The Sensitivity and Specificity of Vestibular Evoked Myogenic Potential (VEMP) in the Diagnosis of Definite Ménière’s Disease Patients

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Abstract
Objective
This study was a retrospective review of the data to compare the sensitivity and specificity of cervical VEMP (cVEMP) in unilateral definite Ménière’s Disease (MD) patients with those in Vestibular Migraine (VM) and control subjects.

Material and Method
All patients diagnosed as unilateral definite MD and Vestibular Migraine (VM) patients and normal control adults whom underwent cVEMP tests with short tone burst of 500 Hz. at 95 dBHL during January 2007 - December 2015 were included in this study. Age, gender, routine audiometric and cVEMP results were collected. SPSS for windows was used in data analysis; F-test, Chi-square and Fisher’s exact test were used for comparison of the means and percentages.

Results
The unilateral definite MD group (22 males, 45 females) had mean age of 50.62 ± 9.41 years and mean Pure Tone Average (PTA) in the affected ears (Rt.ear = 37, Lt. ear = 30) of 45.95 ± 22.58 dBHL. The VM group (5 males, 51 females) had mean age of 49.04 ± 9.85 years and mean PTA in Rt. and Lt. ears of 18.96 ± 7.65 and 19.41 ± 7.96 dBHL, respectively. Normal control adults (13 males, 19 females) had mean age of 45.47 ± 9.54 years and mean PTA on both ears of 16.02 ± 6.28 dBHL. The percentage of abnormal cVEMP result found in the MD group was significantly different from those in the VM (62.68% vs 19.64%; Fisher’s exact test, p<0.0001) and control groups (62.68% vs 3.12%; Fisher’s exact test, p<0.0001). The sensitivity and specificity of cVEMP in MD were 62.68 and 96.88%, respectively. The percentage of abnormal cVEMP in MD was significantly higher than those in the VM and control groups.

Conclusion
The percentage of abnormal cVEMP in MD was highly significant over those in VM and control groups. Although the sensitivity of cVEMP in unilateral MD was not dominantly better than other vestibular test battery for the diagnosis of MD, these findings supported more saccular dysfunction, the second most often occurred lesion, in MD than in VM group. However, the high specificity (96.88%) of abnormal cVEMP in MD and VM showed non-specific pathology involving the saccule. The results suggested that cVEMP should be used as a confirmative test or for staging of the disease progression to differentiate between MD vs. VM rather than a screening test for detection of hydrops.

Keywords: Cervical Vestibular Evoked Myogenic Potential (cVEMP), Ménière’s disease, Sensitivity; Specificity; Vestibular migraine

Introduction
Ménière’s Disease (MD) is an inner ear disease, which is characterized by episodic vertigo, fluctuating sensorineural hearing loss, aural fullness, and tinnitus. MD has been diagnosed mainly based on clinical criteria [1]. Laboratory investigations such as Electrocochleography (ECochG), caloric, and glycerol or dehydrating tests [2], however, are helpful in some cases. The sensitivity and specificity of these tests for detecting MD are varied. The ECochG shows sensitivity of 60 to 65% depending on electrode sites [3-6]. A significant reduction of caloric response is found in 48 to 74% of patients with MD [7-10]. In addition, the sensitivity of the glycerol test is reported at 50-60% [11-12]. Each tool has limitation either in site of lesion or unpleasant side effects during the procedure. The cervical Vestibular Evoked Myogenic Potential (cVEMP) has been suggested as being useful in supporting the diagnosis of MD as information of the saccular involvement of the labyrinth, including the pathway from the saccule, inferior vestibular nerve, vestibular nucleus, vestibulospinal tract, through the Sternoclidomastoid (SCM) muscle [13-15].

Vestibular migraine and MD seem to share some similar clinical symptoms and laboratory profiles [16]. Many studies investigated cVEMP sensitivity in Ménière’s patients showing various results ranged from 50% to 75% [17-28]. To set our laboratory protocols, this retrospective review in Thai patients aimed to compare the sensitivity and specificity of the cVEMP results in unilateral definite MD patients with those in vestibular migraine patients and healthy controls.

Subjects and Methods
All patients with unilateral definite MD and Vestibular Migraine (VM) who were treated at the Otolaryngology clinic at Ramathibodi Hospital during January 2009 - December 2015 were included. The diagnosis of the MD was defined by the 1995 criteria of the AAO - HNS [1]. The VM patients were diagnosed according to the criteria suggested by Neuhauser and Lempert [16].

The cVEMP data from 32 healthy control subjects described in the previous report were used as normal controls [29]. Each subject gave
a detailed history and underwent physical examination, a routine audiometry, and the cVEMP tests using 500 Hz tone burst at 95 dBHL as stimulus [29]. The measurement of cVEMP response, which was considered “abnormal,” included absent response or abnormal Asymmetry Ratio (AR). The 35% cut-off was used as the upper limit of normal AR response in Thai subjects [29].

Data analysis

SPSS for Windows was used for data analysis in comparison of the percentage and means. Age, gender, and Pure Tone Average (PTA) at 500, 1000, 2000 and 3000 Hz were collected. The Fisher’s exact test (F - test) was used to test for the mean age among different subject groups. The Chi - square test was used to compare the percentages of abnormal cVEMP response among all groups while the Fisher’s exact test was used to compare those between two groups. The sensitivity and specificity of the cVEMP results in the MD group and the VM group were investigated and compared.

Results

Table 1 showed the demographic data for each group. No significant difference in age was found among all groups (F - test, p = 0.066). However, the majority of the patients in the VM group were female showing significant differences from those in the MD and control groups (p<0.05). The PTA hearing thresholds in the MD group were significantly higher than those in both the VM and control groups (p<0.001). There was no significant different between the VM and control groups.

Table 2 shows that 62.68% of the patients in the MD group, compared to nearly 20% of the patients in the VM group, had abnormal cVEMP responses. Only one subject in the control group showed abnormal cVEMP response. The Chi - square test of cVEMP and disease status percentages showed a significant difference at p<0.001. The Chi - square test of these percentages showed significant differences from those in the MD and control groups (p<0.05). The PTA hearing thresholds in the MD group were significantly higher than those in both the VM and control groups (p<0.001). There was no significant different between the VM and control groups.

Discussion

The possibility of having a lower cVEMP threshold could be found in other inner disorders, such as dehiscence, perilymph fistula, and BPPV [17,30]. The cVEMP test has been widely used to detect sacular dysfunction. The abnormalities of VEMP findings in patients with MD and VM have been previously reported [16-24,31-35]. The sensitivity of cVEMP in patients with MD was higher in patients with MD than those with VM (62.68 vs. 19.64). On the other hand, the specificity of cVEMP for both groups was the same (96.88 vs 96.88). Individuals with MD were more likely to have abnormal cVEMP responses than those with VM, suggesting that sacular involvement occurs more frequently in the MD group than the VM group. This finding was consistent with that by Egami et al., They reported that cVEMP helped provide the appropriate diagnosis in 50% of 114 MD cases but had a specificity of 48.9% in other vestibular disorders. In the VM group, they reported a higher percentage of abnormal cVEMP than our study (29.3%) [31]. Absent or augmented cVEMP amplitude on the affected ear was found in 54% to 71% of MD patients [18,25,26]. On the other hand, the cohort study from Mexico found a similar reduction of cVEMP amplitudes in both the MD (n = 20) and VM (n = 21) groups [27].

The sensitivity of cVEMP in patients with MD has been reported with various results, ranging from 50% to 75% [17-28]. Various authors have investigated cVEMP in MD and have taken a wide range of parameters into consideration [17-24,28,30]. Rauch et al., [21] studied VEMP recordings from 14 normal individuals compared to those at stages 3 & 4 of MD than those at stages 1 & 2. Similarly, the proportions of individuals with abnormal cVEMP responses tended to be higher among the patients with more than 10 years of the disease onset than those with less than 10 years.

### Table 1: Demographic data.

<table>
<thead>
<tr>
<th>Data</th>
<th>MD (n = 67)</th>
<th>VM (n = 56)</th>
<th>Control (n = 32)</th>
<th>P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean ± SD) years</td>
<td>50.62 ± 9.41</td>
<td>49.04 ± 9.85</td>
<td>45.47 ± 9.54</td>
<td>0.066</td>
</tr>
<tr>
<td>Sex - Female (%)</td>
<td>45 (67.17)</td>
<td>51 (91.07)*</td>
<td>19 (59.37)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Male (%)</td>
<td>22 (32.83)</td>
<td>5 (9.03)</td>
<td>13 (40.63)</td>
<td></td>
</tr>
<tr>
<td>PTA (mean ± SD) dBHL</td>
<td>45.95 ± 22.58</td>
<td>LE = 19.41 + 7.96</td>
<td>16.02 + 6.28</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

**MD - Meniere’s Disease group, VM - Vestibular Migraine Group, SD - Standard Deviation, PTA = Pure Tone Average, RE = Right Ear, LE = Left Ear**

*Significant difference from other groups.

### Table 2: Number and percent of patients with normal and abnormal cVEMP results in different stage of MD.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Abnormal n (%)</th>
<th>Normal n (%)</th>
<th>Total n (%)</th>
<th>X²</th>
<th>P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>16 (57.14)</td>
<td>12 (42.86)</td>
<td>28 (100)</td>
<td>2.69</td>
<td>0.26</td>
</tr>
<tr>
<td>II</td>
<td>16 (59.26)</td>
<td>11 (40.74)</td>
<td>27 (100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>III &amp; IV</td>
<td>10 (83.33)</td>
<td>2 (16.67)</td>
<td>12 (100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>42 (62.69)</td>
<td>25 (37.31)</td>
<td>67 (100)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 3: Number and percent of patients with normal and abnormal cVEMP results based on duration of onset of the MD.

<table>
<thead>
<tr>
<th>Duration (years)</th>
<th>Abnormal n (%)</th>
<th>Normal n (%)</th>
<th>Total n (%)</th>
<th>X²</th>
<th>P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤5</td>
<td>21 (60.0)</td>
<td>14 (40.0)</td>
<td>35 (100)</td>
<td>2.408</td>
<td>0.3</td>
</tr>
<tr>
<td>&gt;5 - ≤10</td>
<td>14 (58.33)</td>
<td>10 (41.67)</td>
<td>24 (100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;10</td>
<td>7 (87.50)</td>
<td>1 (12.50)</td>
<td>8 (100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>42 (62.69)</td>
<td>25 (37.31)</td>
<td>67 (100)</td>
<td></td>
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</tr>
</tbody>
</table>
from 34 patients with MD. They found a significant difference in cVE-
MP amplitudes among normal ears, unaffected MD ears and affected
ears. With the low frequency tone bursts, the cVEMP was presented
in all normal subjects but only in 82 - 85% of MD ears. Later, they also
studied the clinical assignment of side - of - disease in 20 unilateral
Ménière's subjects to side assignment using AAO - HNS clinical cri-
teria and previous audiogram as gold standard compared to cVEMP
interaural threshold difference, caloric asymmetry, and multivariate
statistical analysis of a vestibular test battery. Their results showed that
the accurate method of side assignment scored correctly by 250 Hz.

The sensitivity of cVEMP was 80% and that for the click cVEMP was
55% [24]. Taylor et al., combined measurement of cVEMP by using an
abnormally low 0.5/1 kHz frequency ratio and/or an elevated 0.5 kHz
AR. They found a sensitivity of 75% and specificity of 80% in differen-
tiating MD from VM [30].

Difference in the percentage of abnormal cVE MP results in MD
might be due to differences in the protocol of study using TB of 500 Hz
that showed less sensitivity of using 1000 Hz. (resonance frequen-
cy tuning shift) [30] and also due to the number of study subjects and
variation in disease staging. Our study focused on the laboratory pro-
tocol, and the 500 Hz tone burst for cVEMP testing was used for other
vestibular disorders as well. However, when the test is abnormal, all
patients should have some pathology in the saccule, e.g., endolym-
phatic hydrops or ischemic process.

In MD, the ECochG is aimed mainly to identify cochlear hydrops;
meanwhile, a cochlear test is used for the detection of horizontal semi-
circular canal function. The sensitivity of ECochG was about 60 -
65% using ear tip-trode [3-6] and the sensitivity of acalaric test was
about 48 - 74% using 25 - 30% interaural different criterion [7,8,10],
while the test using dehydrating agents showed 50 - 60% of sensitivity
[11,12]. Although the sensitivity of cVEMP in this present study was
not superior to the previous audio-vestibular tests (ECochG, caloric
test, dehydrating agent), cVEMP was easier to perform, less uncom-
fortable, and well tolerated by patients. In addition, the cVEMP test
had no risk of hypotension, dizziness, nausea, vomiting, or muscle
weakness, in contrast to the test using dehydrating agents or a caloric
test. From clinical observations, the ECochG test took more time to
operate than the cVEMP test in the same cases. Moreover, it could be
performed on patients with severe to profound hearing loss in which
the ECochG test was confounded because of its limitation. Hence, the
cVEMP test should be included as one of the audio - vestibular test
battery for MD or other vestibular disorders suspected for a saccular
portion involvement.

A controversy was found in the cVEMP investigation in MD as the
percentage of abnormal cVEMP should be greater in more advanced
stages of the disease [31,33-35]. Moreover, a saccular involvement
showed to have a greater chance of having poor hearing outcome [35].
More importance in identifying abnormal cVEMP on unaffected ear
(35%) should alert a physician for possible subclinical hydrops on the
good ear [36]. Our study found a higher percentage of abnormal cVE-
MP in later stages (stage 3+4 = 83.33%) than in earlier stages and also
with longer durations of onset (>10 years = 87.5%) than shorter du-
rations; however, this was not statistically significant. There might be
variation in a small number of subjects especially in the more severe
and longer duration group.

The limitation of this study is a single institutional study with rel-
atively small sample size in each group particularly the control group.
However, our findings suggest that the cVEMP shows a fair effect as
a screening tool due to a slightly low sensitivity (62.68%) depending
on disease staging, but it could be used for identifying saccular in-
volve in the case of definite MD because of its high specificity
(96.88%). The results also suggest that cVEMP should be used as a
confirmative test or for staging of the disease progression to differen-
tiate between MD vs. VM patients rather than a screening test for the
detection of hydrops. Further study should be investigated for more
information regarding the exact parameter which could improve the
cVEMP testing protocol.

Conclusion

The usefulness of the cVEMP test for assessing saccular function
in MD has been widely reported. This study found that the sensitivity
and specificity of the cVEMP in patients with unilateral definite MD
were 62.68%, and 96.88%, respectively. The sensitivity of the cVE-
MP test in the MD group was significantly higher than in the VM
(19.64%) and control (3.12%) groups. These findings suggest that the
MD group shows a more saccular involvement than the VM group.
Also, we found that the VEMP test was not more sensitive than the
ECochG, caloric and dehydrating tests. Higher percentage of cVEMP
abnormality was found in patients who suffered for a longer duration
and a higher level of severity, indicating more saccular involvement.
Thus, the cVEMP test should be used as a confirmative test or for stag-
ing disease progression to differentiate between patients with MD and
VM rather than just as a screening test for the detection of hydrops.

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