

Amplitude and area ratios of summing potential/action potential (SP/AP) in Meniere's disease

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Abstract

Conclusions. Our results suggest that summing potential/action potential (SP/AP) area ratio may not necessarily have higher sensitivity in the diagnosis of endolymphatic hydrops of Meniere's disease (MD) than SP/AP amplitude ratio in transtympanic electrocochleography (ECoChG). **Objective.** Recent studies suggested that SP/AP area curve ratio was more sensitive to endolymphatic hydrops in comparison with SP/AP amplitude ratio in extratympanic ECoChG. The purpose of the present study was to evaluate the utility of the SP/AP area curve ratio in transtympanic ECoChG for the diagnosis of MD. **Patients and methods.** A retrospective chart review of 198 patients (209 ears) was conducted in cases of MD. **Results.** With regard to SP/AP amplitude ratio, 57.1% in definite cases of MD (group 1), 39.6% in probable cases of MD (group 2), and 50.0% in the cases who had transformed from probable MD to definite MD (group 3) showed abnormally high values, respectively. Abnormally high values were observed in 43.9%, 27.7%, and 30.0% in SP/AP area ratio in groups 1, 2, and 3, respectively, indicating that abnormal values were observed more frequently in the amplitude ratio than in the area ratio in all three groups.

Keywords: *Amplitude ratio, area ratio, electrocochleography (ECoChG), summing potential/action potential (SP/AP), Meniere's disease*

Introduction

Elevated summing potential/action potential (SP/AP) amplitude ratios in electrocochleography (ECoChG) have been observed in many animal models of endolymphatic hydrops (ELH) [1,2]. Clinically, SP/AP amplitude ratio has been widely used as one of the useful indicators for the detection of ELH in Meniere's disease (MD). However, in previous studies on ECoChG in patients with MD, the percentage of elevated SP/AP amplitude ratios was varied, ranging from approximately 60% to 90% [3–7]. There have been many attempts to develop quantitative diagnostic tests in the diagnosis of MD and ELH including ECoChG; however, there has been no ideal test with high sensitivity. Therefore, a more sensitive diagnostic tool for MD and ELH has been anticipated. Recently, it was reported that the SP/AP area curve ratio in extratympanic ECoChG

significantly improved the diagnostic sensitivity of ELH in comparison with conventional SP/AP amplitude ratio in MD [8,9]. Ferraro and Tibbils [8] showed that the SP/AP area curve ratio was abnormally high in 44% of probable cases of MD (11/25) as well as in 90% of definite cases of MD (18/20). Devaiah et al. [9] compared SP/AP amplitude ratio and SP/AP area ratio in eight patients with possible MD, and showed that abnormally high values were observed in seven of the eight patients in the SP/AP area curve ratio, whereas they were observed in only four patients in the SP/AP amplitude ratio. Thus, SP/AP area ratio seems a promising measuring method and if the SP/AP area ratio indicates higher sensitivity to ELH, it is expected that the SP/AP area ratio can also become a more helpful diagnostic tool to predict probable cases of MD that are enigmatic as regards ELH as well as definite cases with MD.

However, to the best of our knowledge, of approximately 300 papers on ECoChG in MD that have been published there is no study evaluating SP/AP area ratio recorded by transtympanic ECoChG among the classification of MD based on the criteria of the Committee on Hearing and Equilibrium of the American Academy of Otolaryngology-Head and Neck Surgery guidelines (AAO-HNS, 1995) [10]. Therefore, we retrospectively compared the diagnostic sensitivity between SP/AP amplitude ratio and SP/AP area ratio in patients with definite MD in our recordings of transtympanic ECoChG and investigated whether SP/AP area ratio showed higher sensitivity than SP/AP amplitude ratio in cases with probable MD, and also whether transformation from probable MD to definite MD can be predicted by SP/AP area ratio.

Patients and methods

Classification of patients

In the present study, a retrospective chart review of a 15-year period (1982–1996) was conducted and among approximately 2000 cases who underwent ECoChG, 198 patients (209 ears) with MD (76 males and 122 females) were selected as subjects, for whom complete records of both clinical course and ECoChG were preserved. Diagnosis was based on the criteria of the Committee on Hearing and Equilibrium of the American Academy of Otolaryngology-Head and Neck Surgery guidelines (AAO-HNS, 1995) [10]. The subjects were divided into three groups. Group 1 contained 95 patients (98 ears) with definite MD. Patients with probable MD were divided into two groups to investigate whether SP/AP area ratio could predict transformation from probable MD to definite MD. One group contained 101 patients (101 ears) – possible cases of MD who did not transform to definite MD (group 2) – and the other group contained 10 patients (10 ears) who transformed to definite MD during a period of 1 month to 17 years of observation (group 3). As normal subjects, 16 volunteers (16 ears) were also examined.

Technique for ECoChG recording

All ECoChG was recorded by the transtympanic electrode technique. The active electrode was made of a stainless steel needle (0.2 mm in diameter) and was enameled except at the tip, which was pointed. A reference electrode was placed on the ipsilateral earlobe, and a ground electrode was placed on the forehead. The recording electrode was connected by shielded low-noise cables to a wide-band differential preamplifier. The amplified signals were then routed

to a bandpass filter with a setting of 15 Hz to 4 kHz for the measurement of AP, SP, and cochlear microphonics (CM) at 0.5 kHz, and 15 Hz to 10 kHz for the measurement of CM at 4 kHz. The signals were then summed up by a computer (Signal Processor 7T08, Sanei, Japan) [5]. Sample size varied from 50 to 400 depending on the signal-noise ratio of the response in the ongoing background activity. The average responses were recorded by an XY recorder. The acoustic stimulation used for the measurement of AP and SP was a click produced by one cycle of 4000 Hz at 90 dB HL. Click stimuli were alternated in polarity to prevent the appearance of the CM in the average response. The impedance between the promontory and reference electrodes was always maintained within 10 k Ω .

Measurement of the SP/AP amplitude and area ratio

The SP amplitude was defined as the difference in the amplitude between prestimulation baseline and the first trough, while the AP amplitude was measured from the onset of the SP deflection to its first negative peak in a manner previously described by us in several studies (Figure 1). The SP and AP areas were also measured referring to previous studies [8]. An image of a wave form of AP and SP complex was captured by an image scanner (ES 2200, Epson, Japan). The outline of the captured image was then traced by use of a computer mouse and the area was calculated using NIH Image (version 1.62) (Figure 2). Upper limits of normal (ULN) SP/AP amplitude ratio and the SP/AP area ratio were defined by two standard deviations (SD) from the mean of normal subjects. Cases in which it was impossible to trace the outline (positive SP) were excluded from the study.

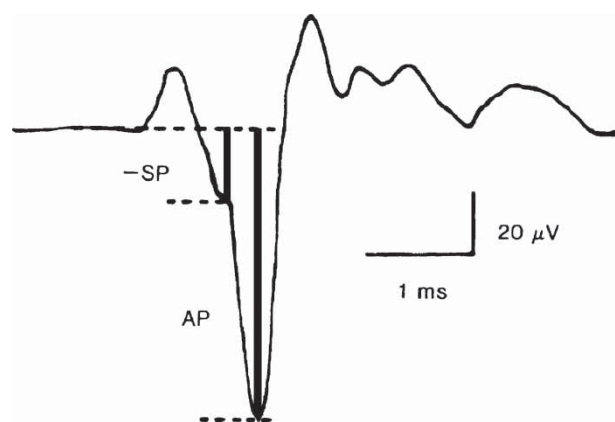


Figure 1. Method for measuring the amplitudes of the summating potential (SP) and action potential (AP).

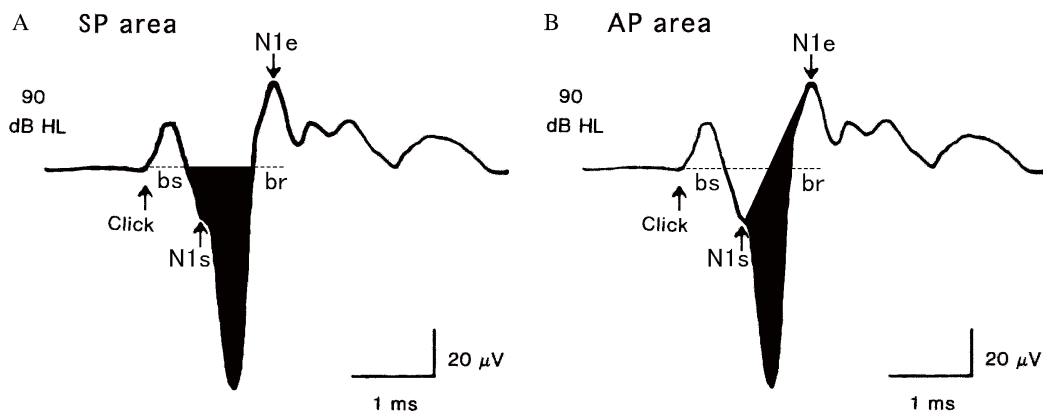


Figure 2. Methods for measuring the summing potential (SP) area (A) and action potential (AP) area (B) in electrocochleography (ECoChG). Br, base line returned; bs, baseline start; N1s, start of N1; N1e, end of N1.

Results

In normal subjects, the ULN of SP/AP amplitude and area ratios were determined as 0.314 (mean \pm SD = 0.198 ± 0.058) and 1.56 (mean \pm SD = 1.086 ± 0.237), respectively (Table I). In the SP/AP amplitude ratios, abnormally higher values than the ULN were observed in 57.1% (56/98 ears), 39.6% (40/101 ears), and 50.0% (5/10 ears) in groups 1, 2, and 3, respectively, while in the SP/AP area ratios it was observed in 43.9% (43/98), 27.7% (28/101), and 30.0% (3/10) in groups 1, 2, and 3, respectively. Abnormally high values occurred significantly more often in the SP/AP amplitude ratio than in the area ratio in group 1 (SP/AP amplitude ratio mean \pm SD 0.378 ± 0.201 , SP/AP area ratio mean \pm SD 1.973 ± 1.550 , Table II, χ^2 test, $\chi^2 = 3.841$, $p < 0.05$). However, no significant difference was found in the remaining two groups.

Discussion

From the viewpoint of electrophysiology, it is assumed that a prolonged SP-AP complex should be generated by ELH, in which the initial movement of the basilar membrane may be more restricted by a load of excessive endolymph volume. Since the latency of the AP depends on the velocity of the traveling wave [11,12], and since AP latency differences for condensation to rarefaction clicks may not

Table I. Values of SP/AP amplitude ratio and SP/AP area curve ratio in normal subjects.

Normal subjects	SP/AP amplitude ratio	SP/AP area curve ratio
Mean \pm SD	0.1981 ± 0.237 (0.102–0.266)	1.086 ± 0.237 (0.696–1.449)
ULN	0.314	1.56

SP, summing potential; AP, action potential; ULN, upper limits of normal.

Table II. Values of SP/AP amplitude ratio and SP/AP area curve ratio in definite cases with Meniere's disease.

Definite Meniere's disease	SP/AP amplitude ratio	SP/AP area curve ratio
Mean \pm SD	0.378 ± 0.201 (0.037–1.280)	1.973 ± 0.550 (0.022–10.62)

SP, summing potential; AP, action potential.

be pronounced correctly under the condition of ELH, AP latency would be prolonged in ELH. In addition, it was reported that a widening of the SP/AP complex observed in patients with MD was attributed to prolonged after-ringing of the CM [13]. The concept that SP/AP area ratio may be more sensitive to the presence of ELH is based on an idea that measurements of the SP/AP area ratio can capture the essence of both amplitude and duration changes observed in a prolonged and widened SP-AP complex induced by an alteration of traveling waves in a hydroptic ear. To improve diagnostic sensitivity of ECoChG to the presence of ELH in MD, SP/AP area ratio seemed useful theoretically, and we expected that the SP/AP area ratio would show higher sensitivity than the SP/AP amplitude ratio. However, the results of the present study were contrary to our expectation.

Discrepancies in our present results and those of the previous studies on SP/AP area ratio may result from differences in methods used for measuring the area. The observation period in the present study was longer than the observation periods of previous studies on SP/AP area ratio. In general, the clinical method has changed very little over a long period. If instruments or methods used for ECoChG in the present study had changed during our observation period, measurements of SP and AP by different methods would have been included in our results. As our instruments and methods were not changed

during the whole observation period, changes of sensitivity of SP/AP amplitude or area ratio due to changes in methods over the long observation period can be excluded. However, different methods for analyzing images of SP and AP wave forms may account for the discrepancies in our results as compared with previous studies. We used NIH Image to analyze SP/AP area ratio, and a manual procedure was included. For instance, the outlines of captured images of SP/AP wave forms were manually traced by use of a computer mouse in the present study. In contrast, Ferraro and Tibbils [8] and Devaiah et al. [9] used the Nicolet Path fiber or Nicolet SPIRIT system that calculated the whole procedure in a digital manner. In our method, the possibility that an error in manual operation could occur during a calculation of the area cannot be entirely excluded.

As another explanation for the discrepancy, we may point out the differences of instrumentation settings and recording methods. For instance, it is known that there is wide variation with regard to the upper limits that come from the difference between transtympanic and extratympanic recordings [14]. In the present study, transtympanic recordings were performed; however, extratympanic recordings were used in the previous studies on SP/AP area ratio. In previous studies on transtympanic ECoChG, an SP/AP amplitude ratio of 0.33 was used as the ULN [14–17], which is similar to the ULN in our transtympanic recordings. On the contrary, although there was wide variation ranging from 0.34 [18] to 0.51 [19] in the ULN of SP/AP amplitude ratio in the previous extratympanic recordings evaluating SP/AP area ratio, a value of approximately 0.40 has been employed as the ULN of SP/AP amplitude ratio. Although the ULN of SP/AP area ratio (1.51) in the present study is similar to the ULN of SP/AP area ratio in the previous studies evaluating SP/AP area ratio, the ULN of SP/AP amplitude ratio in the previous studies seems to be higher compared with the ULN of our SP/AP amplitude ratio. Although it is not certain if the tendency for the ULN of SP/AP amplitude ratio in extratympanic ECoChG to be higher than those in transtympanic ECoChG, it may have effected the discrepancy between our results and previous studies on sensitivity of the SP/AP area ratio. This possibility cannot be completely ruled out. If sensitivity of the SP/AP area ratio to ELH easily changes according to various methods of measurement, we should reconsider whether the SP/AP area ratio is a truly suitable indicator of ELH and the essential meanings of SP/AP area ratio. Further studies are required to confirm whether the SP/AP amplitude ratio is more sensitive in

transtympanic ECoChG and the SP/AP area ratio is more sensitive in extratympanic ECoChG.

In addition, although it can be concluded from our results that the SP/AP area ratio is not suitable to predict the presence of ELH in cases of probable MD, one of the objectives of ECoChG is to detect early MD and ELH. Kimura et al. [20] suggested that the combination of ECoChG and the glycerol test was helpful in diagnosing ELH and that ECoChG and the glycerol test were effective tools for predicting the progression to definite MD in patients with atypical MD. To increase the sensitivity of the early diagnosis of MD and ELH, further studies evaluating the diagnostic sensitivity of the SP/AP area ratio in combination with the SP/AP amplitude area and other parameters such as vestibular evoked myogenic potentials (VEMPs) or the glycerol test should be conducted.

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