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FOR CLINICAL AUDIOLOGY
September 2009

Vestibular Evoked Myogenic Potentials Why is monitoring of the EMG important?

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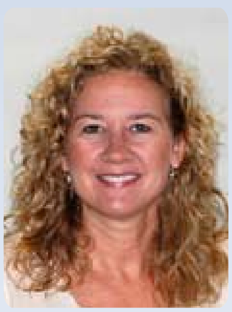
Bio:



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Fiona Barker, Clinical Scientist, has worked in Audiology since 1994. She began work in Reading but moved to her current position at East Berkshire Audiology Unit, King Edward VII Hospital, Windsor, England later the same year. During her time in post Fiona has worked to establish, maintain and develop the assessment service for patients with vestibular and other balance problems. She works closely with her colleagues in Hearing Therapy, Physiotherapy and Psychology to maintain a cohesive vestibular assessment and rehabilitation service.

Understanding VEMP

The inner ear contains five vestibular sensory organs that contribute to gaze and postural stability. Traditionally, routine clinical vestibular assessment has been limited to the evaluation of one of the five sensory organs: the horizontal semicircular canal. Vestibular disorders affecting the superior and posterior semicircular canals and/or the otolith organs, therefore, may not be identified using a traditional vestibular test battery. More recently, the vestibular evoked myogenic potential (VEMP) has been established as a clinical vestibular test of saccular (one of the otolith organs) and/or inferior vestibular nerve function (Colebatch, 2001).

VEMPs are short latency electromyograms (EMG) evoked by high-level acoustic stimuli recorded from surface electrodes over the tonically contracted sternocleidomastoid (SCM) muscle. The VEMP waveform consists of an early positive-negative component (p13-n23) and a later negative-positive (n34-p44) component (see **Figure 1**).

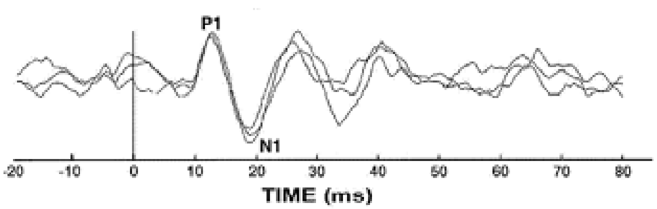

Figure 1: *Vestibular evoked myogenic potential waveforms with positive peak (P1 or p13) at 12 ms and negative peak (N1 or n23) at 19 ms.*

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The early positive-negative component is dependent on the integrity of vestibular afferents as it is abolished after vestibular nerve section but preserved in subjects with severe-to-profound sensorineural hearing loss (Colebatch & Halmagyi, 1992). The neurophysiological and clinical data indicate that VEMPs are mediated by a pathway that includes the saccular macula, inferior vestibular nerve, the vestibular nucleus, the medial vestibulospinal tract, and the motoneurons of the ipsilateral SCM muscle (Halmagyi & Curthoys, 2000).

Clinical Utility

In patients with saccular and/or inferior vestibular nerve involvement, VEMPs are absent or reduced in amplitude.

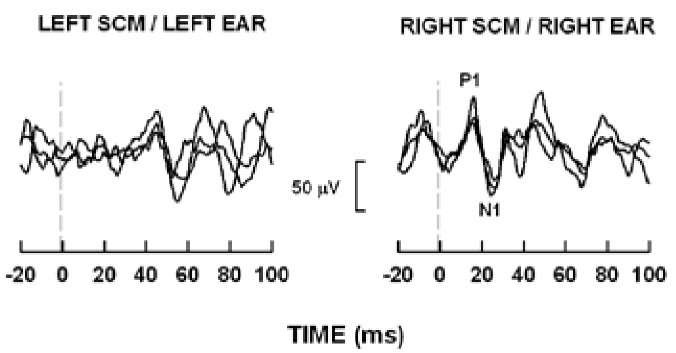


Figure 2: *VEMP waveforms from an individual who underwent a left vestibular neurectomy. VEMPs are absent on the left side (left panel) and present on the uninvolved right side (right panel).*

Figure 2 shows a patient with absent VEMPs following a left vestibular neurectomy and present VEMPs on the intact side. Due to the large intersubject variability of absolute VEMP amplitude, the clinical interpretation of the VEMP has focused primarily on amplitude or threshold asymmetries between the right and left ears as an indication of the likely side of the pathology. Asymmetry ratio is calculated as

$$100\,|(AL - AS) / (AL + AS)|$$

in which AL equals the larger P1-N1 amplitude and AS equals the smaller P1-N1 amplitude. An asymmetry ratio ≤ 40% indicates side-to-side amplitude differences within normal limits.

Electromyography and its Relationship with VEMP

The VEMP is generated by the activation of the SCM muscles, and the amplitude of the VEMP is proportional to the magnitude of the SCM muscle activation. Electromyography (EMG) can be used to record the activation signal of the SCM muscle. To record an electromyogram, surface electrodes are placed on the skin over the activated muscle, and the electromyograph records the action potentials occurring in the muscle fiber of the activated (or un-activated) SCM muscle(s).

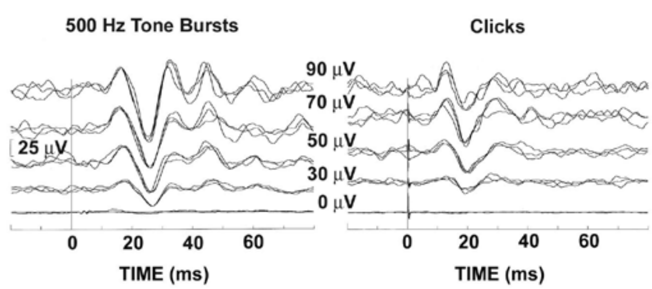


Figure 3: *Tone burst (left panel) and click-evoked (right panel) VEMPs obtained at SCM muscle EMG levels ranging from 0 to 90 µV (indicated in the center).*

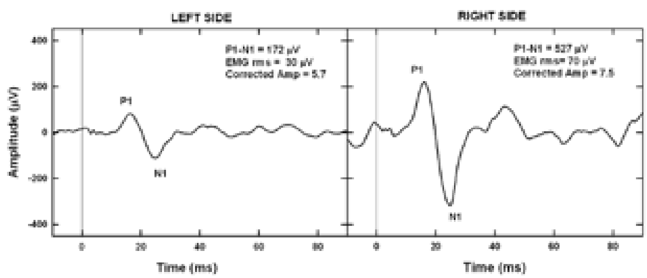
Figure 3 shows VEMPs recorded at EMG levels ranging from 0 µV (no muscle activation) to 90 µV (head turned laterally from center for maximum SCM muscle activation). Since VEMP amplitude is proportional to EMG level, controlling the level of tonic EMG is a prerequisite for the accurate interpretation of interaural VEMP amplitude differences.

Most VEMP recording methods account for the tonic state of the SCM muscle by using one of two methods. One method utilizes direct control of the magnitude of tonic neck muscle activity by monitoring and maintaining the amplitude of the rectified EMG at a constant target level during activation of the SCM muscle (Colebatch et al., 1994; Lim et al., 1995; Murofushi, Matsuzaki, & Chih-Hsiu 1999; Todd, Cody, & Banks, 2000; Akin & Murnane, 2001; Versino, Colnaghi, Callieco, & Cosi, 2001). Typically, this method is performed by providing the patient with visual feedback of the SCM muscle EMG level during the evoked potential recording.

In a second method, the patient is not instructed to maintain a target EMG level or provided visual feedback. Rather, a corrected VEMP amplitude is calculated by division of the P1-N1 amplitude by the mean rectified EMG level of a 20 ms pre-stimulus baseline (e.g., Colebatch et al., 1994). The corrected VEMP amplitude can also be calculated by the division of all data points in the averaged post-stimulus period by the post-stimulus mean rectified EMG level (e.g., Brantberg, Lofqvist, & Fransson, 2004).

Importance of Monitoring EMG

The following example demonstrates the importance of considering the effect of the SCM muscle EMG level when interpreting the VEMP test findings.



AR for Uncorrected for EMG Level:

$$\frac{527\mu V - 172\mu V}{527\mu V + 172\mu V} \times 100 = \mathbf{51\%}$$

AR for Corrected for EMG Level:

$$\frac{7.5\mu V - 5.7\mu V}{7.5\mu V + 5.7\mu V} \times 100 = \mathbf{14\%}$$

Figure 4: *VEMPs obtained from each side using a 500-Hz tone burst at 120 dB peakSPL in a subject with normal audiovestibular function at two different SCM muscle EMG rms levels. Peak-to-peak amplitude (P1-N1) and corrected amplitude are indicated in the top right of each panel for the left VEMP obtained with a 30 µV EMG level (left panel) and the right VEMP obtained with the 70 µV EMG level (right panel). The asymmetry ratio (AR) is calculated using peak-to-peak VEMP amplitude uncorrected for SCM muscle EMG level (left) and for VEMP amplitude corrected for SCM muscle EMG level (right).*

Figure 4 shows the VEMPs recorded using a 500-Hz tone burst at 120 dB peakSPL in a subject with normal audiovestibular function who was instructed to rotate his head to the right (activate unilaterally the left SCM m.) to produce 30 µV of EMG (left panel). The left P1-N1 amplitude is 172 µV. The right panel shows the VEMP during unilateral activation of the right SCM muscle (head turned left) to produce 70 µV of EMG. The right P1-N1 amplitude is 527 µV. The asymmetry ratio yields a 51% interaural amplitude difference (100 |(AL – AS) / (AL + AS)| = (100 |(527 – 172) / (527 + 172)| = 63%). Based upon normative studies, this asymmetry ratio is abnormally large and indicates vestibular involvement on the left side. In contrast, note the change in the asymmetry ratio (and test interpretation) when the peak-to-peak amplitudes are corrected for the SCM muscle EMG level. The left P1-N1 amplitude (172 µV) is divided by the EMG rms (30 µV) to calculate a corrected right amplitude of 5.7 µV. Similarly, the right P1-N1 amplitude (527 µV) was divided by the EMG rms (70 µV) to calculate a corrected right amplitude of 7.5 µV. Using corrected amplitudes, the asymmetry ratio yields an 14% difference between sides (100 |(15.7– 10.9) / (15.7 + 10.9)| = 18%). This asymmetry ratio is within normal limits and indicates normal saccular and/or inferior vestibular nerve function. Thus, the validity of the asymmetry ratio may be compromised if the SCM muscle EMG level is not considered in the analysis of VEMP amplitude.

Incorporating VEMP into a Clinic

Achieving SCM contraction

The level of SCM contraction is critically important for obtaining a good VEMP. The required muscle contraction can be achieved in several ways. Some studies have used a head forward technique with pressure applied to a force plate on the forehead. However most studies have used one of the two following techniques:

Head raise

In this position contraction is achieved by asking the patient to lie in a supine position and then asking them to raise their head by about 5cm.

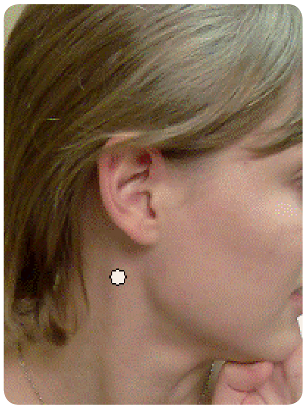
Head turn

The head is turned AWAY from the side being tested. In the example above the right SCM would be tested and the right ear stimulated, so the head needs to be turned to the left.

Either method can be used successfully, depending on clinician and patient preference and on whether stimulation is presented bilaterally or unilaterally. In practice we have found the head turn to be better tolerated particularly by elderly patients who fatigue quickly when trying to keep their head raised. However test duration as a whole can be shortened by presenting and recording bilaterally.

Proper Electrode Placement

Placement of the electrodes on the SCM is important in obtaining a good quality trace, in obtaining consistent responses both within and across patients and ensuring recording of the maximum contraction of the muscle. The electrode should be placed on the belly of the muscle.



Before placing the electrode the patient should be asked to contract the muscle as they will do during the test. It helps to feel the contracted muscle gently to appreciate the fullest, plumpest part rather than just looking. In most people this will be roughly the same height on both sides and placement should be even.

Binaural vs Monaural stimulus

The VEMP is an ipsilateral response when using a head turn and monaural stimulation. Contralateral responses are sometimes, if rarely, observed and this may become a factor in the calculation of an interaural amplitude ratio particularly if the VEMP is absent or very small on one side. It is thought that these contralateral responses are due either to a volume-conducted artifact or to a brief 'accidental' excitation of the contralateral muscle in the case of unilateral contraction and recording.

The head raise technique can be used with either binaural or monaural stimulation but it would make sense to utilize a binaural approach if possible as this will halve test time.

Tips for Using the VEMP Monitor and Obtaining the Best Response

Remember, monitoring and controlling the level of tonic activation in the SCM is essential if the interaural amplitude ratio is to be calculated accurately.

The ICS Chartr EP 200 allows both the clinician and patient to monitor electromyogenic activity in the SCM during testing. It ensures more consistent muscle contraction within the patient's comfort and capability. This improves repeatability and enables corrected amplitude ratios to be calculated if needed. The clinician can see the EMG value of the muscle activation on the computer screen while the patient views a monitor with a 3 light display:

ORANGE – muscle contraction is too high
GREEN – just right
BLUE – muscle contraction is too low

Importantly, the boundaries between these levels can be set by the clinician prior to the start of data collection so that the levels are set individually for that person, maintaining their comfort and ensuring better compliance. This has been of particular value with elderly patients and with those who have difficulty with contracting the relevant muscle. We can ensure a good SCM contraction before the test begins so we know the instructions are followed correctly.

The correction for underlying muscle activity can be applied in 2 ways. First, and the most efficient way of using this system, is if a patient is able to achieve good, consistent contraction within the same boundaries on both sides, so that the VEMP amplitudes obtained can be compared directly. Alternatively, the average EMG muscle activity during testing can be used to correct the P1-N1 amplitude obtained so that the corrected responses can be compared between ears.

In general at East Berkshire Audiology Unit, we have found the visual feedback from the display easy for patients to follow. Patient feedback has been that they usually find the monitor easy to understand and that they enjoy the element of control it gives them in the test. They feel like active participants. They also find the test as a whole very easy to tolerate especially in comparison to some of the other tests in which they have participated.

We have found that a routine suprathreshold test takes about 20 minutes to complete but most of this is in fact explanation and preparation. It only takes 5-10 minutes to collect the data itself. We usually run 2-3 trials for each ear to get 2 repeatable responses which we then use for analysis.

Quick tips for Quality Data Collection

- Run the test on 10-20 norms first to get a feel for the equipment and the response. The response is much larger and therefore very different from the more well-known auditory evoked potentials. You will also get a feel for the level of EMG activity required to elicit a good response from a patient. 100uV raw EMG activity is a good target.
- Consider introducing the VEMP initially for patients with a canal paresis so that you get a feel for how the results fit into and add to the existing test battery.
- Snap the electrode leads on the disposable snap electrodes before applying them to the skin. When doing conventional auditory EPs it is possible to apply the electrodes and then snap on the leads because the skull is hard and pressure can be applied without causing discomfort. This is not the case with the neck!
- Double electrodes are useful for the neck (top one used in the recording of the VEMP response and both are differentially recording the EMG activity) rather than applying two single ones.
- Suggested stimulus parameters:

500Hz tone burst

Onset phase	Rarefaction
Level	90-95dBnHL (120-125dB peak SPL)
Rate	5.1/sec
Rise/fall	2 cycles
Plateau	0 cycles
Gating	Blackman

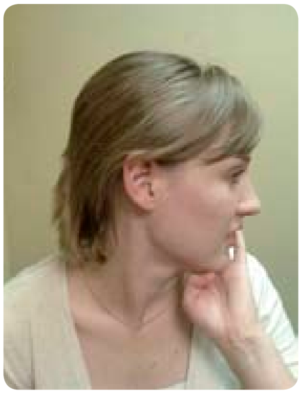
Click

Polarity	Rarefaction
Level	95-100dBnHL (129-134dB peak SPL)
Rate	5.1/sec
Duration	100usec

- Suggested recording parameters:

Amplifier gain	5000x
Filter settings	10-1000Hz
Time window	100msec
Number of sweeps	150
Artifact rejection	Off
Non-inverting electrode	Mid SCM (top snap of the differential electrode)
Inverting electrode	Top of the sternum or its junction with the clavicle
Ground electrode	Forehead

- If using the head-turn technique it helps to tuck the chin in and push into the hand if you are getting insufficient contraction. Compare the prominence of the muscle in the two examples below. The SCM is more contracted in the example on the right.



Clinical Case Study from East Berkshire Audiology Unit

The importance of correcting the raw amplitude figures is demonstrated in the following example:

	RIGHT ear	LEFT ear
P1-N1 amplitudes	27uV	64uV
EMG activity	35uV	62uV
Corrected value	27/35=0.77	64/62=1.03

Initially, the data indicated an asymmetry:
((Amplitude difference between ears)/(Total amplitude response from both ears))x100
(37/91)x100 = 41%

If a 40% asymmetry is taken as the cut off for normal (Akin and Murnane, 2008) then this would be a significant result indicating a weakness in the right ear.

However once corrected for the underlying EMG activity the calculation is as follows:
((Difference of corrected values)/(Total response of the corrected values))x100
(0.26/1.8)x100 = 14%

This shows that, once the effect of underlying tonic muscle activity has been taken into account there is in fact no significant difference between the ears in this case. Monitoring EMG was not effectively used in this case. Setting the boundaries (for example 60-100uV) and ensuring good muscle contraction within them on both sides would have ensured that the responses could be directly compared.

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