Vestibular Evoked Myogenic Potentials (VEMP) and Other Electrophysiologic Techniques in the Evaluation of the Vestibular System
Recorded January 29, 2013

Vestibular Evoked Myogenic Potentials
And Other Electrophysiologic Techniques in the Evaluation of the Vestibular System

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Agenda

- Current Vestibular Assessment
  - Evaluation of the VOR
  - The Vestibulogram
  - Genesis of VEMP
  - Protocol
  - Stimulus and Recording Parameters
  - Recording Technique

- Diagnostic Utility
- Dehiscence Syndrome
- Superior Semicircular Canal Dehiscence
- Perilymphatic Fistula
- Spontaneous
- Traumatic PLF
- Case Studies
- Alternative/Augmentative Test Techniques

Current Vestibular Assessment – VNG and Rotational Tests

- VNG and rotation testing assess horizontal semicircular canal function
  - Angular acceleration
- Hallpike assessment – posterior semicircular canal
  - In BPV the post canal is typically the “innocent bystander”
- CNS and Brainstem connections
  - Tests of Ocular Control
Current Vestibular Assessment – VNG and Rotational Tests

- The VOR Responds to Natural Head Movements Over a Broad Frequency Range (Frequency Response)
  - Frequency Range of VOR From .05 to 5Hz for Normal Head Movements
  - VOR Can Respond Efficiently Up to Frequencies Approaching 8 Hz (Gresty, Hess & Leech; Sayer Et. Al.)

Current Vestibular Assessment – VNG and Rotational Tests

- VOR function – Visual Stabilization During Active Head Movement
  - Below 2 Hz, Smooth Pursuit Contributes To Gaze Stability

Vestibulo-Ocular Reflex Function “Vestibulometry”

- Low Frequency Testing
  - Caloric Testing – Evaluation of the low frequency response of VOR
    - Analogous To A Head Movement Below Range of VOR

- Mid Frequency Testing
  - Rotary Chair Testing Is Used To Evaluate The Horizontal Vestibulo Ocular Reflex Below .64 Hz

- High Frequency Testing
  - Autorotation (VAT or VORTEQ) Testing Is Used To Evaluate Horizontal VOR from 2 to 6 Hz.
Vestibulo-Ocular Reflex Function

- Inferences are made about the integrity of the Vestibular Labyrinth based on the Caloric Test (ABBT).
- Analogous to evaluating hearing using only low frequency tones (e.g., 125 Hz) and inferring integrity of the Auditory System on the basis of the findings.

Other Techniques to Evaluate the VOR

- Halmaygi
- Head Shake Nystagmus
- VOR Cancellation
- Dynamic Visual Acuity Exam (with Snelling Chart)
  - Test for Oscillopsia

Other Techniques to Evaluate the VOR

- Halmaygi
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- VEMP
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VEMP – Why Do We Need It?

- Normal ENG?
  - Indicates that the horizontal semi-circular canal is functioning normally infer normal function
- Normative Range for RVR
  - < 20% asymmetry
- Bilateral RVR**
  - combined SPEV < 20 deg
- Otolith Assessment Not Possible via ENG or Rotation Testing

VEMP – Why Do We Need It?

- VEMP Assesses The Saccule and Inferior Vestibular Nerve
- Neural Pathway Is Unique
  - Differs From Horizontal VOR
  - Lateral Vestibulospinal Tract

So What is the VEMP?

- Short Latency EMG (Electromyographic Response)
- Can Be Evoked by:
  - high level acoustic stimulation
  - Electrical Stimulation
  - Mechanical Stimulation (Skull Taps)
- Recorded from surface electrodes over the contracted sternocleidomastoid muscle
- Presumed to originate in the saccule of the vestibular system
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So What is the VEMP?

- Intense sound pressure
- Saccule stimulation produces
- Vestibulo-spinal tract response
- Myogenic potential

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VEMP – Clinical Indications

- When it’s the only vestibular test you can do
  - Young children
  - Patients with severe to profound HL – ABR/EcoGm
- Especially useful in the presence of otherwise normal findings
- Routine component of the vestibular test battery

---

Before We Begin.... A Little Anatomy Review

- What Are the Five Sensory Structures of The Peripheral Vestibular System?
  - Three Cristae of the Semicircular Canals
  - Two Maculae of Saccule and Utricle
- Larger Structure in Inner Ear: Cochlea or Vestibule?
  - 2/3 of the "Inner Ear" Is Dedicated to Vestibular Function
- Phylogenetically Older: Cochlea or Vestibule?
  - Vestibule
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- Vestibular Evoked Myogenic Potentials (VEMP)
- Other Electrophysiologic Techniques

Seo & Yoshida (1999)

Semicircular Canals
- Sense rotational acceleration in their plane
- Semicircular canals are orthogonal to each other
- Each lateral canal is at 30 degree inclination
- Superior/posterior canals 45 degrees off of sagittal plane
  - Superior canal is in the same plane as contralateral posterior canal
- Ampullae contain cupula and neuroepithelium = Cristae ampullaris

Cristae Ampullaris

- Angular acceleration in one direction results in deflection of cupula in contralateral direction from inertia of endolymph

Utricle and Saccular Maculae

- Maculae: contain neuroepithelium and otolithic membrane
- Utricle: senses linear acceleration in the horizontal plane (MU)
- Saccule: senses linear acceleration in the vertical plane (MS)

Maculae

- Stiola: curved central portion of otolithic membrane
- Anatomical curvature allows for sensation of linear acceleration along multiple trajectories
- Utricle: kinocilia polarized toward striola
- Saccule: kinocilia polarized away from striola
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**Maculae**

- Hair cells extend to otolithic membranes which contain otoconia (calcium carbonate)
- Specific gravity of otoconia 2.71-2.94
- Linear acceleration displaces otolithic membrane resulting in deflection and depolarization/hyperpolarization of hair cells


**Hair Cell Response**

- Displacement of sensory hairs relative to kinocilium determines change from resting activity


**Vestibular Reflexes**

- Reflex Projections from Cristae

Vestibular Reflexes

- Reflex Projections from Saccule
  - Also referred to as...
    - Vestibulospinal reflex
    - Vestibulocollic reflex

Vestibular Reflexes

- Reflex Projections from Utricle

Vestibular Response to Sound?

“An Evolutionary Perspective”

- Presumed original function of inner ear: monitor rotational and linear movements of head and orientation of head relative to earth (proprioception)

- The saccule evolved to become the receptor of sound and vibration (exteroception) in some amphibians and fish

- Precursors of the mammalian cochlea have evolved from recesses within the saccule
  - May still “respond to sound”
  - In Man innervates the antigravity muscles
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Vestibular Response to Sound: Historical Framework

- Tullio (1928): fenestration of bony labyrinth of alert animals (pigeons, rabbits, and dogs) produced head movement, eye movement, and postural changes in response to sound
- Sound-evoked vestibular symptoms or signs (Tullio’s phenomenon)
  - Vertigo
  - Nystagmus
  - Oscillopsia
  - Postural imbalance

Vestibular Response to Sound: VEMP Generators

- Bickford, et al (1964) described click evoked potentials of the neck muscles.

VEMP

Lateral Vestibulospinal Pathway

- Saccule to the
  - inferior vestibular nerve,
  - lateral vestibular nucleus,
  - medial vestibulospinal tract, and finally to the
  - motoneurons of SCM.
The VEMP Reflex Arc

- The saccule is the organ that modulates the antigravity muscles. This pathway descends from the saccule to the SCM and down to the legs.

Clinical Parameters

- Latency of P1 (P13) and N1 (N23)
- Absolute amplitude of P1-N1
- Amplitude asymmetry of P1-N1 amplitudes
  - Asymmetry Ratio (AR):
    \[
    \frac{(P1 \text{ to } N1 \text{ Amp L}) - (P1 \text{ to } N1 \text{ Amp R})}{(P1 - N1 \text{ Amp L} + P1 - N1 \text{ Amp R})}
    \]

VEMP

- P1 latency is around 12-15 msec
- N1 latency is around 20-25 msec
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<table>
<thead>
<tr>
<th>STUDY</th>
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</table>

Clinical Application:
Halmagyi, et al., 2002
- 2 patients with ‘vestibular neuritis’
- Diagnosis: inferior vestibular neuritis (of posterior canal origin)
- ENG - Normal
- VEMP – Abnormal
- ABR results not reported

Clinical Application:
Murofushi, et al. (2001)
- Abnormal VEMP found in
  - 77% of acoustic neuroma
    (n=48)
  - 51% of patient w/ Meniere’s Disease
    (n=22)
  - 25% of pts w/ MS
    (n=6)
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<table>
<thead>
<tr>
<th>Pathology</th>
<th>VEMP Response</th>
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<td></td>
<td>Normal</td>
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<td>Vestibular Schwannoma</td>
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<td>Superior Canal Dehiscence</td>
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<td>Abnormal</td>
</tr>
<tr>
<td></td>
<td>63</td>
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<tr>
<td></td>
<td>153</td>
</tr>
<tr>
<td></td>
<td>7*</td>
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<tr>
<td></td>
<td>11*</td>
</tr>
<tr>
<td></td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>* abnormally low threshold</td>
<td></td>
</tr>
</tbody>
</table>

Diagnostic Utility of The VEMP

- Peripheral Vestibular Disease
  - Saccular (Otolith) Involvement
  - Inferior Vestibular Nerve
    - e.g. Vestibular Neuritis
    - Vestibular Schwannoma/AN
    - Determination of Total Vestibular Loss
  - Menieres Disease

- Dehiscence Syndrome
  - Perilymphatic Fistula
  - Spontaneous PLF
  - Traumatic PLF
- Vestibular assessment of patients with low vision or congenital nystagmus
Recording the VEMP

Stimulus Parameters

Recording Parameters

Stimulus Parameters

**Click**
- Polarity: Rarefaction
- Duration: 100 usec
- Intensity: 100 dB nHL (134 dBpSPL)
- Stim Rate: 5.1/sec

**Tone Burst**
- Polarity: Rarefaction
- Rise/Fall: 2 cycles
- Plateau: 0 cycles
- Ramp: Blackman
- Intensity: 95 & 75 dB nHL (120 dBpSPL)
- Stim Rate: 5.1/sec
- Tone Burst Frequency:

Stimulation Parameters

<table>
<thead>
<tr>
<th>Presentation Level</th>
<th>RIGHT Response</th>
<th>LEFT Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>250-Hz</td>
<td>500-Hz</td>
<td>1000-Hz</td>
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<tr>
<td>130 dBpSPL</td>
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<tr>
<td>125 dBpSPL</td>
<td><strong>Black</strong></td>
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<tr>
<td>120 dBpSPL</td>
<td></td>
<td></td>
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<tr>
<td>100 dBpSPL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90 dBpSPL</td>
<td></td>
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</tr>
</tbody>
</table>

Testing should be completed @ Minimum 2 frequencies and At recommended intensity levels per frequency...
**Grey = Recommended / White = Optional / Black = DNT**
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250 and 500 Hz VEMP

[Images of graphs and computer screens showing VEMP recordings]
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Parameters of VEMP

I. Rate: 5.1 – 13.1
II. Scale: 10-50 uV
III. Gain: 2k
IV. Sweeps: 50-150
V. High pass filter: 10 Hz
VI. Low pass filter: 1k Hz.
VII. Artifact: OFF
Time base: 50 msec
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Recording Technique: Electrode Montage

One Channel Recording
Channel 1
- Input 1 (non-inverting aka "positive" or "active")
  - Upper 1/3 of the SCM of stimulus ear
- Input 2 (inverting aka "negative" or "reference")
  - Sternum – Below Clavicular notch
- Ground
  - Forehead (FpZ)

Two Channel Recording
Channel 1
- Input 1 (non-inverting)
  1. Upper 1/3 of the SCM of stimulus ear
- Input 2 (inverting)
  1. Sternum

Channel 2
- Input 1 (non-inverting)
  1. Upper 1/3 of the SCM of contralateral side
- Input 2 (inverting)
  1. Sternum (jumper or electronically synched)

Recording Technique
- Patient turns head 90 degrees away from the stimulated side.
- Head should be elevated to produce maximum contraction of the SCM muscle.
- Recording cycle duration: typically 30 seconds (128 repetitions)
Recording Technique

- Two repeatable recordings obtained for each stimulus condition
- Patients given 30 to 60 seconds to relax between each recording
- Issue of response fatigue

Recording Technique

Standard Intensity Levels

- 95 dB nHL
- 75 dB nHL

Recording Technique

Normal VEMP Response

- 500 Hz Tone Burst
- 120/100 dB SPL
VEMP Response

- The VEMP response is an amplitude measure, and therefore, the influence of the tonic level of the EMG must be taken into account.
- If no correction is made to account for R/L differences in tonic level of EMG, VEMP amplitude data will not be accurate for comparing symmetry.

VEMP Response Amplitude

- Ongoing EMG of SCM
  - Tonic Contraction
- Stimulus Level
  - Click intensity should be about 134 dB pSPL for VEMP optimal amplitude measurements,
  - Toneburst stimulus only requires 120 dBpSPL and therefore, is a better default stimulus.
- Stimulus Frequency
  - Highest amplitude for 500 Hz Toneburst

VEMP Response Amplitude

- SCM Activation
  - Head Turn – Unilateral
  - Head Raised – Bilateral
  - Head Bar (Hand) – Bilateral
  - BP Cuff – Bilateral
  - EMG Monitor – Unilateral or Bilateral
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VEMP – Technical Issues

**EMG Rectification**

- EMG Rectification available with some AEP Systems
- For the EMG rectification, there is a 20 ms prestimulus baseline - the amplitude for each point is averaged together - that value is divided into each of the 256 points on the VEMP recording

VEMP – Technical Issues

**EMG Rectification**

- Highlight the collected wave to be corrected and click on “Pre-stim Rectify” icon
- Pre-stim Rectify appears as last icon on “Calculations” toolbar

Technical Issues Summary

**If The VEMP Is Absent**

- Monitor for EMG
  - Is absent response secondary to inadequate activation?
  - Conductive Hearing Loss
- Increase EMG level
  - can tilt chin downward
  - use of hand on cheek to provide isometric resistance if response is low amplitude/absent
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VEMP Stimulus Protocol
(for each frequency)

At the upper limit of the threshold norm, was there a response?

YES

Run 2-3 recordings at the lower limit of the threshold norm. Were there repeatable responses?

YES; very clear

NO

Go as high as you can on the equipment.

YES; barely

NO

Run 2 recordings at 10 dB above the lower limit of the threshold norm.

NO

Run 2 recordings at 5 dB below the lower limit of the threshold norm.

Run 3-6 recordings at 10 dB below the lower limit of the threshold norm.

YES; very clear

NO

Run 2 recordings at 10 dB below the lower limit of the threshold norm.

YES

VEMP Stimulus Protocol

Stimulus And Recording Parameters

- **Stimulus Level** – Amplitude increases with stimulus level
- **EMG Level** – Amplitude increases with EMG rms amplitude
- **Stimulus Frequency** – Largest amplitudes obtained at 500 and 750 Hz
- **Latency** of VEMP is not affected by changes in stimulus level, EMG rms amplitude

Normative Findings

Laboratory Norms

- **Latency**
  - P I (P 13)
    - < 12.5 ms or > 19.5 ms = abnormal
  - N I (N 23)
    - < 19.7 ms or > 27.7 ms = abnormal
- **Amplitude**
  - < 25 uV or > 185 μV
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**Descriptive Statistics**

**Latency**

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<tr>
<th>Wave</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
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**P1 (Wave I) and N2 (Wave II) Latency**

Latency RE vs. LE Latency

![Bar Chart: VEMP Wave I and II Latencies]

n/s

**Statistics**

- P1 (Wave I) Latencies in comparison with “normal” data
  - N/S
- N1 (Wave II) Latencies in comparison with “normal” data
  - N/S p = 0.91
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Descriptive Statistics

- Amplitude (μV) in comparison with "normal" data

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<tr>
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<th>SD</th>
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<td>115.80</td>
<td>81.69</td>
<td>22.70</td>
<td>354.00</td>
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<td>Normal controls</td>
<td>104.63</td>
<td>40.724</td>
<td>55.00</td>
<td>190.00</td>
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Peripheral Vestibular Disease

- Otolith Involvement
  - Absent
  - Low Amplitude VEMP
  - Elevated Threshold
  - Asymmetric VEMP Responses (Amplitude)

- Horizontal SCC Involvement
  - RVR With or Without VEMP Abnormalities
Peripheral Vestibular Disease

- Increased VEMP thresholds - low amplitude or absent responses - may suggest a saccule disorder such as Menieres' syndrome
- Must Rule Out Middle ear pathology or ossicular chain abnormality

Asymmetry Ratio (AR):

\[(P1 \text{ to } N1 \text{ Amp L}) - (P1 \text{ to } N1 \text{ Amp R}) / (P1 - N1 \text{ Amp L} + P1 \text{ to } N1 \text{ Amp R})\]

- Recommendation is to collect own normative data
- Significant difference = 2.5 S.D. from the mean
- Most often proposed are about 30-40% difference between R & L VEMP response amplitude

Analysis Technique

- Asymmetry Ratio or IAD > .36 is abnormal
- Augmented VEMP
  - Young, Wu & Wu, '02
  - High amplitude ratio suggests saccular hydrops (saccule distention against the stapes footplate)
**Peripheral Vestibular Disease**

10 Meniere’s vs. 10 sudden SNHL pts.

\[
\text{interaural amplitude diff} = \frac{\text{right SCM} + \text{left SCM amplitude}}{2} > .36 = \text{Abnormal}
\]

Indicates saccular hydrops with saccule distention against the stapes footplate

Augmented VEMP
Young, Wu & Wu, ’02

---

**Menieres’ Syndrome Protocol**

- **Audiometry**
  - Pure Tone Audiometry
    - Assess Hearing At 125 Hz
    - Mid Octaves Above 1000 Hz
  - Speech Audiometry
    - Speech UCL and LDL
  - Recommend Serial Studies

- **ECOGm**
  - Elevated SP/AP ratio

- **VEMP**
  - Amplitude Asymmetry
  - Elevated Thresholds

- **ENG**
  - Hallpike (positive BPV)
  - Caloric Studies

---

**Superior Canal Dehisence (SCD)**

- Dizziness or unsteadiness
  - Increases with exertion or activity (relieved with rest)
  - Valsalva induced dizziness
    - Coughing, sneezing, blowing nose

- Pressure sensitivity
  - Change in air pressure in middle ear
  - Hennebret's sign

- Sound sensitivity
  - Own voice or external sound aka “Tullios phenomenon”
  - Conductive Hyperacusis

- Hearing loss
  - Low frequency hearing loss with Air-Bone gap
Peripheral Vestibular Disease
Frequency Specific VEMP (250 Hz nHL)

- Right
- Left

Augmented VEMP = 0.52

Peripheral Vestibular Disease
Frequency Specific VEMP (500 Hz dB SPL)

Superior Canal Dehisence (SCD)
- Bony covering over inner ear (membranous labyrinth) is missing or removed or worn away
- SCD – roof of the SSC is missing or marginal (e.g. bone defect)
- Fluid is not in direct communication with air filled cavity such as middle ear (PLF) but vulnerable to sound or pressure changes
Superior Canal Dehisence (SCD)
- Normally two point of increased compliance in the inner ear:
  - Oval window thru which sound energy is transmitted into the inner ear via stapes
  - Round Window thru which sound energy is Bony dissipated from the inner ear after traveling around the cochlea
- A so called third window into the inner ear (yielding to pressure or sound) results in a minute hydraulic phenomenon within the inner ear

“Hydraulic” System of Cochlea and Vestibule
- Stapes acts as a piston pushing into the perilymph of the inner ear

“Hydraulic” System of Cochlea and Vestibule
- Perilymph is not “compressible” and there must be a compensatory displacement somewhere in the system that coincides with the input to the stapes
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Dehiscence Syndromes
- Superior canal dehiscence
- Lateral canal dehiscence (mastoid dehiscence)
- Posterior canal dehiscence

How Is Diagnosis Made?
- High Resolution CT of the temporal bone
  - Three Consecutive Cuts on the CT Scan
  - History

Dehiscence Abnormalities
- Developmental abnormality
- Hereditary
- Post surgical complication (aka fenestration)
- Trauma
- PLF
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CT Scan

Bilateral SCD

VEMP and SCD

Brandtberg et al, 1999

- Low intensity VEMPs are obtained (Reduced thresholds)
- A repeatable VEMP response at low levels (75-80 dB nHL) is believed to be indicative of SCD
- The presence of VEMP's in a person with a conductive hearing loss is also suggestive of SCD.
VEMP Results in SCD

- Abnormally low threshold in involved ear (< 80 dB)
- Typical threshold for normal ears 85-95 nHL
- Decreased threshold is due to increased inner ear immittance (conductance)

Recording Technique

VEMP (Screening for SCD)

Tone Burst nHL

VEMP Result in SCD

Left
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VEMP Result in SCD

VEMP Result in SCD

Threshold VEMP - SCD
Other “Dehiscent-Like Syndromes”

- Perilymph Fistula
  - Round window
  - Oval window
  - Middle ear mastoid sinus into intracranial cavity of temporal bone or otic capsule

VEMP Findings – Bilateral PLF

Perilymph Fistula (PLF)

- Audiograms – Attempts at finding specific pattern have failed.
- PTA & Word Recognition - Fluctuating PTA and/or WRS has been reported, but not consistent
- ECochG – Can not distinguish PLF from Menière’s
- Tullio – Not always positive
Fistula Test Battery
- Pure tones of 500, 1000, and 2000 Hz. with intensities between 100-110 dB (use the impedance bridge and present at intensity limits at each frequency).
- Tympanometry – Wide Range
- VNG Pressure Test (or pressure on the tragus and ear canal)
- Platform Pressure Test
- Vibration Test

VNG Pressure Test (Positive)
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Platform Pressure Test

Vibration Test

Perilymphatic Fistula
- Can they occur Spontaneously?
- What symptoms are specifically associated?
- What tests diagnose a fistula?
- What is the “Gold Standard” for confirming the presence of a fistula?
- How should a fistula be treated?
Other Findings With PLF

- Henneberts Sign
  - Observed for nystagmus (visual or measured)
  - Questioned for dysequilibrium (subjective)
  - Tested with patient seated, standing, on a moving platform.
    - One study showed 97% sensitivity (Black et al.)
    - Another study showed 33% (Meyerhoff)
- Vestibular Test Battery
  - Hypeactive response or UW (sometimes)
  - Spontaneous/positional nystagmus (sometimes)

VEMP Abnormalities - Summary

- Decreased VEMP thresholds (below 80 dB nHL) – may indicate SCD or PLF
- Increased VEMP thresholds - low amplitude or absent responses – may suggest a saccule disorder such as Menieres’ syndrome
  - Middle ear pathology or ossicular chain abnormality
- Prolonged latencies – may suggest a vestibular n. /caudal brainstem disorder or VS disorder
- Must consider the integrity of the spinal and neck muscles – rule out neuropathy/myopathy

A Few Case Presentations
CC: 64 Year Old Male

- Severe Vertigo 5-9-2008 while exercising in gym – ambulance dispatched. Had three brief episodes prior to 5-2008
- MRI, CT negative. Diagnosis by exclusion of neuronitis or labyrinthitis
- Dizziness, lack of balance and fear of falling from 5-6 to 6-24-2008. Dizziness exacerbated by movement
- No vertigo as of July 9, 2008

CC: Audiogram (6-21-2011)

CC: Audiogram (6-25-2011)
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CC: Gaze Testing (2008)

CC: Caloric Findings (2008)
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CC: Audiogram (9-2011)

“Leo” Clinical History

39 year old male

- Sx: brief positional vertigo (looking down) w/ nausea; symptoms were very brief 1 to 2 seconds
- Unilateral tinnitus left ear
- Hx of chronic headaches usually following the positional vertigo;
- Hx of dizziness when “chewing” described as “eyes move while chewing”

Differential Diagnosis

- BPPV?
- Migraine Associated Vertigo?
- Oscillopsia? (Bilateral reduced vestibular response)
- Tullio's Phonemenon? (Superior Canal Dehiscence)
“Leo” Clinical Exam

- Dynamic Visual Acuity Screening (Snellen) - Normal
- VNG – Normal
  - Normal horizontal canal VOR response
  - Vestibular evoked myogenic potentials (VEMP) while chewing
  - Fistula test was normal
  - Tullio screen normal
- Audiogram – Normal (tinnitus);
  - Normal tympanograms
  - Elevated MEMRs
- ABR – Normal
- VEMP – Significant amplitude asymmetry

History: KS

- 57 y/o female with dizziness that comes in spells intermittently since 2004
- Sensation of dizziness with sudden movement of Visual Surround
- Aural Pressure, fullness and tinnitus right ear.
- In 2005 had normal Audiogram, MEMR, OAEs, ABR and ECogm
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KS - 250 Hz Tone Burst

KS 250 and 500 Tone Burst

KS – Cochlear Hydrops Masking Technique
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History: C.O.
- 57 y/o male with history of TBI 2004 – Fell Down A Flight of Stairs
- Baltimore Shock Trauma Unit 3.5 weeks (comatose)
- Right Craniotomy for Subdural Hematoma
- Transferred to Rehab Facility

CO Exam July 2007
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“DP” - History
- Dizziness and loss of balance since 2001
- Father was diagnosed with unilateral Menieres disease
- Recent symptoms
  - Dizziness
  - Oscillopsia
  - Patient reports her symptoms are from right ear
  - Pressure sensitivity

“DP” - History

“DP” Initial Audiogram 12-14-2005
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"DP" Initial Audiogram 12-14-2005

"DP" Audiometric Studies 2-09

"DP" – Tympanometry and Acoustic Reflex
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“DP” Platform Posturography

“DP” – Platform Pressure Test

DP – Platform Posturography

HISTORY: Mr. P presents with a three-year history of dizziness. He presented with a mild, low-frequency (25-50 Hz) hearing loss in the right ear, and normal hearing in the left ear. His hearing loss is reportedly fluctuating. Mr. Palko reported occasional ear pain and pressure that he assumes to be dizziness. Results from her balance test, DPOAE, ABR, ECoG, and infrared fundus test are on file.

SUMMARY TEST: Normal results obtained in 10/10 conditions. A Composite score of 87% was obtained and is within the normal limits.

MOVEMENT COORDINATION TEST: Normal results obtained for evaluation of rapid forward and backward transitions on each side. Normal results were obtained for analysis of adaptability to change with two hands. Normal results were obtained in all 5 conditions for adaptability with two hands.

PRESSURE TEST: Pressure test results were not outside the normal limits for anterior-posterior sway on the left side. Pressure test results were not positive over the two standard deviations for normal sway on the right side. Pressure test results were normal for anterior-posterior sway on the right side and lateral sway on the left side.
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DP – Infra Red Pressure Test
2004

“DP” Infra Red Fistula 2005
Positive and negative Pressure

“DP” Infra Red Fistula

Impression:
Normal Infra-Red Fistula testing. Due to the downbeat nystagmus in the baseline head hanging and supine positions, this patient should be referred for a full ENG examination.
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“DP” 2004
Two Channel VEMP

Left ear
95 dB nHL 500 Hz

Right ear
95 dB nHL 500 Hz

“DP” 2004
VEMP – Threshold Screen

RIGHT: 70 dB

DP Fistula Test
Head Below Horizontal

Negative Pressure

Positive Pressure

DP Fistula Test

“DP” 2004
Two Channel VEMP

Left ear
95 dB nHL 500 Hz

Right ear
95 dB nHL 500 Hz

“DP” 2004
VEMP – Threshold Screen

RIGHT: 70 dB

DP Fistula Test
Head Below Horizontal

Negative Pressure

Positive Pressure
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DP 2-09 Tullio Test (Baseline)

Findings Suggested a Right PLF Based On:
- Audiometry (ABR With Intact MEMRs)
- Platform Pressure Test
- Tullio Test.

Recommended VNG Examination

In View of Normal VEMP Clinical Suspicion Was High Enough to Warrant Exploration

DP 2-09 Tullio Test
Right Ear: 500 Hz @ 110 dB

“DP” Findings

Findings Suggested a Right PLF Based On:
- Audiometry (ABR With Intact MEMRs)
- Platform Pressure Test
- Tullio Test.

Recommended VNG Examination

In View of Normal VEMP Clinical Suspicion Was High Enough to Warrant Exploration
Paul C.

- 33 year old male
- Longstanding unilateral hearing loss in the right ear.
- Recent reports of off balance and transient dizziness not characterized as vertigo

Paul C. - Audiogram

Paul C. - VNG

Vestibular Evoked Myogenic Potentials (VEMP) and Other Electrophysiologic Techniques in the Evaluation of the Vestibular System

Recorded January 29, 2013
Vestibular Evoked Myogenic Potentials (VEMP) and Other Electrophysiologic Techniques in the Evaluation of the Vestibular System

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Paul C. – VNG
Static Positional Testing

<table>
<thead>
<tr>
<th>Position</th>
<th>POSITIONAL TESTS (CPT 9545, 9547)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting (Supine)</td>
<td>No</td>
</tr>
<tr>
<td>Supine</td>
<td>No</td>
</tr>
<tr>
<td>Head Right</td>
<td>No</td>
</tr>
<tr>
<td>Head Left</td>
<td>No</td>
</tr>
<tr>
<td>Right Lateral</td>
<td>No</td>
</tr>
<tr>
<td>Left Lateral</td>
<td>No</td>
</tr>
<tr>
<td>Head Hanging Right (Bilateral)</td>
<td>No</td>
</tr>
<tr>
<td>Head Hanging Left (Bilateral)</td>
<td>No</td>
</tr>
</tbody>
</table>

Paul C. – VNG
Bithermal Caloric Testing

ALTERNATE BITHERMAL CALORIC TESTING (CPT 9540 x 4)

Average Slow Phase Eye Velocity:
- Left 30° SPEV: \( \frac{\text{deg}}{\text{sec}} \)
- Right 30° SPEV: \( \frac{\text{deg}}{\text{sec}} \)
- Left 45° SPEV: \( \frac{\text{deg}}{\text{sec}} \)
- Right 45° SPEV: \( \frac{\text{deg}}{\text{sec}} \)

Fixation Suppression:
- Left: \( \frac{\text{deg}}{\text{sec}} \)
- Right: \( \frac{\text{deg}}{\text{sec}} \)

Caloric Calculations (Joukowsky Formula):
- Directional Preponderance (DPR):
- Right: \( \frac{\text{deg}}{\text{sec}} \)
- Left: \( \frac{\text{deg}}{\text{sec}} \)

Patient’s symptoms were elicited during testing procedures:
- Yes
- No
Paul C. – VNG
Caloric Response Pods

Caloric - Both Eyes

Paul C. - Caloric Responses

Paul C. - Caloric Responses
(Ice)

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Paul C. – VNG
VEMP

Paul C. – VNG
VEMP

Paul C. – VNG
VEMP
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ECochG Response

VEMP Summary
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VEMP Abnormalities

- Absent
  - No Response at UL
  - No Response at limits of equipment
- Elevated Thresholds
  - No Response at UL
  - Response at upper limits of equipment
- Reduced Thresholds
  - Response at LL
  - Below 80 dB nHL
- Delayed Responses
  - Retro-labyrinthine disease
  - MS
  - Vestibular Neuritis
- Asymmetry
  - Amplitude
  - Thresholds – 10 – 15 dB
  - Latency – 4 msec.

VEMP Abnormalities - Summary

- Decreased VEMP thresholds (below 80 dB nHL) – may indicate SCD or PLF
- Increased VEMP thresholds - low amplitude or absent responses – may suggest a saccule disorder such as Menieres’ syndrome
- Prolonged latencies – may suggest a vestibular n. /caudal brainstem disorder or VS disorder
- Must consider the integrity of the spinal and neck muscles – rule out neuropathy/myopathy

VEMP Summary – Future Utilization

- Diagnostic Utility
  - Improve Sensitivity and Specificity of Vestibular Diagnostics
- Simultaneous Recording of BAEP and VEMP
- Monitoring Conditions such as Meniere’s Syndrome; BPPV
- Cochlear Implant – Pre/Post OP
  - Saccule can be easily damaged
- Multiple Sclerosis Protocol
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So Much For Sound Pressure.....Thank You

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