 patient, *wave III and V*). Excluding these 10 patients, the mean interaural difference of I–V interpeak latency was 0.73 ms in Class A (n = 55) and 0.99 ms in Class B (n = 48). The difference was marginally significant ($p < 0.1$). Among all 113 patients with wave V, the mean interaural latency difference of wave V was 0.88 ms in Class A (n = 57) and 1.26 ms in Class B (n = 56), a significant difference ($p < 0.05$) (Table 1). Useful hearing was preserved after surgery in 1 patient in the *flat* group and 2 patients in the *wave I only* group. Useful hearing was preserved in 54 of 113 patients with wave V on ABR (Table 2).

## Discussion

ABR has been the most widely employed monitoring method during acoustic neuroma surgery.[7,8,10,14,15] The waves corresponding to the auditory tract of the brainstem are waves I to V. For most clinical neurophysiologists, wave V is considered to be the best electrophysiological indicator of cochlear nerve

**Table 1 Prolongation of wave V latency**

| ABR-finding | N | AAO-HNS | |
|---|---|---|---|
| | | Class A | Class B |
| Mean IPL I-V (ms) | 103 | 0.73 ± 0.8 | 0.99 ± 1.4 |
| Mean ILD V (ms) | 113 | 0.88*± 0.8 | 1.26*± 1.4 |

*Significant difference by Mann-Whitney U test ($p < 0.045$). AAO-HNS: the American Academy of Otolaryngology-Head and Neck Surgery, ABR: auditory brainstem response, ILD V: interaural latency difference of wave V, IPL I-V: interaural difference of I-V interpeak latency.

**Table 2 Result of hearing after surgery**

| ABR-finding | | Useful hearing preservation | |
|---|---|---|---|
| Wave V (–) | Flat | 33% (1/3) | 37.5% (3/8) |
| | Wave I only | 40% (2/5) | |
| Wave V (+) | | 48% (54/113) | |

ABR: auditory brainstem response.

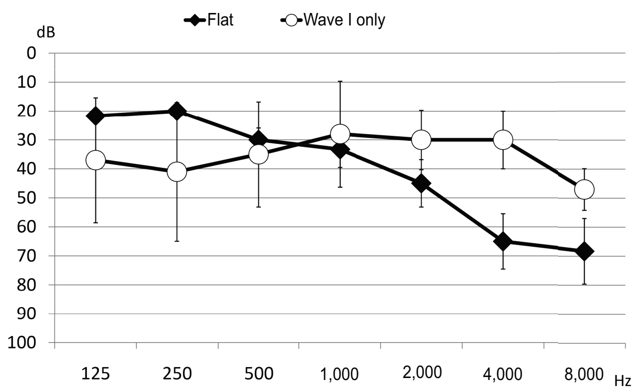


**Fig. 2 Mean hearing threshold of the cases without wave V on auditory brainstem response (ABR). Error bar indicates standard deviation. High-frequency hearing above 2,000 Hz was impaired in *flat* group (*square*) compared to *wave I only* (*circle*) group.**

damage during surgery.[7,8,10,14] Cochlear nerve damage results in a delay in latency and a reduction in the amplitude of wave V. Thus, difficulty in estimating wave V is a serious problem for intraoperative ABR monitoring. In this study, wave V could not be detected in 8 patients (7%) before surgery. These 8 patients were classified into two groups. The reason why wave V could not be detected may have differed between the two groups. No apparent wave could be detected in 3 of these 8 patients. As shown in Fig. 2, high-frequency hearing was impaired in these 3 patients as compared to the other 5 patients. The click is currently the most widespread stimulus used to record ABR. In this study, ABR was recorded by the click stimulus. The click stimulus is not frequency-specific, but rather broadband. Moreover, click-evoked ABR is mainly determined by the ear's sensitivity to higher frequencies, above 2,000 Hz.[16] We consider that high-frequency hearing impairment is a likely cause of the absence of wave V. Thus, in order to record ABR, a click stimulus is probably not suitable for cases of impaired high-frequency hearing.[3,17] One solution to this problem is to use alternative methods of stimulation. There are several procedures available, including a brief tone sound. We should confirm the state of wave V using alternative sound-evoked ABR before surgery, as the normal latency and amplitude may be different from those on click-evoked ABR. The mechanism underlying the detection of wave I must be severe conduction block. For these cases, another solution is needed. Higher reliability for monitoring cochlear nerve action potential (CNAP) has been reported.[18–21] Although ABR explores the far-field responses from the cochlear nerve to the ascending auditory pathways, CNAP has the advantage of being a near-field technique. There is a higher chance to estimate cochlear nerve damage during surgery by monitoring CNAP compared to ABR. In fact, click-evoked CNAP during surgery could be detected in patients without apparent waves in ABR.[22] Conditions for recording ABR are very different between the laboratory and the operating room. Because of electrical interference from operating equipment, artifactual responses are expected, and monitoring ABR in the operating room is usually more difficult. Actually, intraoperative ABR could not detect wave V in all 8 patients without wave V on preoperative ABR. Therefore, it is recommended that CNAP be monitored when wave V is not detected in the laboratory. In our experience, click-evoked CNAP could be detected in 4 of 5 patients in the *wave I only* group before tumor resection. We could not monitor CNAP in a patient with a Koos Grade IV tumor, because the cochlear nerve could not be identified during surgery. CNAP can be recorded by brief tone sounds. Therefore, we are trying to record CNAP by brief tone sound stimulation for the high-frequency hearing-deficient patients. The significance of brief tone sound-evoked CNAP is under investigation. The incidence of an absent wave V in an ABR is not high, but hearing can be preserved in these patients.[23] In our study, useful hearing preservation in patients without wave V was 37.5% (Table 2). We expect alternative solutions to monitoring cochlear nerve damage during surgery in order to improve hearing preservation and guide better surgical strategies.

When wave V is detected, a delay in wave V latency is usually a good indicator. However, there is a point to estimate cochlear nerve damage during surgery by a delay in wave V latency during surgery. As we described, wave I-V interpeak latency was prolonged compared to the non-tumor side. Similarly, the latency of wave V was delayed compared to the non-tumor side. Even if the I-V interpeak latency or absolute latency of wave V is used as an indicator, estimation of the delay in wave V (or prolongation I-V interpeak latency) during surgery may not completely reflect cochlear nerve damage. Before surgery, the cochlear nerve is likely already damaged by the tumor, even if preoperative hearing is useful, especially in AAO-HNS Class B. During microvascular decompression surgery for hemifacial spasm, the intraoperative 0.4-ms delay in wave V latency is thought to be the safety limit for hearing, and a 1-ms delay is thought to be critical.[24] Therefore, during acoustic neuroma surgery, a 0.4-ms delay in wave V latency must be critical for hearing when a 0.6-ms delay in wave V latency is recorded before surgery. The mean interaural latency difference of wave V in this study was over 0.6 ms in Class A before surgery. We recommend, before surgery, that ABR should be recorded by stimulation of both sides and the latency of wave V or I-V interpeak latency on both sides is important and should be considered.

Thus, stimulation on both sides, CNAP and alternative sound stimulation are alternative methods that should be considered for intraoperative monitoring of acoustic neuroma surgery. However, it is also important to estimate ABR before surgery.

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## Conflicts of Interest Disclosure

The authors report no conflicts of interest concerning the materials or methods used in this study or the findings specified in this article.

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