Update on the Clinical Utility of Vestibular Evoked Myogenic Potentials

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Disclaimer

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The views expressed here are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs or the United States government.
Two-Channel Recording of cVEMP

Right SCM M. Activation / Right Ear Stimulation

![Graph showing two-channel recording of cVEMP with labeled time axis (0-60 ms) and voltage scale (12.5 μV). The graph indicates peaks labeled P1 and N1 for Right SCM and N1 for Left SCM.]

![Image of a woman wearing electrodes and a device for cVEMP recording, with cables connected to her neck and ear. She is seated on a chair with restraints.]
cVEMP Pathway

Midline

Vestibular Nuclei

Inferior Vestibular n.

MVST

SCM m.

CN XI

Utricle

Saccule
Ocular VEMP: Air Conduction

Recorded from electrodes beneath the eyes with patient looking up

Initial negativity (10-12 ms) and a subsequent positivity (15-20 ms)

adapted from Murnane & Akin, 2009
oVEMP B&K 4810 Minishaker
oVEMP Pathway

- Superior Vestibular Nerve
- Utricle
- Saccule
- MLF
- CN III
- Inferior Oblique m.

References:
- Suzuki et al., 1969
- Curthoys, 1987
- Weber et al., 2012
Origin of cVEMP and oVEMP

Adapted from Curthoys, 2009
Agenda

• Recording and stimulus parameters
• Normative data
  – Response prevalence and amplitude
  – Asymmetry ratio
• Clinical data
• Effect of aging
• Effect of noise exposure
• TBI/blast exposure
cVEMP Recording and Stimulus Parameters
AC cVEMP: Stimulus Frequency

120 dB \text{peak SPL}
Rise/Fall = 4 ms

adapted from Akin, Murnane, Proffitt (2003)
AC cVEMP: Stimulus Level

Akin, Murnane, Proffitt (2003)

P1-N1 AMPLITUDE (µV)

TONE BURST LEVEL (dB pSPL)

Akin, Murnane, Proffitt (2003)
Stimulus Parameters: AC cVEMP

- **Type:** 500-Hz tone burst
- **Phase:** Rarefaction
- **Rise/Fall:** 2 cycles
- **Plateau:** 0 cycles
- **Gating:** Blackman
- **Level:** 120 dB pSPL (90 dB nHL)
- **Rep Rate:** 5/s
cVEMP Amplitude is Proportional to SCM m. EMG Level

Akin, Murnane, Panus, Caruthers, Wilkinson, Proffit, 2004
Strategies to Account for the Effects of EMG Level on cVEMP Amplitude
SCM Muscle EMG Feedback

Control for EMG level during cVEMP recording by providing visual feedback to the patient
Correct P1-N1 amplitude after cVEMP recording by using pre-stimulus baseline as a gross estimate of EMG level

Colebatch et al., 1994
oVEMP Recording and Stimulus Parameters
AC oVEMP: Frequency

Murnane, Akin, Kelly, Byrd, 2011
AC oVEMP: Stimulus Level

Murnane, Akin, Kelly, Byrd, 2011
AC oVEMP Stimulus Parameters

- Transducer: ER-3A
- Type: 500-Hz tone burst
- Onset Phase: Alternating
- Rise/Fall: 2 ms
- Plateau: 0 ms
- Gating: Blackman
- Level: 125 dB pSPL
- Rep. Rate: 5 Hz
AC oVEMP: Gaze Elevation

INDIVIDUAL WAVEFORMS

GRAND AVERAGE

5 μV

30° N = 17

1 μV

15° N = 13

1 μV

0° N = 7

-20 -10 0 10 20 30

TIME (ms)

26

24

22

20

18

16

14

12

10

8

6

4

2

0

VERTICAL GAZE ELEVATION (°)

N1-P1 AMPLITUDE (μV)

LATENCY (ms)

Murnane, Akin, Kelly, Byrd, 2011
AC oVEMP

Recording Parameters

- No. of channels: 2
- Amplifier gain: 100,000 x
- Response filter: 1 – 1000 Hz
- Sweep time: 50 ms
- No. of sweeps: 500
- Artifact rejection: 36 µV
- Vertical gaze angle: 30° (midline)
BC oVEMP: Stimulus Level

- **Right Eye**
  - 160 dB_{peak FL} (5V_{pp})
  - 155 dB_{peak FL} (4V_{pp})
  - 150 dB_{peak FL} (2V_{pp})
  - 145 dB_{peak FL} (1V_{pp})
  - 140 dB_{peak FL} (0.5V_{pp})

- **Left Eye**
  - 160 dB_{peak FL} (5V_{pp})
  - 155 dB_{peak FL} (4V_{pp})
  - 150 dB_{peak FL} (2V_{pp})
  - 145 dB_{peak FL} (1V_{pp})
  - 140 dB_{peak FL} (0.5V_{pp})

**Time (ms)**
BC oVEMP Stimulus Parameters

- Amplifier: B&K model 2718
- Transducer: B&K model 4810
- Type: 500-Hz tone burst
- Onset Phase: rarefaction
- Rise/Fall: 2 ms
- Plateau: 0 ms
- Gating: Blackman
- Level: 155 dB peak FL
- Rep. Rate: 5 Hz
Linear Acceleration at Mastoids

Mean linear acceleration at Fz: 20.0 g (0.99)
BC oVEMP Recording Parameters

- No. of channels: 2
- Amplifier gain: 100,000 x
- Response filter: 1 – 1000 Hz
- Sweep time: 50 ms
- No. of sweeps: 75
- Artifact rejection: off
- Vertical gaze angle: 30° (midline)
Normative Data
VEMP Prevalence

- AC cVEMP 50 µV EMG
- AC oVEMP 30° Vertical Gaze
- BC oVEMP 30° Vertical Gaze

N = 54 ears/eyes

Mean Age = 23 (18-35 years)
VEMP Prevalence

- AC cVEMP
- AC oVEMP
- BC oVEMP

N = 54 ears/eyes
Mean Age = 23 (18-35 years)

50 µV EMG Max Vertical Gaze
Max Vertical Gaze
VEMP Prevalence

AC cVEMP 50 µV EMG
AC oVEMP Max Vertical Gaze
BC oVEMP Max Vertical Gaze

N = 54 ears/eyes
Mean Age = 23 (18-35 years)
AC cVEMP Amplitude

Mean P1/N1 = 124 µV (±78)

50 µV EMG

Mean Age = 37 years (±18)

N = 252 Ears
AC cVEMP Asymmetry Ratio

N = 115 subjects

50 µV EMG
BC oVEMP Amplitude

30° Vertical Gaze

Mean Age = 35 years (±17)

Mean N1/P1 = 10.5 μV (±6)
BC oVEMP Asymmetry Ratio

N = 74 subjects

30° Vertical Gaze
Clinical Data
Demographics

• 312 consecutive patients referred to Vestibular Clinic

• Age Range = 22 - 89 years (X = 60 ±15 yrs)
VEMP Protocol

- **AC cVEMP**
  - 500-Hz tone bursts at 120 dB pSPL (90 dB nHL)
  - 50 µV EMG
    - If no response, maximum voluntary contraction (MVC)
  - SSCD Screen at 65 dB nHL

- **BC oVEMP**
  - 500-Hz tone bursts at 155 dB pFL
  - 30° vertical gaze angle
    - If no response, then maximum gaze angle
AC cVEMP Amplitude: Patients vs. Healthy Individuals

![Bar graph showing comparison of AC cVEMP Amplitude between controls and patients. The graph indicates a higher amplitude for controls compared to patients.]
cVEMP Asymmetry Ratios in Clinic Patients

![Graph showing cVEMP Asymmetry Ratios with N = 235]
BC oVEMP Amplitude: Patients vs. Healthy Individuals
oVEMP Asymmetry Ratios in Clinic Patients

N = 259
## VEMP Findings in Clinic Patients

|                  | AC cVEMP  
|-----------------|-----------
| N = 312         | BC oVEMP N = 289 |
| **Normal Findings** |           |
| 32%@ 50 µV EMG  | 61%@ 30° gaze |
| 28% @ MVC       | 17% @ max gaze |
| **Total**       | **60%**    | **78%**    |
| **Abnormal Findings** |          |
| AR > 40%        | 19%       | 11%       |
| left/right      | 8/11%     | 5/7%      |
| Bilateral absence | 12%     | 10%      |
| **Total**       | **31%**   | **22%**   |
| + SSCD screen   | 2%        | N/A       |
| Could not test  | 11%       | 0.01%     |
Effect of Aging on cVEMP
Decrease in cVEMP amplitude in individuals > 60 years

Ochi and Ohashi 2003; Basta et al. 2005; Basta et al. 2007; Su et al. 2004; Welgampola and Colebatch 2001b; Zapala and Brey 2004; Brantberg, Granath, Schart 2007
Akin, Murnane, Tampas, Clinard (2011). The effect of age on the vestibular evoked myogenic potential and sternocleidomastoid muscle tonic EMG level, *Ear & Hearing*

- Are amplitude decrements influenced by age-related changes in the vestibular system or age related changes in SCM muscle?

- 24 young individuals (22 – 31 years; X = 24 ± 3)
- 24 older individuals (61 – 86 years; X = 70 ± 6)
Effect of Age on SCM m EMG Level

Akin, Murnane, et al., 2011
cVEMPs Recorded at Various EMG Levels

Akin, Murnane, Tampas, Clinard, 2011
Effect of Age on cVEMP Amplitude

Akin, Murnane, Tampas, Clinard, 2011
## Age Trends for VEMP Clinic Findings

<table>
<thead>
<tr>
<th></th>
<th>Mean Age (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AC cVEMP</td>
</tr>
<tr>
<td>NORMAL</td>
<td>57 ±15</td>
</tr>
<tr>
<td>BILATERAL</td>
<td>65 ±12</td>
</tr>
<tr>
<td>UNILATERAL</td>
<td>63 ±17</td>
</tr>
<tr>
<td>CNT</td>
<td>65 ±17</td>
</tr>
<tr>
<td>50 µV / 30° GAZE</td>
<td>52 ±16</td>
</tr>
<tr>
<td>MVC/ MAX GAZE</td>
<td>63 ±12</td>
</tr>
</tbody>
</table>
Effect of Noise Exposure on cVEMP
Effect of Noise Exposure on cVEMP
Akin, Murnane et al. 2012  The Effect of Noise Exposure on the cVEMP

43 subjects with asymmetric NIHL and history of asymmetric noise exposure
(25 – 63 years, X = 52 yrs)
14 age-matched controls
Signed Asymmetry Ratio

(Poorer-Hearing Ear P1-N1 – Better-Hearing Ear P1-N1) X 100
(Poorer-Hearing Ear P1-N1 + Better-Hearing Ear P1-N1)
Asymmetry Ratios: Control and Noise Exposure Groups

Akin, Murnane et al., 2012
Asymmetry Ratios: Control and Noise Exposure Groups

Akin, Murnane et al., 2012
Asymmetry Ratios: Control and Noise Exposure Groups

Akin, Murnane et al., 2012
Asymmetry Ratios: Control and Noise Exposure Groups

Akin, Murnane et al., 2012
Asymmetry Ratios:
Control and Noise Exposure Groups

Akin, Murnane et al., 2012
Are there differences in hearing loss between noise-exposed subjects with cVEMPs present and the noise-exposed subjects with cVEMPs absent?

Akin, Murnane et al., 2011
Effect of mTBI/Blast Exposure
Abnormal vestibular function test findings in individuals with dizziness/imbalance related to TBI/blast exposure

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>hSCC</th>
<th>Otolith organ</th>
<th>Ocular motor</th>
<th>Gait/balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davies &amp; Luxon 1995</td>
<td>100</td>
<td>51%</td>
<td>-</td>
<td>8%</td>
<td>-</td>
</tr>
<tr>
<td>Ernst et al. 2005</td>
<td>63</td>
<td>19%</td>
<td>25%</td>
<td>5%</td>
<td>27%</td>
</tr>
<tr>
<td>Dae Lee et al. 2011</td>
<td>28</td>
<td>7%</td>
<td>54%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Shupak et al. 1993</td>
<td>5</td>
<td>40%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Van Campen et al. 1999</td>
<td>30</td>
<td>7%</td>
<td>-</td>
<td>7%</td>
<td>37%</td>
</tr>
<tr>
<td>Cohen et al. 2002</td>
<td>17</td>
<td>0%</td>
<td>-</td>
<td>-</td>
<td>4%</td>
</tr>
<tr>
<td>Scherer et al. 2011*</td>
<td>11</td>
<td>27%</td>
<td>17%</td>
<td>45%</td>
<td>-</td>
</tr>
</tbody>
</table>
### Mountain Home VAMC Study: Preliminary Findings

<table>
<thead>
<tr>
<th></th>
<th>TBI/Blast N = 51</th>
<th>Control N = 21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>37 (10)</td>
<td>26 (5)</td>
</tr>
<tr>
<td>MMSE</td>
<td>29 (1.8)</td>
<td>30 (.4)</td>
</tr>
<tr>
<td>PTSD</td>
<td>92%</td>
<td>0%</td>
</tr>
<tr>
<td>Tinnitus</td>
<td>98%</td>
<td>14%</td>
</tr>
<tr>
<td>Sensorineural Hearing Loss</td>
<td>67%</td>
<td>0%</td>
</tr>
</tbody>
</table>
## Symptom Characteristics of mTBI/Blast Group (n = 51)

<table>
<thead>
<tr>
<th>Symptom</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertigo</td>
<td>25 (49%)</td>
</tr>
<tr>
<td>Imbalance</td>
<td>45 (88%)</td>
</tr>
<tr>
<td>Lateropulsion</td>
<td>26 (52%)</td>
</tr>
<tr>
<td>Lightheadedness</td>
<td>37 (73%)</td>
</tr>
<tr>
<td>Oscillopsia</td>
<td>3 (6%)</td>
</tr>
</tbody>
</table>
## History of Blast Exposure for 51 Veterans

<table>
<thead>
<tr>
<th>Number of blasts</th>
<th>Number of Veterans</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>1-2</td>
<td>13</td>
</tr>
<tr>
<td>3-5</td>
<td>6</td>
</tr>
<tr>
<td>5+</td>
<td>29</td>
</tr>
</tbody>
</table>

**Time since worst exposure**

- **Range** = 6 months – 10 years
- **Mean (SD)** = 5 years 9 mos (30 mos)
- 4 Veterans with symptoms ≥ 20 years
Tests of Peripheral Vestibular Function

- Caloric Test
- Rotary Chair
- oVEMP
- cVEMP

Normal Findings (%)

- Caloric Test: TBI/Blast 90%, Control 100%
- Rotary Chair: TBI/Blast 90%, Control 100%
- oVEMP: TBI/Blast 80%, Control 100%
- cVEMP: TBI/Blast 70%, Control 100%

* p = 0.014

hSCC/SVN: utricle/SVN, saccule/IVN
cVEMP Amplitude in mTBI/Blast and Control Groups

P1/N1 AMPLITUDE (µV)

MTBI/BLAST  CONTROL

0  20  40  60  80  100  120  140
cVEMP Asymmetry Ratios in Control and mTBI/Blast Groups
Future Directions

• Role of VEMPxs in diagnosis of common vestibular disorders – need clinical trials
• How do VEMPxs correlate with patient symptoms and other tests of vestibular function?
• How does otolith loss affect postural stability and rehabilitation outcomes?
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