The Vestibular Evoked Myogenic Potential (VEMP)

Devin L. McCaslin, Ph.D.
Division of Audiology

Vanderbilt Bill Wilkerson Center
Vestibular Disorders Clinic

- 4 ENG/VNG Laboratories
- Rotational testing
- Posturography
- Evoked Potential Room
- 1300 dizzy patients per year

Outline

- Historical background
- Anatomy and Physiology of the vestibular system
- Anatomic origins of the VEMP
- Conventional parameters for recording the VEMP
- Normal response (i.e. waveform and measurement parameters)
- Clinical Implications
- Responses from abnormal populations
- Summary
Sonomotor Responses
For some time it has been recognized that...
- In addition to movement, vestibular afferents may be activated by:
  - loud sounds
  - vibration and
  - electrical stimulation applied over the mastoid process

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Sonomotor Responses
- Dr. Pietro Tullio (1881-1941)
  - Conducted observations of sound-evoked head movements and eye movements after fenestration of areas of the bony labyrinth
Sonomotor Responses

• Von Bekesy (1935)
• Observed that high intensity sounds (e.g. 128-134 dB SPL) evoked head displacement toward the stimulated ear.

Background

• Sonomotor evoked potentials were first described by Geisler, Frishkoph, and Rosenblith (1958)
• ... although they were thought by the authors to represent neurogenic responses

Background

• Mid 1960’s Cody, Bickford et al. showed that a large portion of these responses were indeed attenuated by anesthesia
## Background

- The high amplitude responses were, sound-evoked myogenic responses (i.e. “sono-motor” responses).
- Sonomotor responses are near-field recordings (i.e. greatest in amplitude when recorded from the muscle and decrease amplitude by the inverse²)
- Usually represent a high intensity sound-evoked transient decrease in muscle tone.

## Sonomotor Responses

Usually Represent a Sound-induced Reduction in EMG

## Acoustic Jaw Reflex

Meier-Ewert et al. (1974)

- Non-inverting electrode over the masseter m.
- Represents synchronized sound-evoked inhibition of the masseter m. during voluntary activation
- Response was absent in 6 deaf patients with normal vestibular function (auditory system origin)
Post-Auricular Muscle Potential

- Non-inverting electrode over the PAM (immediately posterior to the pinna)
- Amp. decreases 90% if non-inverting electrode is 2 cm from the optimum site

Inion Potential
Cody et al. 1964; Townsend and Cody, 1971

- Circuit:
  - Saccule?
  - VIII N.
  - Vestibular nucleus?
  - C1 nucleus
  - C1 nerve root – nerve –
  - neck musculature
- High intensity sound synchronized attenuation of cervical EMG recorded from the occipital protuberance

Inion Response
Cody et al. (1964)
Inion Potential
Cody et al. (1964)

• Could be recorded from deaf patients with intact vestibular system function
• Suggested that the peripheral receptor was probably the saccule

The Vestibular System is Sensitive to Sound

Acoustically Responsive Fibers in the Vestibular Nerve of the Cat

Michael P. McCutcheon and John J. Oleria, A

Clicks were used

Acoustically responsive vestibular afferents were most responsive to 500 and 1000 Hz.
The Vestibulo-collic Response

- Colebatch, Halmagyi, and Skuse (1994)
- Devised a reliable method of recording myogenic potentials using clicks
- Placed electrodes on the SCM rather than on the inion.
- Termed these “click-evoked vestibulo-collic responses” which is now known as the VEMP.

VEMP
Halmagyi and Curthoys, 1990's

- Similar to inion potential.
- Can be recorded from SCM, trapezius and quadriceps muscles (e.g. Ferger-Viart et al. 1998)

Nomenclature

- 1st positive and negative complex is P13/N23 (aka P1/N2).
- Positive wave represents inhibition
- Negative wave represents excitation

Nomenclature

- Also a 2nd negative/positive complex N34-P44
- Has a lower stimulus threshold than VEMP
- Absent in 30-40% of normal subjects
- Most discussions focus on P13/N23.
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Vestibular Reflexes

- Three Functional roles
  - Maintain posture
  - Produce “kinetic” or transitory contractions of muscles for maintenance of equilibrium and ocular stability during movement
  - Help maintain muscular tone

Baloh and Honrubia
Peripheral Vestibular System

- Sense organs consist of:
  - Semicircular canal system
    - horizontal, anterior, and posterior
    - Convert angular acceleration and deceleration into an electrical “code”
  - Otolith system - utricle and saccule
    - Convert linear acceleration and deceleration into an electrical “code”
  - VIIIth nerve - conduit

Semi-Circular Canals

- Three semicircular canals extend from the utricle:
  - Lateral/Horizontal
  - Anterior/Superior
  - Posterior/Inferior
Mechanosensory Hair Cells

Vestibulo-Ocular Reflex Arc

Otolith Organs
When the head tilts out of the upright position, the component of the gravitational vector tangential to the macula creates a shearing force on stereocilia of hair cells.

- Newton's Laws
**Vestibular Nerve**

- Superior vestibular nerve contains fibers from:
  - horizontal SCC
  - anterior SCC
  - utricle
  - part of saccule
- Inferior vestibular nerve contains fibers from:
  - posterior SCC
  - majority of saccule

**Vestibulospinal Projections**

- Stabilize the head and control erect stance
- Static and dynamic
- Effector organs are of the VSR are the antigravity muscles
- Stimulation of canal or otolith receptors leads to a variety of patterns of activation of neck and body muscles.

**Vestibulospinal Reflexes**

- Concept: Labyrinths send outputs to spinal cord motoneurons via the vestibulospinal tract, reticulospinal tract, and descending MLF.
- Stimulation of the labyrinth results in increases in extensor tone and decreases in flexor tone resulting in facilitation of antigravity muscles.
Vestibulospinal Reflexes

- The head/trunk is tilted to one side where both the otoliths and SCCs are stimulated.
- The vestibular nerve and vestibular nucleus are activated.
- Impulses are transmitted via the lateral and medial vestibulo-spinal tracts to the spinal cord.
- Extensor activity is induced on the side to which the head is inclined and flexor activity is induced on the opposite side.
- Has the effect of extending the left limbs and flexing the right ones to oppose the perturbation.

Medial Vestibulospinal Tract

- Medial Vestibular Nucleus
- Pathway is bilateral but the ipsilateral projection is more dense.
- Pathway innervates cervical and upper thoracic spinal cord influencing neck and axial muscles.

Anatomy & Physiology of VSR

- MVST
  - Neurons enter spinal cord in descending MLF.
  - Most terminate at cervical anterior horn cells.
  - Links SCC with cervical cord and sets of neck muscles.
  - Stabilizes head in space.
  - Transmits movement and position of eyes in orbits with vestibular signals to the cervical cord.
  - Plays important role in VEMP.

Lateral Vestibulospinal Tract

- Lateral vestibular Nucleus
- Pathway is uncrossed and courses the entire length of the spinal cord.
- Pathway enable vestibular system to influence the ipsilateral proximal limb muscles.
Anatomy & Physiology of VSR

- LVST --
  - rostroventral neurons supply cervical cord
  - intermediate neurons supply thoracic cord
  - dorsolateral neurons supply lumbosacral cord
  - Ipsilateral pathway
  - Activation of LVST: results in ipsilateral activation of extensor motor neurons and inhibition of flexor motor neurons
Unilateral destruction of a labyrinth or LVN results in an ipsilateral decrease in tone since the main excitatory input to anterior horn cells arrives from the ipsilateral LVST.
Past-Pointing

Otolith-Ocular Connections

Utriculo-ocular Connections

Saccular-ocular Connections

- The neural linkage in the SOS is relatively weak in comparison to the utriculo-ocular and sacculo-colic systems.
- Saccule connects bilaterally to SR and IR and contralaterally to IO and SO.

• oVEMP
Unilateral Disorder of Otolith

Right side disordered

Perception

Response

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Vestibular Evoked Myogenic Potential (VEMP)

Why the SCM?

- Responses obtained from the trapezius were 7.1 mV larger on average than those from the SCM
- Latencies were 3.8 msec longer from the trapezius

Vanderbilt Bill Wilkerson Center
Purpose/Function of the Vestibulocollic Reflex

- To stabilize the head in response to unpredictable displacements.
- Reflex affects position of the head in acute unilateral loss (i.e., head deviates to ipsilesioned side).

Vestibulo-collic Reflex

- A naturally occurring vertical acceleration such as a sudden fall from a height is accompanied by relaxation of neck flexors (SCM) and activation of the extensors (splenius capitis).
- The effect is elevation of the head.

Response is Generated by the Saccule?

- The saccule can be stimulated using unnatural stimuli such as an air/bone-conducted sound or a tapping to the forehead.
- These stimuli create excitatory responses in the neck extensors and inhibitory responses in the flexors (Wu et al., 1999).
- These responses are recordable from surface electrodes.

VEMP is a Sonomotor “Reflex”

- What is a reflex pathway?
  - Reflex pathway consists of a/an:
    - receptor (end organ)
    - afferent pathway
    - central connections
    - efferent pathway, and,
    - end muscles
  - Short onset latency of the VEMP (~ 8 ms) suggests that the pathway is either oligosynaptic or disynaptic.
Receptor is the Saccule?
Hamagyi & Curthoys (2000)

- Saccule is vestibular end organ most sensitive to sound
- Lies under the stapes footplate
- Neurons from saccular maculae that respond to tilts also respond to click stimuli

Receptor is the Saccule?
Halmagyi & Colebatch (1995)

- Response is present in patients who are deaf but have intact vestibular system function (Colebatch et al. 1994)

Receptor is the Saccule?

- Present in patients with:
  - SCC ablation
  - deformation of the cochlea but normal saccule
  - Present in patients who have had a unilateral vestibular neurectomy (Cody et al., 1964, Colebatch and Halmagyi, 1992)

Afferent Pathway

- Afferent information from the saccule is transmitted through the inferior vestibular nerve.
- Therefore the response probably is transmitted through it.
**Afferent Pathway**

- Response is absent for patients with vestibular nerve section or vestibular neuritis

**Central Connections & Efferent Pathway**

“Vestibulocollic Reflex” (From: Colebatch et al. 1994)

- Saccule (a)
- Scarpa’s ganglion (a)
- Inferior vestibular nerve (a)
- Medial vestibular nucleus (a)
- Medial vestibulospinal tract (MVST) – (e)
- SCM m. (e)

**Electromyography**

- Electromyography (EMG) is a technique for evaluating and recording physiologic properties of muscles at rest and while contracting.
- The VEMP is an EMG response that is mediated by the vestibulo-spinal reflex and can be recorded using a typical evoked potential system (ABR).
- The muscle must be contracted in order to record the response

**Inhibition of SCM EMG**
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Recording Concerns

- The VEMP is a field potential from a muscle. It is not neurogenic (ABR) in origin.

- EMG is a much larger response than an neurogenic one so it is important that the artifact reject be turned off.

Filtering

- Set the high pass filter between 1 and 5 Hz
- Low pass filter between 200 and 500 Hz
- Turn down amplifier gain (if set for ABR) X5000
Recording Array

- Non-inverting electrode placed over the belly of the SCM
- Inverting electrode placed on the sternum or dorsum of the hand
- It helps the recording to secure the electrodes to the SCM to avoid them from becoming detached during SCM contraction

Electrode Array

Patient Preparation

Recording Characteristics

<table>
<thead>
<tr>
<th>Recording Condition</th>
<th>Seated in comfortable reclining chair, or, laying on a table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-inverting electrode</td>
<td>Ipsilateral or contralateral (middle 3rd) of SCM m.</td>
</tr>
<tr>
<td>Inverting electrode</td>
<td>Dorsum of hand</td>
</tr>
<tr>
<td>Ground electrode</td>
<td>Fpz</td>
</tr>
<tr>
<td>Filtering</td>
<td>10–30 or 1500–3000 Hz</td>
</tr>
</tbody>
</table>
How is the VEMP elicited?

Air conduction VEMP

Mechanical (tap) VEMP (CHL)

Bone conduction VEMP (CHL)

Galvanic VEMP

Acoustic Stimuli

- We are using sound only as a pressure stimulus i.e. sound pressure is being used as a mechanical force to move the endolymphatic fluid and, as a consequence to move the otoliths and create transduction.

Air-Conducted Acoustic Stimuli

- Must use a transient stimuli
  - Click or Tone-burst
  - Must be presented at a high stimulus level (90 dBNHL)
  - Presence of bothersome tinnitus is a contraindication for acoustical test (Welgampola & Colebatch, 2005)
  - Response can be abolished by air-bone gap as small as 9 dB
Acoustical VEMP

- 90-100 dB nHL = 140-145 dB SPL
- 100 msec
- Rate – 5 sec
- Intensity – 100 dBnHL
- Transducer - ER3a insert earphone

Stimulus Variables

- Stimulus Frequency
  - 1 = 500 Hz
  - 2 = 1000 Hz
  - 3 = 2000 Hz
  - 4 = 4000 Hz

P13 Latency – Effect of Frequency

- Rate = Optimal ~ 3-5 Hz
- Intensity = VEMP grows quickly once threshold is exceeded

Acoustical VEMP
Tone-burst
• Intensity- 110-120 dB pSPL
• Polarity – Rarefaction
• Rise-Fall – 2 cycles
• Plateau – none
• 5 per second
• Blackman Gating
• ER3a insert earphone

Procedures for Activating Muscles
• Lay supine and ask patient to lift head against gravity (bilateral)
• Turn head contralaterally to ear stimulated (unilateral)
• Apply loads to muscle through loop and pulley that changes the traction on the neck muscle
• Lift head and push against a padded bar,
• Ask patient to lift head and push against gentle pressure of hand (isometric activation)

Recording Characteristics
• If recumbent, patient is asked to raise their head from the table and keep it elevated - (elevation)
• elevation-rotation

Recording Characteristics
• If sitting, patient is asked to turn their head sharply to the side opposite the ear stimulated (rotation)
Comparison of the Head Elevation Versus Rotation Methods in Eliciting Vestibular Evoked Myogenic Potentials
Chun-Yu Young and Wei-Yeung

- Elevation-rotation the response rate was 100%
- Rotation had a response rate of 70% (smaller amplitude)
- Head rotation method may serve as an alternative for eliciting VEMPs in those who cannot sustain SCM muscle contraction by head elevation.
- The lower response rate and smaller amplitude must be considered when using this method.

Unilateral Air-Conduction Stimulation

Muscle Fatigue and EMG

- Extended contraction of the muscle will result in it fatiguing
- This will in turn reduce the EMG amplitude and alter the response
- Subjects may recruit other muscle groups to help support the head
- Recording in smaller blocks is an option for this situation.

Averages

10 stimuli
80 stimuli added
Recording Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplifier gain</td>
<td>~ 5000</td>
</tr>
<tr>
<td>Epoch length</td>
<td>40-100 msec</td>
</tr>
<tr>
<td>Sweeps per average</td>
<td>80-120 (averaged in subgroups)</td>
</tr>
<tr>
<td>Waveform replication</td>
<td>X1 minimum</td>
</tr>
<tr>
<td>Artifact rejection</td>
<td>Off</td>
</tr>
</tbody>
</table>

Normal Limits for Vestibular Evoked Myogenic Potential
500 Hz Tone Burst (Mayo Clinic data)

<table>
<thead>
<tr>
<th>Pooled Left and Right</th>
<th>Mean</th>
<th>Sd</th>
<th>+2 SD limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>P13 latency, msec</td>
<td>16.90</td>
<td>1.43</td>
<td>20.47</td>
</tr>
<tr>
<td>N23 latency, msec</td>
<td>25.24</td>
<td>1.63</td>
<td>29.31</td>
</tr>
<tr>
<td>P1-N1 amplitude, uV</td>
<td>180.71</td>
<td>120.42</td>
<td></td>
</tr>
</tbody>
</table>

From: Zapala & Brey, 2004

Bone-Conduction VEMP

Bone Conduction VEMP

- BC VEMPs can be elicited bilaterally

Two-channel recording with head elevated
Bone Conduction VEMP

- Examiner can evaluate otolith function in patients with conductive hearing losses.

Tone burst delivered to a Radioear B1 bone vibrator

- Optimum stimulus is 3cm post. and 2 cm sup. to EAM

Best frequency is 200-250 Hz

- Latency is stable across freqs

Frequency Tuning of Air vs. Bone conducted VEMPs

- Air – Peak amplitude at 500-1000 Hz
- Bone – Peak amplitude at 250Hz
Thresholds Using Three Modes of Stimulation

- Click – 120-135 dB SPL
- Tone (500 Hz) – 106-124 dB SPL
- Bone (500 Hz) - 95-107.5 dB SPL

Mechanisms BC-VEMP Generation

- There are most likely utricular contributions to the VEMP response when using BC stimuli.

Mechanical VEMP

Alternative Methods of Stimulation

- Can be used in cases of conductive hearing loss
- Reported that 59% of their OM sample generated a VEMP to tone bursts but 91% generated a VEMP to light skull taps (Yang and Young, 2003)
- VEMP latencies are similar to those obtained for acoustical stimuli
Methods – Mechanical VEMP

- Electrode placement identical as for acoustical stimulation
- Patient supine with head elevated from table
- Light pressure applied to forehead as patient elevates head to increase muscle tone (isometric activation)

- Light taps are presented to Fpz, from a reflex hammer that contains an inertial trigger
- Trigger pulse (for EP machine) is generated by the hammer every time it strikes the forehead
- Approximately 80-100 stimuli are presented at a rate approximating 3 Hz.
Mechanical (tap) VEMP

- Result is a P13/N23 in both SCMs (both saccules are stimulated by the stimulus)
- Tap elicits a 2nd negativity (N2) of unknown significance

Mechanical VEMP

Advantages
- VEMP amplitude is 1.5-3X greater for mechanical than acoustical stimulus
- Preserved in older patients who might not generate acoustical VEMPs
- Present in patients with conductive hearing loss

Limitations
- Technique is operator dependent
- Stimulus is uncalibrated (i.e. force and distribution of energy)
- Afferent pathway is unknown although the utricle has been hypothesized as the end organ.
Comparison of Tone Burst and Tapping Evocation of Myogenic Potentials in Patients with Chronic Otitis Media

• Skull taps – 91% generated responses to light skull taps
• Tone bursts (500Hz) – 59% generated VEMPs at 95 dB nHL

Ocular VEMP (oVEMP)

OVEMP

Ocular vestibular evoked myogenic potentials (OVEMPs) produced by air- and bone-conducted sound

Neil P. McGregor Todd 1,2,3, Kelly M. Rossignon 2,3, Sue E. An 4, James G. Gribbach 5

Vestibular-evoked extracocular potentials by air-conducted sound: Another clinical test for vestibular function

Yoshido Oshto 6,7, Bharti Joshi 8, Manuelata uito 8, Yoohduo Maruflari 7,8

OVEMP

• AC stimulation is believed to activate the contralateral inferior oblique and the ipsilateral superior rectus
**OVEMP**

- Gaze direction effects the amplitude of the OVEMP
- Superior gaze produces the largest OVEMP

![Graph showing the effect of gaze direction on OVEMP amplitude](image)

<table>
<thead>
<tr>
<th>Gaze Direction</th>
<th>Amplitude (µV)</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial</td>
<td>5.2 ± 0.3</td>
<td></td>
</tr>
<tr>
<td>Supranasal</td>
<td>5.2 ± 0.4</td>
<td></td>
</tr>
<tr>
<td>Inferonasal</td>
<td>2.6 ± 0.7</td>
<td></td>
</tr>
<tr>
<td>Lateral</td>
<td>3.6 ± 4.1</td>
<td></td>
</tr>
</tbody>
</table>

N=20


**OVEMP**

- The largest amplitude of the OVEMPs were obtained from the inferior electrodes with superior gaze.

![Diagram of OVEMP recording](image)
When is it Abnormal to Have a Bilaterally Absent VEMP?

Cross-check Principle

- Proposed by Jerger and Hayes, 1976
- Concept – the results of a single test are cross-checked by an independent test measure.
If you have bilaterally absent VEMPS or no EMG monitoring system then one cannot be sure whether the problem is in the MVST or the SCM.

**Stimulus Characteristics-oVEMP**

- **Stimulus type/s**: 500 Hz tone-burst
- **Transducer**: ER3a insert earphone or bone conductor
- **Rate**: 3-5/second
- **Intensity**: +5 dB re: VEMP response threshold (usually 90-100 dB nHL)

**Recording Characteristics-oVEMP**

- **Gain**: 100,000X
- **Non-inverting electrode**: 2 channels
- **Recording Epoch**: 50+ msec
- **Gaze**: Supra-medial for optimal response
- **Artifact Reject**: 40 mV
- **Filtering**: 1 to 1000 Hz
Galvanic VEMP

- 4 mA, 2 ms duration electrical pulses delivered to the mastoid (i.e. transmastoid stimulation) can be used to depolarize the inferior vestibular nerve.
- Evokes an ipsilateral P13/N23
- Technique may differentiate end organ from neural lesions
  - 10/10 subjects w-MD had preserved galvanic VEMPs
  - 16/18 subjects with CP angle lesions had reduced or absent VEMPs

Outline

- Historical background
- Anatomic origins
- Conventional stimulus (e.g. intensity, frequency, rate), subject (e.g. age, gender, muscle tone) and recording variables (e.g. filtering, amplification, artefact rejection)
- Normal response (i.e. waveform and measurement parameters)
- Responses from abnormal populations
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Galvanic VEMP

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Quantification of VEMP

- Prominent components are P13/P1 (ms) and N23/N1 (ms)
- Measurements = latency P13, N23; p/p amplitude P13/N23

VEMP Amplitudes

- Vary from a few μV to several hundred μV
- Can be resolved with less than 100 samples in neurologically and otologically intact subjects

Measures

- P13 & N23 latency (msec): ~ P13 (< 20.47), ~ N23 (< 29.31)
- P13-N23 amplitude (μV): range from 15 μV – 350 μV for tone bursts and 15 – 200 μV for clicks
- P13 threshold: ~ 90 dB (range 75-100 dB nHL)
- Interaural latency difference P13: 3.39 msec
- Asymmetry ratio (amplitude): ≤ 40% (range 0% – 40%)

Formula for Computing P13/N23 Amplitude Asymmetry Ratio

\[
\text{Asymmetry ratio (amplitude)} = \frac{(P13/N23 \text{ amplitude right side}) - (P13/N23 \text{ amplitude left side})}{(P13/N23 \text{ amplitude right side}) + (P13/N23 \text{ amplitude left side})}
\]
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<td>.09</td>
<td>1.35</td>
<td>3.39</td>
</tr>
<tr>
<td>N23 latency, msec</td>
<td>-.16</td>
<td>1.42</td>
<td>3.54</td>
</tr>
<tr>
<td>P13-N23 amplitude</td>
<td>-.02</td>
<td>.19</td>
<td>.47</td>
</tr>
</tbody>
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From: Zapala & Brey, 2004

VEMP Amplitude
- VEMP amplitude is proportional to:
  - Stimulus level reaching vestibular system
  - Electrode locations
  - Muscle mass
  - Magnitude of tonic SCM activity
  - Magnitude of stimulus-induced attenuation of tonic EMG
- magnitude of change is related to pathology
EMG Monitoring

- **Method 1:** Provide visual or acoustic feedback
  - Rectified raw EMG displayed on screen as a horizontally moving line

- **Method 2:** Adjusting amplitude based on background EMG
  - Employs a correction based on an average of background EMG

- **Method 3:** Blood Pressure Cuff
  - A certain pressure is maintained in order to keep the SCM consistently contracted.

Control for EMG Level: Method 1

**Visual Feedback of EMG Level**

- Rectified raw EMG activity is displayed on a screen as a horizontally moving line
- Patient is asked to maintain EMG at target level

From: Akin & Murnane, 2001

Effect of Muscle Tension on VEMP

- Linear relationship between the amplitude of the VEMP and the mean level of EMG activity.
- Patient can view EMG target amplitude on a CRT during data collection
- Patient can hear EMG as well
Control for EMG Level: Method 2
Amplitude Normalization & Calculation of Amplitude Asymmetry

- Condition A:
  - Left VEMP is 100 μV
  - w-EMG background of 50μV
  - Right VEMP is 400 μV
  - w-EMG background of 100 μV
  - Amplitude ratio (uncorrected) is 300μV/500μV or .60 abnormal

- Condition B:
  - Left VEMP is 100 μV/50 μV RMS
    background = 2 μV corrected Left VEMP
  - Right VEMP is 400 μV/100 μV RMS
    background = 4 μV corrected Right VEMP
  - Amplitude ratio (corrected) = 2μV/6μV or .30 normal
Control for EMG Level: Method 3
Blood Pressure Manometer

Improve Vestibular Evoked Myogenic Potential Reliability by using a Blood Pressure Manometer

Test-Retest Reliability

- Versino et al. 2001
- The authors reported that the test-retest reliability of the absolute latencies and amplitude of p13 and n23 were good to excellent
- Had a correlation coefficient of .93-.69.

Demonstration

- Air-Conducted VEMP
- Bone-Conducted VEMP
- Mechanical VEMP
- oVEMP

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    - magnitude of change is related to pathology

Subject Variables

- Conductive deficit (e.g. stapes fixation) makes it difficult for appropriate SPL to reach the saccule
  - Solution: Bone conduction VEMP, or, skull tap VEMP
  - Patient’s ability to generate large and symmetrical background EMG for both left and right SCM's
    - Solution: Visual feedback of muscle tone to patient, or “amplitude normalization” of responses

Subject Variables

- Present in:
  - 98% - < 20 – 40 years
  - 90% - 41-60 years
  - 60% - > 60 years of age
  - Decreased amplitudes and increased thresholds begin at 6th decade
    - Mean threshold 20-30 year old = 85 dB nHL
    - Mean threshold 70-80 year old = 96 dB nHL
  - No age effect on latency

Subject Variables

- Age (elderly)
  - Present in:
  - 98% - < 20 – 40 years
  - 90% - 41-60 years
  - 60% - > 60 years of age
  - Decreased amplitudes and increased thresholds begin at 6th decade
    - Mean threshold 20-30 year old = 85 dB nHL
    - Mean threshold 70-80 year old = 96 dB nHL
  - No age effect on latency
Effect of Age and Stimulus Type on the VEMP

- 30 subjects (3-11) – All participants had responses
- 28/30 had symmetrical responses
- Peak latency
  - P1 -11.3  N2 -17.6
- Peak Amplitude
  - 122 mV
- Average test time was 15 minutes

EMG Monitoring for Children

- Monitor with a video connected to EMG system
- Monitor would only trigger when the child applied enough tension to the SCM to reach target.
- Stimuli were delivered once the EMG target was reached.

Vestibular Evoked Myogenic Potentials in Newborns

- 20 subjects (40 ears) (2-5 days old)
- Based on adult criteria
  - 40% demonstrated normal VEMPS
  - 35% had prolonged P13 latencies
  - 25% had absent VEMPs
  - Shorter inter-peak p13-n23
  - Smaller p13-n23 amplitude
- Authors propose this may reflect incomplete maturity of the sacculocollic reflex pathway (myelination)
Development of Vestibular Evoked Myogenic Potentials in Preterm Neonates

- 27 low-risk preterm and 25 healthy full-term neonates
- 26% of 54 ears in preterm group had responses vs. 72% of the full-term
- Preterm P13 and N23 latencies were significantly longer than full-term
- Conclusions – when body weight reaches 2.26 for pre and 2.82 for full-term VEMPs can be expected.

Caloric does not predict VEMP

<table>
<thead>
<tr>
<th>Canal Paresis</th>
<th>Absent</th>
<th>Decreased</th>
<th>Normal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;90%</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>50%-90%</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>20%-50%</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>&lt;20%</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>15</td>
<td>2</td>
<td>4</td>
<td>21</td>
</tr>
</tbody>
</table>

Murofushi et al. 1998

Outline
- Historical background
- Anatomy and Physiology of the vestibular system
- Anatomic origins of the VEMP
- Conventional parameters for recording the VEMP
- Normal response (i.e. waveform and measurement parameters)
- Clinical Implications
- Responses from abnormal populations
- Summary

DISORDERS
Meniere's Disease

- The saccular response was absent on the affected side in 54% of the patients with Meniere's disease.
- This absence was correlated with the degree of low frequency hearing loss but not with canal paresis.
- Patients with abnormal VEMPs had a significantly poorer postural performance than those without on condition 5.

VEMP Responses and Meniere's Disease

<table>
<thead>
<tr>
<th>Investigator</th>
<th>#</th>
<th>% abnormal</th>
</tr>
</thead>
<tbody>
<tr>
<td>De Waele et al. 1999</td>
<td>59</td>
<td>54%</td>
</tr>
<tr>
<td>Young et al., 2002</td>
<td>20</td>
<td>55%</td>
</tr>
<tr>
<td>Young et al., 2002</td>
<td>10</td>
<td>30%</td>
</tr>
</tbody>
</table>
Meniere’s Disease and Dehydration

- Has been used to increase the sensitivity of the VEMP (furosemide and glycerol)

- Osmotic diuretic that ameliorates MD by restoring inner ear pressure

<table>
<thead>
<tr>
<th>Investigators</th>
<th>#</th>
<th>%</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Murofushi et al., 2001</td>
<td>17</td>
<td>41%</td>
<td>Five ears increased amplitude - two ears decreased in amplitude</td>
</tr>
<tr>
<td>Shojaku et al.</td>
<td>15</td>
<td>53%</td>
<td>Increase amplitude</td>
</tr>
<tr>
<td>Magliulo et al.</td>
<td>38</td>
<td>42%</td>
<td>Increased amplitude</td>
</tr>
<tr>
<td>Seo et al., 2003</td>
<td>25</td>
<td>40%</td>
<td>Increased amplitude</td>
</tr>
</tbody>
</table>
Clinical Applications of VEMP

Meniere's Syndrome

- Absent VEMP responses on one side with normal ENG and rotational test has been shown to decrease performance on condition 5 of CDP. (Waele et al. 1999)

- Return of VEMP following administration of diuretics suggests reversal of saccular hydrops.

Meniere's Disease

Mild (right) and moderate (left) sensorineural hearing loss

Superior Canal Dehiscence
Clinical Applications of VEMP
Hypersensitivity Disorders

- Superior canal dehiscence – SCD
- Patients have sound and/or pressure-induced vertigo (Tullio’s phenomenon)
- Caused by thinning (dehiscence) of bone overlying the posterior SCC resulting in abnormal site of compliance and fluid motion

SCD
from Rosowski et al. 2004

Clinical Applications of VEMP
Hypersensitivity Disorders

- Patients show large VEMP’s at reduced thresholds and abnormally large VEMP
- VEMP threshold differences 72 dB +/- affected side vs 96 dB +/-4 dB on the unaffected side.

From: Minor (2005)

Clinical Applications of VEMP
Hypersensitivity Disorders

- Presents as a conductive hearing loss where immittance is normal and stapedial reflexes are present
- Conductive loss exists because dehiscence occurs at a site where acoustic energy escapes

From: Minor (2005)
History
• 59 yo female
• C/O
  • lightheadedness and true vertigo occurring frequently
  • positional vertigo turning head to right
  • dizziness when she blows her nose
  • pain in right ear
  • blurred vision
  • migraine headaches
• First began 8 months ago
• Attacks last ~30 min.

Dizziness Handicap Inventory (DHI)
• 8/100 point total score representing no self-report dizziness disability/handicap

Medication History
• Meclizine prn for dizziness
• Paxil for depression

Audiometric Examination
Spontaneous Nystagmus

Rotational Testing

VOR Suppression

Monothermal Warm Caloric Examination
Asymmetry = 1%
VEMP 95 dB nHL 500Hz tone bursts

VEMP Right Threshold ~60 dB nHL

VEMP Left Threshold ~65 dB nHL

CT Scan

• "There is no obvious bony roof over the bilateral superior semicircular canals. These findings are consistent with bilateral superior semicircular canal dehiscence, more apparent on the right."

• Impression: Findings consistent with bilateral superior semicircular canal dehiscence, more prominent on the right
oVEMP and SCD

- Amplitude – Amplitudes were significantly larger (p<.001). n10 oVEMP from the contralateral inferior electrode could reach 40 mV in SCD patients with upgaze.
- Thresholds – were pathologically low

VESTIBULAR NEURITIS

Clinical Applications of VEMP

- Superior and inferior vestibular nerve variants
- Viral infection affects nerve
- Causes delay in, or absence of, VEMP if inferior vestibular nerve is affected.
  - VEMP recovers within 6 mos-2 years 30% of the time
- Normal VEMP suggests that the superior vestibular nerve is selectively affected.

Vestibular Neuritis (Case 1)

Bilateral high frequency sensorineural hearing loss
**Vestibular Neuritis (Case 1)**

**Normal caloric examination**

- Caloric: Both Cases

**Vestibular Neuritis (Case 1)**

**Normal rotational testing**

**Vestibular Neuritis (Case 1)**

**Delayed left VEMP (7.35 msec)**

- Left VEMP: 7.35 msec
- Right VEMP: 12.74 msec

**Vestibular Neuritis**

**Sensory Organization Test**

- Equilibrium Score

![Graph showing sensory organization test results]
Clinical Applications of VEMP

Vestibular Schwannoma

- Abnormal VEMP amplitude in 72%-80% of patients (most absent)
- Absence of VEMPs has ranged from 35%-100% in patients with tumors originating from the inferior vestibular nerve
- Latency may be normal 90% of the time
The VEMP was absent on the affected side in patients with CPA lesions (90% of which were VS) ~50% of the time. Absent responses occurred more frequently in patients with “medium” and “large” tumors (58% absent) than in patients with “small” tumors (33% absent). The VEMP amplitude ratio was abnormal between 61% (using a 0.47 asymmetry criterion) and 71% (using a 0.35 asymmetry criterion) of the time for these patients. Tumor size (“small,” “medium,” “large”) did not impose a systematic effect on P13-N23 amplitude although maximum caloric SPV was affected by tumor size.
VEMP and CPA Tumors

10% - 20% of the patients demonstrated abnormal VEMP with normal caloric responses

17% of patients demonstrated abnormal caloric tests and had normal VEMPs

37%-41% of the sample had significant VEMP asymmetries yet demonstrated normal auditory brainstem responses

The VEMP test provides complementary information about VIIIth N function unavailable from caloric, and ABR tests

McCaslin et al. (2008)