Current Perspectives in Balance Assessment
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Topics for Today
• Evaluating the Dizzy Patient – looking back, looking ahead
• The (Not So) New Kids on the Block:
  – VEMPs, Whole Body Rotation
• An Integrated Approach to Balance Assessment

How are we doing?
• Where did we derive the current protocols?
• What evidence is there for their success?
• Where do our test batteries fail?
Evidence-Based Practice

“Although clinical experience in the development of clinical instincts is important, it can be misleading if it is not observed systematically.

“Clinicians will need the skills to make independent assessments of evidence and evaluate the credibility of opinions being offered by authorities.”


What is evidence-based medicine?

Evidence-based medicine is the conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients. The practice of evidence-based medicine means integrating individual clinical expertise with the best available external clinical evidence from systematic research.


Our Current Dizzy Battery

• ENG/VNG
  – Oculomotor tests
  – Positional/positioning tests
  – Bithermal Caloric stimulation
• Head Shake Tests
• Rotary Chair Tests
• Posturography
THE ENG BATTERY

Oculomotor Tests
• Pursuit Tracking Tests
• Saccade
• Optokinetic ??

Positional/Positioning Testing
• Positions?
• Vision denied/ permitted
• Dix-Hallpike
• Sensitivity/Specificity?
Caloric Testing

- Stimulation of Horizontal SCC
- Bithermal
- COWS
- Sensitivity?

Vestibular Autorotation Test (VAT)

- “no” & “yes” gestures in time with metronome
- Frequencies from 0.5 to 6 Hz over 18 seconds
- While pt. fixates visually
- Head motion recorded by accelerometer
- Eye motion recorded via video or electrodes

VAT Normal Responses

- Gain values near 1.00
  - peripheral vestibular lesions can produce abnormally low or high gains.
- Phase values near 180°
- Symmetrical Right/Left Responses
  - asymmetry associated with uncompensated unilateral vestibular lesions.
Use of Passive Rotational Testing

• Verification of bilateral caloric weakness
• Alternative when VNG/ENG calorics not possible
  – Pediatric population
  – External ear anomalies
• Serial Monitoring
  – vestibulotoxicity
  – compensation

Dynamic Posturography

Sensory Organization
Motor Control Testing
Posture Evoked Response
Vestibular Evoked Myogenic Potentials

- Sound stimulates the saccule, which activates the inferior vestibular nerve, medial vestibular nucleus, medial vestibulospinal tract ipsilaterally, and then the sternocleidomastoid muscle in the neck.

What is a VEMP?

- Saccular activation can generate a motoric response in:
  - Neck muscles, including the sternocleidomastoid & trapezius, and from
    - Lower postural muscles, such as the quadriceps, soleus, & gastrocnemius.
- Current clinical interest: the sternocleidomastoid response.

“VEMP reflects a vestibulocollic reflex, that is, a quick reflexive change in muscle tone (flexor or extensor, depending on the muscle group) that occurs to stabilize the head following an unexpected translation.”

(Zapala & Brey, 2004)
Vestibular Evoked Myogenic Potentials - History

- Dawson (1954) used first signal averager to extract somatosensory evoked potentials from EEG
  - First account of the “Early Auditory Evoked Potential”

Vestibular Evoked Myogenic Potential (VEMP)

- Colebatch & Halmagyi (1992):
  - Transient change in contraction strength of the neck muscles (mainly the sternocleidomastoid [SCM] muscle) in response to a transient acoustic stimulus.
    - VEMP present in deaf patients
    - VEMP lost with vestibular nerve section

Vestibular Evoked Myogenic Potential (VEMP)

- Method:
  - Intense transient acoustic stimulus presented monaurally
    - Clicks must be > 95 dBnHL
    - Tone bursts (250 - 1500 Hz) > 85 -105 dBnHL
      - Best frequency is 500 Hz,
  - Active electrodes are placed over the upper 1/2 of the sternocleidomastoid muscle
  - Reference & ground electrode on forehead
Clinical Relevance of the VEMP

- VEMP reflects stimulation of saccule, a vestibular end organ not evaluated by typical vestibular procedures, e.g., ENG
- VEMP evaluates neural pathways (caudal from vestibular organs) not measured in measures of the vestibulo-ocular reflex, or VOR (rostral from vestibular organs)
- Saccule (in vertical plane) responds to vertical head movements, e.g., during walking, running, etc.

Suggested Clinical Protocol

- Stimulus
  - Transducer = insert earphones
  - Type = click or tone burst (low frequency is optimal)
  - Duration = 0.2 or 0.5 ms* click, or 2-0-2 cycle tone burst
  - Intensity = ≥ 95 dB nHL
  - Polarity = rarefaction
  - Rate = 3 to 5/second
- Patient status
  - Supine in reclining chair or on table
  - Head rotated toward non-test ear (test ear up)
  - Head lifted slightly
  - Provide rest periods between averages

* - Huang, Su & Cheng (2005)

Myographic Acquisition

- Analysis time
  - Pre-stimulus = 10 to 20 ms
  - Post-stimulus = 50 to 100 ms
- Electrodes
  - Non-inverting = belly of the sternocleidomastoid muscle
  - Inverting = sternoclavicular junction or other sites, e.g., hand
  - Ground = forehead
- Filter settings
  - High pass = 1 to 30 Hz
  - Low pass = 250 to 1500 Hz
  - 60 cycle Notch = out
- Amplification = X 50 to X 5000
- Trials in average = 50 to 250
- Summed waveforms often used in analysis
VEMP: Waveform Analysis

Amplitude (μV)

P1 (15–19 ms)

P2 (23–27 ms)

100 μV

50 ms

Normative Data
(Zapala & Brey. JAAA 15: 2004)

<table>
<thead>
<tr>
<th>Component</th>
<th>Mean</th>
<th>SD</th>
<th>Upper Limit</th>
<th>Side Difference</th>
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</thead>
<tbody>
<tr>
<td>P1 latency</td>
<td>17 ms</td>
<td>1.5 ms</td>
<td>21 ms</td>
<td>3.5 ms</td>
</tr>
<tr>
<td>N1 latency</td>
<td>25 ms</td>
<td>1.6 ms</td>
<td>30 ms</td>
<td>3.5 ms</td>
</tr>
<tr>
<td>P1 – N1 amp</td>
<td>181 μV</td>
<td>120 μV</td>
<td>0.50 μV</td>
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</tr>
</tbody>
</table>

VEMP: Effect of Age
(from Zapala & Brey. JAAA 15: 2004)

Age in Years

Latency (ms)

N1 Latency

P1 Latency
Effect of Stimulus Intensity
(Akin, Murnane & Proffitt. JAAA 14: 2003)

Applications
• Ototoxicity
• Vestibular neuritis
• Acoustic Neuroma
• Meniere's disease
  – (VEMPs abnormal in 50% of cases)
• Multiple Sclerosis
• Idiopathic Vestibulopathy
• Superior canal dehiscence

Important Issues to Consider
• Middle ear status.
• Patients with limited neck mobility (e.g., elderly).
• Somewhat low specificity (high false positive rate)
• VEMP evaluates different neural pathways than the VOR.
• Saccule is also served in part by the superior vestibular n.
Rotary Testing

THE BARANY CHAIR

ROBERT BARANY
(1876-1936; Nobel Prize 1914)

Invented device to stimulate the semicircular canals through controlled rotation.

Passive and Active Rotation

• Passive—pt is moved (head or whole body) by examiner.
  — Halmagyi Head Thrust
  — Rotary Chair tests
  — Off-Axis Rotation
• Active—pt is asked to turn their own head.
  — Head Shake
  — VAT
The Classic Rationales for Passive Rotational Testing

- Verification of bilateral caloric weakness
- Alternative when VNG/ENG calorics not possible
  - Pediatric population
  - External ear anomalies
- Serial Monitoring
  - Vestibulotoxicity
  - Compensation

Rotary Chair Tests

- Sinusoidal Harmonic Acceleration (SHA) Test:
  - Oscillating (left-right) in rotary chair
  - Freqs from 0.01 to 0.64 Hz
  - Peak angular velocities 50° per sec
- Velocity Step Tests:
  - Sudden Acceleration to constant velocity (L or R)
  - To velocities of 60 or 240° per sec
  - Responses recorded:
    - Per Rotary (during rotation)
    - Post Rotary (following rotation)
  - Measuring Decay in slow phase velocity

Head & Eye Velocity Curves

- Head velocity
- Slow component eye velocity

\[ \text{Gain} = \frac{b_2}{b_1} \]
\[ \text{asymmetry} = \frac{b_2 - b_1}{b_1} \times 100 \text{ (in %)} \]
Expected Responses in SHA

*Eyes moving in opposite direction from head*

- **Phase:** Eye approximately 180° re: Head.
- **Magnitude:** Eye speed < head speed
- **Symmetry:** Right speed = Left speed

Velocity Step

- **Time Constant:** time taken for eye velocity to decline to 37% of peak value
  - A measure of vestibular response decay (feature of the velocity storage mechanism).
- **Per rotary and Post rotary should be similar**
- **Should be 10 seconds or more**
  - Manufacturers provide norms
  - Variability: alerting, system noise.

* Shepard (2001) 13 second

Off-Axis Rotational Testing

- **Rotation on vertical axis passing through one inner ear.**
- **Can assess utricular function**
  - Subjective Visual Vertical
Dynamic Visual Acuity Tests

- Visual Acuity—discrimination of shapes of different sizes
- during active head movement.
- Packaged systems / Snellen Chart

Questions?