Clinical Uses of Cervical Vestibular-Evoked Myogenic Potential Testing in Pediatric Patients

The Harvard community has made this article openly available. Please share how this access benefits you. Your story matters

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Published Version</td>
<td>doi:10.1097/MD.0000000000000037</td>
</tr>
<tr>
<td>Citable link</td>
<td><a href="http://nrs.harvard.edu/urn-3:HUL.InstRepos:23474037">http://nrs.harvard.edu/urn-3:HUL.InstRepos:23474037</a></td>
</tr>
<tr>
<td>Terms of Use</td>
<td>This article was downloaded from Harvard University's DASH repository, and is made available under the terms and conditions applicable to Other Posted Material, as set forth at <a href="http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#LAA">http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#LAA</a></td>
</tr>
</tbody>
</table>
Clinical Uses of Cervical Vestibular-Evoked Myogenic Potential Testing in Pediatric Patients

Guangwei Zhou, MD, ScD, Jenna Dargie, BS, Briana Dornan, AuD, and Kenneth Whittemore, MD

Abstract: To demonstrate the feasibility and clinical significance of cervical vestibular-evoked myogenic potential (cVEMP) test in pediatric patients.

In 2006, we started to implement cVEMP test for diagnostic purposes in our clinic. To address the increasing demand of vestibular evaluation, we decided to conduct this retrospective review of cVEMP testing in children at our facility to meet the increasing demand of vestibular complaints. To demonstrate the clinical value of cVEMP test in children and share our experience of this practice, we decided to conduct this retrospective review of cVEMP testing in >200 pediatric cases.

Materials and Methods

Our study was approved by the institutional review board at Boston Children’s Hospital.

Patient Selection

After reviewing all available records, we identified a total of 278 pediatric patients who underwent cVEMP testing.
between July 2006 and July 2012. All selected cases had usable records, including physicians’ visit notes, clinical/working diagnoses, imaging studies, and cVEMP outcomes.

Conducting cVEMP Test and Other Audiologic Evaluations
Prior to cVEMP testing, all patients had a hearing evaluation with air and bone conduction threshold testing. Tympanometry and acoustic reflex thresholds were also obtained if clinically warranted. We used a commercial evoked potential system (NavigatorPro, Natus Medical Inc., San Carlos, CA) to record cVEMP under a customized pediatric protocol. All normative cVEMP parameters, including threshold, amplitude and latencies, were established at our facility. The details of the protocol can be found in our previous publications.24,37 Briefly, acoustic stimuli (500Hz tonebursts and/or clicks) were presented via insert phones or bone oscillator. All cVEMP was recorded from sternocleidomastoid muscle. Head-turning is required to have sternocleidomastoid muscle contracted and the contraction is monitored to ensure its appropriateness. For younger children, an assistant was employed to attract the patients’ attention, allowing them to make a head turn to toys with colorful lights. To obtain cVEMP thresholds, a stimulus level of 90 dB normal hearing level (nHL) was used as the default starting intensity. The stimulus intensity would decrease in steps of 10 dB or increase in steps of 5 dB depending upon the presence or absence of cVEMP, respectively. The lowest stimulus intensity at which a clear and repeatable wave was recorded would be considered absent. For patients with middle ear pathologies and conductive hearing loss, bone-conducted stimuli were also used to elicit cVEMP if air-conducted stimuli were not sufficient.

Data analysis
We exclusively used descriptive analysis in this study. Age, sex, reasons for cVEMP test, referring physician, and so on were summarized for all patients.

RESULTS

General Information
Among the 278 patients included in this study, there were 119 boys and 159 girls. The average age was 10.5 years (SD = 4.6), with the youngest at the age of 5 months. To better demonstrate patients’ makeup, we classified them into 6 age groups, from the youngest group of “Age 3 & Under” to the oldest group of “Age 16 to 18”, as shown in Figure 1. Notably, there were a significant number of children in each age group, and even in the youngest group there were >20 children although the Age 13 to 15 group had the largest case number at 72 (259% of the total). Similarly, we divided the numbers of cVEMP testing conducted by calendar year, demonstrated in Figure 2. As shown, we have conducted 30 to 50 cVEMP tests in pediatric patients each year, except the beginning year of 2006. Of note, the number of cVEMP performed trended toward to an increase in 2012 since the number in 2006 and 2012 reflected only 6 months of clinical work.

VEMP Referrals
Various reasons for cVEMP testing were documented in patients’ medical records and these were summarized in Table 1. As listed, the main reason for requesting a cVEMP test was to evaluate children’s dizziness, vertigo or balance issues, and accounted for almost 45% of the total requests. The second leading reason for cVEMP testing in our facility was pre- and postcochlear implant workup that accounted for nearly 15%. Investigation of middle ear–related conductive hearing loss and inner ear structural anomalies such as SSCD and EVA

FIGURE 1. Enumerated data of pediatric VEMP test conducted in 6 age groups.
by cVEMP testing, accounted for 13.7% and 11.9% respectively. Twelve children with sensorineural hearing loss caused by unknown etiology underwent cVEMP testing because of a concern of possible coexisting vestibulopathy. Ten children with postconcussion syndrome also underwent cVEMP testing as a part of a comprehensive workup. The remaining 21 children, 7.5% of the total, were referred for other nonspecific complaints such as tinnitus or headache.

In addition to tracking the reasons for cVEMP test, we also looked over the referring physicians and their specialties. As shown in Table 2, the overwhelming majority of patients were referred by pediatric otolaryngologists (about 48%) and otologists/neurotologists (45%). Referrals by neurologists and neurosurgeons accounted for only 5%. Fewer than 3% of the referrals originated from other specialists such as audiologists.

**Outcomes of cVEMP in Pediatric Patients**

Among the 278 children in this study, only 3 children were not able to complete cVEMP testing, mostly due to fears of recording electrodes and wires, or they were intolerant of insert phones. VEMP results obtained from the remaining 275 children were analyzed. If no repeatable cVEMP responses were present at the highest intensity of the stimuli, we would call the cVEMP absent. If present, the cVEMP threshold would be determined along with the cVEMP latency and amplitude, as described in the method section. Abnormal cVEMP outcomes found in each referring category are summarized in Table 3. As shown, abnormal cVEMP responses were found in all children with conductive hearing loss related to middle ear pathologies, most had absent cVEMP responses to air-conducted stimuli; however, robust cVEMP were present when bone-conducted stimuli were used in these cases. Also, the cVEMP seemed to be very responsive, at 94%, to inner ear structural anomalies such as EVA and SSCD. Typical cVEMP findings related to EVA and SSCD included a lower cVEMP threshold and higher amplitude. In children with cochlear implant(s), abnormal cVEMP (absent cVEMP, elevated cVEMP thresholds, and reduced amplitude) were found in 35 of 40 cases. Only 25% of children with complaints of dizziness or vertigo had an abnormal cVEMP. Approximately two-thirds of the children with congenital hearing loss had abnormal cVEMP, indicating possible cochlear-vestibulopathy although the exact etiology is unknown. Overall, abnormal cVEMP results were found in 54% of children who completed the test.

![Number of patients](chart.png)

**FIGURE 2.** Numbers of pediatric VEMP test conducted in each calendar year at our facility from 2006 to 2012. Of note, the number in 2006 and 2012 reflected only 6 months of clinical work.

**TABLE 1.** Summarization of Reasons for Requesting VEMP Testing in Our Study

<table>
<thead>
<tr>
<th>Reasons for Requesting VEMP test</th>
<th>Number of Cases</th>
<th>Percentage, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dizziness/vertigo/balance problems</td>
<td>124</td>
<td>44.6</td>
</tr>
<tr>
<td>Pre-/postcochlear implantation evaluation</td>
<td>40</td>
<td>14.4</td>
</tr>
<tr>
<td>Conductive loss due to middle ear involvements</td>
<td>38</td>
<td>13.7</td>
</tr>
<tr>
<td>Suspicion of inner ear structural anomalies</td>
<td>33</td>
<td>11.9</td>
</tr>
<tr>
<td>Sensorineural hearing loss with unknown etiology</td>
<td>12</td>
<td>4.3</td>
</tr>
<tr>
<td>Postconcussion syndrome workups</td>
<td>10</td>
<td>3.6</td>
</tr>
<tr>
<td>Other nonspecific complaints</td>
<td>21</td>
<td>7.5</td>
</tr>
<tr>
<td>Total</td>
<td>278</td>
<td>100</td>
</tr>
</tbody>
</table>

VEMP = vestibular-evoked myogenic potential.

© 2014 Lippincott Williams & Wilkins  www.md-journal.com  3
DISCUSSION

Our study has revealed a successful experience of carrying out cVEMP testing in pediatric patients, from infants to teenagers, in a busy clinical setting. In fact, cVEMP testing is a noninvasive procedure and is generally well tolerated by children of all ages. Although the literatures on cVEMP testing in children revealed its feasibility, many pediatric professionals have reservations about the clinical value of cVEMP testing, considering most of the published studies were conducted using normal subjects or had a limited number of children. In fact, a recent survey completed by our group presented a dismal picture of the use of cVEMP test in children currently: among the 117 pediatric otolaryngologists who finished our online survey, about 90% believed that cVEMP test cannot be performed in children and more than 80% thought cVEMP testing was unreliable (unpublished data). One encouraging finding from the survey, however, was that the majority of pediatric otolaryngologists have basic knowledge about the test. Consequently, we determined to conduct this current study to demonstrate that cVEMP testing not only is feasible but also has clinical value in evaluating pediatric patients for a variety of clinical scenarios.

We have shown, for the first time, a variety of clinical applications of cVEMP testing in a large group of pediatric patients. The sensitivity of the cVEMP test may vary depending upon the medical conditions present or referring diagnoses. When middle ear pathology associated conductive hearing loss is suspected, our study demonstrated 100% sensitivity of the cVEMP test to confirm such conditions. Specifically, the cVEMP is absent when air-conducted stimuli are used to elicit the cVEMP response. In contrast, cVEMP is usually present if bone-conducted stimuli are used to elicit response, indicating the existence of a sound transmission problem via the middle ear system. Also, cVEMP test has shown to be very sensitive to detect inner ear structural anomalies such as EVA or SSCD, especially when conductive hearing loss or air-bone gaps are exhibited on the audiogram. Although our study showed a relatively low sensitivity of cVEMP test in evaluating children with dizziness, vertigo, or balance problem, and its diagnostic value should not be overlooked. In these circumstances, the cVEMP test can only assess the otolith function without semicircular canal function involved, which is a limitation. Therefore, cVEMP test can be a complimentary procedure to standard rotational and caloric test.

Conducting VEMP test in pediatric patients, especially in young children can be a challenge. Most older children (i.e., age 7 to 18 years, can follow instructions during cVEMP testing and make proper head turns to achieve sufficient muscle contraction. When testing younger children (e.g., age 4 to 6 years), on the other hand, an assistant will be helpful to draw patients’ attention so that valid cVEMP responses can be recorded. For younger children who are unable or unwilling to sit by themselves, sitting in their parents’ lap can be adopted to have a better control of the patients. Light-up toys are effective tools to attract patients’ attention but any noise-making toys should be avoided. It’s also important to allow ample time for younger children to “warm-up” before putting recording electrodes and insert phones on them so that their fear of the testing procedure can be reduced.

CONCLUSION

Based on our clinical experience, cVEMP test can be successfully conducted in pediatric patients. Conducting cVEMP test is not only feasible but also valuable in the clinical evaluation of children with auditory and/or vestibular

### TABLE 2. Breakdown of Referrals by Specialists for VEMP Testing in Our Study

<table>
<thead>
<tr>
<th>Referring Doctors</th>
<th>Number of Cases</th>
<th>Percentage, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pediatric otolaryngologist</td>
<td>133</td>
<td>47.8</td>
</tr>
<tr>
<td>Otologist/neurotologist/otoneurologist</td>
<td>125</td>
<td>45.0</td>
</tr>
<tr>
<td>Neurologist</td>
<td>11</td>
<td>3.9</td>
</tr>
<tr>
<td>Neurosurgeon</td>
<td>3</td>
<td>1.1</td>
</tr>
<tr>
<td>Others</td>
<td>6</td>
<td>2.2</td>
</tr>
<tr>
<td>Total</td>
<td>278</td>
<td>100</td>
</tr>
</tbody>
</table>

VEMP = vestibular-evoked myogenic potential.

### TABLE 3. Occurrence of Abnormal VEMP Results in 275 Pediatric Patients

<table>
<thead>
<tr>
<th>Abnormal VEMP Outcomes in Each Category</th>
<th>Number of Cases</th>
<th>Percentage of Abnormal, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dizziness/vertigo/balance problems</td>
<td>30/121</td>
<td>25</td>
</tr>
<tr>
<td>Pre-/postcochlear implantation evaluation</td>
<td>35/40</td>
<td>88</td>
</tr>
<tr>
<td>Conductive loss due to middle ear involvements</td>
<td>38/38</td>
<td>100</td>
</tr>
<tr>
<td>Suspicious of inner ear structural anomalies</td>
<td>31/33</td>
<td>94</td>
</tr>
<tr>
<td>Sensorineural hearing loss with unknown etiology</td>
<td>8/12</td>
<td>67</td>
</tr>
<tr>
<td>Postconcussion syndrome workups</td>
<td>2/10</td>
<td>20</td>
</tr>
<tr>
<td>Other nonspecific complaints</td>
<td>4/21</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>148/275</td>
<td>54</td>
</tr>
</tbody>
</table>

VEMP = vestibular-evoked myogenic potential.
complaints. Although the sensitivity of cVEMP test may vary depending upon medical conditions, it provides diagnostic information in most cases. This noninvasive and low-cost test procedure can be easily implemented in any audiological clinic where an evoked potential recording system is available. Most importantly, pediatric professionals should embrace this cutting-edge technology and consider cVEMP testing before ordering more expensive tests such as MRI and CT scans, which usually bring unpleasant experiences to pediatric patients.

REFERENCES


