Utility of Area Curve Ratio Electrocochleography in Early Meniere Disease

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Background: Electrocochleography (ECochG) is useful in supporting the diagnosis of Meniere disease (MD). Possible MD (early disease as defined by the 1995 American Academy of Otolaryngology–Head and Neck Surgery Committee on Hearing and Equilibrium) is a readily treatable form of MD.

Objectives: To identify whether ECochG summating potential/action potential (SP/AP) area curve measures are more sensitive than conventional SP/AP amplitude ratios in detecting possible MD.

Patients and Methods: A retrospective chart review of a 3-year period (1997-2000) was conducted. All charts of patients diagnosed as having MD who had undergone tympanic ECochG were examined to identify those with possible MD. Exclusion criteria were incomplete workup, ECochG performed using a prior system, cochlear microphonic spike obscuring ratio measurements, and prior otologic surgery. A control group of patients with normal SP/AP ratios and ECochG data were identified. SP/AP amplitude and area curve ratios for both groups were measured.

Results: Of 138 patients with MD reviewed, 20 (14%) had possible MD, and 8 passed exclusion criteria. An audiologist blinded to patients’ diagnoses performed all measurements. The upper limit of normal for SP/AP amplitude and area curve ratios from the control group of ears (n=13) (∝= .05) were similar to previously published results. Of the 8 patients with possible MD, 4 had an abnormal SP/AP amplitude ratio, and 7 had an abnormal SP/AP area curve ratio; the difference between groups was statistically significant (P=.03, χ²).

Conclusions: The SP/AP area curve ratio significantly improves ECochG diagnostic sensitivity in possible MD. This ECochG refinement will allow earlier intervention to preserve inner ear function in MD.

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been explored, and is the subject of this study.

A senior author (G.A.A.) treated all patients. Treatment was performed using the Nicolet SPIRIT system (software version 2.0; Nicolet Biomedical Inc, Madison, Wis), as described in previous studies. Briefly, placement of the gelled, cotton-tipped primary electrode on the tympanic membrane was confirmed by direct visualization as well as monitoring of the electrophysiologic noise floor during advancement. The contralateral earlobe and nasion were used for secondary and ground electrode placements, respectively. Stimuli consisted of alternating polarity clicks (100-microsecond electrical pulses) presented at 90 decibels hearing level at a rate of 11.3/second. For each trial, electrophysiologic responses to as many as 1000 signal repetitions were averaged over a 10-millisecond poststimulus time frame. Trials were repeated at least twice, and averaging of trials was performed to produce final waveform tracings.

The SP amplitude was calculated from stimulus onset to the first trough (SP), while AP amplitude was measured from the onset of the AP deflection to its first negative peak (ie, N1) (Figure). The ratio of these measures was computed for each patient. The SP/AP area ratios were calculated in accordance with a previous study using a new subroutine for measuring the area under a curve. The SP area was determined by measuring from response onset (defined as baseline voltage) to the next point following N1 where the waveform returned to baseline. The AP area was defined from the onset of the AP to its first positive peak following N1. Ratios of these values were calculated for each patient by an audiologist (K.L.D.) blinded to the clinical diagnosis.

The presence of a cochlear microphonic (CM) spike in the ECochG tracing was also determined for each tracing. The number of patients whose ECochG tracing could be accurately examined for SP/AP ratio and area ratios were determined. Patients with a CM spike that compromised either measure were excluded from this study.

CONTROL PATIENT POPULATION

A random alphabetical sample of patients with normal SP/AP ratios were evaluated by retrospective chart review. Patients without evidence of MD or perilymphatic fistula were included in the control population analyzed for comparison. These patients’ ECochG data were compiled (2 ears per patient) for analysis of SP/AP amplitude and area ratios.

STATISTICAL ANALYSIS

The mean and SD were computed for the control population SP/AP amplitude and area ratios. The SP/AP amplitude and area ratios cutoff values were defined at the 95th percentile using the distribution of normative data derived from the control group (α = .05). All statistics were computed using Microsoft Excel software (Microsoft Corp, Redmond, Wash).

PATIENT DEMOGRAPHICS

There were 138 patients with MD (all subcategories). Of these, 20 patients presented with possible MD, and 8 patients passed all exclusion criteria. The mean age of the 8 patients was 49.9 years. Female patients accounted for 79% of the sample (6 of 8 patients). Left ears were symmetric in 7 of the 8 cases. Thirty ear measurements from 8 patients met all inclusion criteria for the control group.

AUDIOMETRIC DATA AND ECochG FINDINGS

All patients with possible MD were classified as stage 1 by 1995 AAO-CHE guidelines. There was no significant hearing deterioration noted in any of the patients tested.

METHODS

MD PATIENT SELECTION AND AUDIOMETRIC DATA

A 3-year (1997-2000) cross section of patients seen at the University of Kansas for MD was reviewed for this study. A retrospective chart review was performed to identify patients with the possible MD subcategory as defined by the AAO-CHE guidelines. Audiometric data for stage classification (using the pure-tone average at 0.5, 1, 2, and 3 kHz) were also obtained using these guidelines. Patients were excluded for prior otologic surgery, incomplete workup, or ECochG performed using the previous systems (without the software to measure the area ratio). A senior author (G.A.A.) treated all patients.

ECochG METHODOLOGY

All ECochGs were performed at the University of Kansas by a senior author (J.A.F.) using the Nicolet SPIRIT system (software version 2.0; Nicolet Biomedical Inc, Madison, Wis), as described above.

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There were no CM spikes obscuring the measurements of patients with possible MD. One patient in the control population was excluded for a CM spike that obscured reliable measurement of the SP/AP ratio.

### SP/AP AMPLITUDE RATIO

The Table depicts results for the 8 patients with possible MD. The control population had amplitude ratios in the range of 0.06 to 0.46 (mean, 0.32; SD, 0.11; upper limit of normal [ULN], 0.53 for \( \alpha = 0.05 \)). By using the ULN as the cutoff for abnormal results, 4 patients (50% with possible MD) had elevated SP/AP ratios.

### SP/AP AREA RATIO

Area ratios for the 8 patients with possible MD are listed in the Table. Results of control population SP/AP area ratio measurements ranged from 1.02 to 1.75 (mean, 1.34; SD, 0.30; ULN, 1.94). Elevated SP/AP area ratios were seen in 7 patients with possible MD.

### COMPARISON OF AMPLITUDE AND AREA RATIOS FOR POSSIBLE MD

Positive and negative results for each method in analyzing ECochG results were compared using the \( \chi^2 \) statistic. Using the amplitude ratio measure, there were 4 positive results and 4 negative results; with the area ratio measure, there were 7 positive results and 1 negative result. The difference between positive SP/AP area ratios and amplitude ratios was statistically significant (\( P = .03 \)).

### CORRELATED SYMPTOMS DURING ECochG

The symptomatic status of patients at the time of ECochG was examined (Table 1). Symptoms included vertigo, aural pressure/fullness, and tinnitus. Of the 8 patients with possible MD, 6 were symptomatic at the time of testing. Of these 6 patients, 4 had elevated SP/AP amplitude ratios, and 5 had elevated SP/AP area curve ratios (positive predictive value of 67% and 83%, respectively).

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**Table: Results of Patients With Possible Meniere Disease**

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Affected Ear</th>
<th>Amplitude Ratio</th>
<th>Area Ratio</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>R</td>
<td>L</td>
<td>R</td>
</tr>
<tr>
<td>1</td>
<td>L</td>
<td>0.59</td>
<td>0.39</td>
<td>2.31</td>
</tr>
<tr>
<td>2</td>
<td>L</td>
<td>1.46</td>
<td>0.16</td>
<td>6.06</td>
</tr>
<tr>
<td>3</td>
<td>L</td>
<td>0.45</td>
<td>0.80</td>
<td>10.66</td>
</tr>
<tr>
<td>4</td>
<td>R</td>
<td>0.85</td>
<td>0.27</td>
<td>4.18</td>
</tr>
<tr>
<td>5</td>
<td>L</td>
<td>0.22</td>
<td>0.88</td>
<td>2.21</td>
</tr>
<tr>
<td>6</td>
<td>L</td>
<td>0.40</td>
<td>1.28</td>
<td>3.85</td>
</tr>
<tr>
<td>7</td>
<td>L</td>
<td>0.30</td>
<td>0.26</td>
<td>1.45</td>
</tr>
<tr>
<td>8</td>
<td>L</td>
<td>0.15</td>
<td>0.39</td>
<td>1.20</td>
</tr>
</tbody>
</table>

*Summating potential/action potential (SP/AP) amplitude and area ratios for left ear (L) and right ear (R). The upper limit of normal for SP/AP amplitude ratio was 0.53 and for SP/AP area curve, 1.94 (\( \alpha = 0.05 \)). Double plus sign indicates positive, because electrocochleogram did not return to baseline.

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**CONTRALATERAL FINDINGS**

The SP/AP amplitude and area ratios for the contralateral ears were examined. For SP/AP amplitude ratios, 2 of the 8 patients had positive results in the contralateral ear with negative results in the ipsilateral ear. No patient had bilateral positive amplitude ratios.

For the SP/AP area ratio, 6 patients had positive findings in the contralateral ear. The single patient with possible MD who did not have a positive ipsilateral area ratio also did not have contralateral findings.

**COMMENT**

The use of ECochG in supporting the diagnosis of MD has become standard testing for many physicians. Margolis et al found that ECochG can be a sensitive test in the early stages of MD, and that the specificity approached 95%. However, the sensitivity of the test ranges from 20% to 70%. Some explanations for the variation in sensitivity include patient hearing levels, method of stimulation, cutoff for positive interpretation, ECochG characteristic measured, and location of electrode; in general, a sensitivity around 60% is a consistent expectation.

Medical intervention in the early stages of MD can help preserve inner ear function, and therefore it is important to identify these patients with possible MD. This particular subpopulation of MD patients has the best chance for functional preservation with intervention, but unfortunately possible MD has an enigmatic presentation. This can delay the diagnosis to the point where inner ear function may be compromised. This group of patients is uniquely poised to benefit from any method to increase sensitivity in confirmatory testing. We advocate initiation of medical therapy for MD based on the clinical presentation consistent with possible MD, exclusion of other pathological conditions, and confirmation with area curve ratio when the SP/AP ratio is negative. In cases where the clinical suspicion is high for possible MD, ECochG is negative (by either area curve or amplitude ratio), and the patient can tolerate medical therapy, we advocate initiating medical therapy (sodium intake restriction with or without diuretic therapy) immediately to see if patients will respond. The dura-
tion of empiric medical therapy, as well as repeated audiogram and ECochG, is tailored to the patient based on symptom progression; testing should be repeated if the patient’s previous workup results are negative but symptoms continue to worsen.

To improve the likelihood of detecting ECochG abnormalities in patients with possible MD, we now calculate both the area curve ratio and amplitude ratio measurements. The SP/AP area curve ratio is sensitive to the widening of the SP/AP complex, which is not detected by computing SP/AP amplitude ratios.4,10 Ferraro and Tibbils1 looked at the SP/AP area ratio using a control population for comparison. In addition, they classified patients according to 1995 AAO-CHE subgroups of MD, focusing on those with more clear-cut symptoms consistent with MD. They found excellent agreement between SP/AP area ratios and amplitude ratios, and an improvement in sensitivity using the area ratio. However, patients with possible MD were not included in their study.

Our results show that the SP/AP area ratio significantly improves detection compared with the SP/AP amplitude ratio. To help support these findings, a control group was established to provide normative data, compare with our MD group, and help validate our results through comparison with previous studies. Our results for the control group’s SP/AP amplitude ratio mean, SD, and ULN were in close agreement with previously published results.1,8-10 The results of our SP/AP area curve ratio mean, SD, and ULN were close, but slightly higher, than previously reported results.1 This finding may contribute to an increased false-negative rate, but would have affected the outcome of only one of the patients in this study. Given a larger sample size, the possibility of a high false-negative rate may be a limiting factor. However, the margin by which the patients with positive results exceeded the 95th percentile for area curve argues against that, and we would have suspected that such a problem would have more profoundly affected our sample as well.

Another explanation for our success with the area ratio may be attributed to our patients with possible MD having good hearing, as they were all at stage 1. Others have noted that with deteriorating hearing, likely due to the loss of hair cells and spiral ganglion cells, the SP and AP amplitudes can be reduced.14 Nevertheless, other results have shown that SP/AP amplitude ratios are consistently elevated except in stage 4.15 Given these findings and the fact that our sensitivity with SP/AP amplitude ratios is similar to that of other studies, it is less likely that the increased sensitivity with SP/AP area ratios is due entirely to hearing status.

Our measurements from the contralateral ears are also interesting. Our findings for SP/AP amplitude ratio parallel previously published percentages, but rates can vary.9,16,17 When using the area ratio computation, there are more positive contralateral ears. We found a trend in the area ratio being more sensitive in detecting contralateral disease, but there are too few patients to detect a statistical significance. The other possibility is that we are seeing an increased false-positive rate, but this is less likely since our ULN cutoff for area curve ratios is slightly higher than (but in reasonable agreement with) previously published data.1 Other studies report various rates of bilateral disease.16,17 One could follow these patients longitudinally to see if they developed symptoms in the contralateral ear. In our study, however, these patients were all treated successfully with medical therapy, thus precluding such an analysis.

The patient demographics portray certain characteristics of our sample. The majority of patients were female, which is not an unusual bias.9 There was a preponderance of left ears as well. To our knowledge, there is no known interaction between ECochG reliability with gender or side of lesion.

The presence of a CM spike was not a confounding issue in the possible MD population examined in this study. There was one patient from the control group who was excluded due to a large CM spike that made accurate SP/AP ratio determination impossible. An area of further study would be the examination of area curve ratios to see if they improve the sensitivity and specificity of ECochG in patients with a large CM spike.

It is possible that false-positive results occurred using this technique. However, all patients in this study were screened for other pathological conditions and responded to therapy for MD. Using our strict criteria for inclusion in this study, we have attempted to minimize the possibility of false-positive results. Certainly the diagnosis of MD is one of exclusion. Using strict inclusion criteria for this study helps ensure that the significantly improved results with our area curve ratio measurement technique minimizes false-positive results.

Another potential drawback of the study is the limited sample size. The exclusion criteria to avoid certain biases, the relative infrequency of early MD presentation, and the difficulty in making this diagnosis all negatively impact on sample size. Despite these limitations, our decidedly positive findings in regard to SP/AP area curve ratio use and our agreement with previous studies in examining the computed SP/AP amplitude ratios support the hypothesis that the area curve ratio significantly improves the sensitivity of ECochG.

The SP/AP area curve ratio significantly improves ECochG diagnostic sensitivity in possible MD. This refinement of ECochG analysis can allow diagnosis of MD at an earlier stage of disease and hasten intervention to prevent inner ear deterioration. We recommend the use of ECochG with SP/AP area curve analysis in examining individuals who portray clinical signs and symptoms suggestive of this disorder.

**CONCLUSIONS**

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REFERENCES


Papers From the AHNS 2002 Meeting

Papers From the AHNS 2002 Meeting to Be Continued in July 2003

The Archives is pleased to be publishing additional papers from the Annual Meeting of the American Head and Neck Society, Boca Raton, Fla, May 2002, in the July 2003 issue. Be sure to look for these in the July issue, in addition to the AHNS papers published in the January 2003 Archives.