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Vestibular evoked myogenic potentials:
which modality should we use?

M GERALDINE ZUNIGA MD

Disclosure Information

This presentation will include discussion of

Off-label use of an evoked potential system to perform VEMP testing

Learning Objectives

After this course, participants will be able to:

1. Describe the different modalities currently available to perform VEMP testing including different types of stimuli, different measurement sites and outcome parameters.
2. Identify which is the 'go to' VEMP modality that may be used routinely when testing any type of patient.
3. Determine if a patient needs a different type of information than what the routine VEMP testing provides and will be able to select the particular modality that will be of greater use.

Overview

VEMP fundamentals

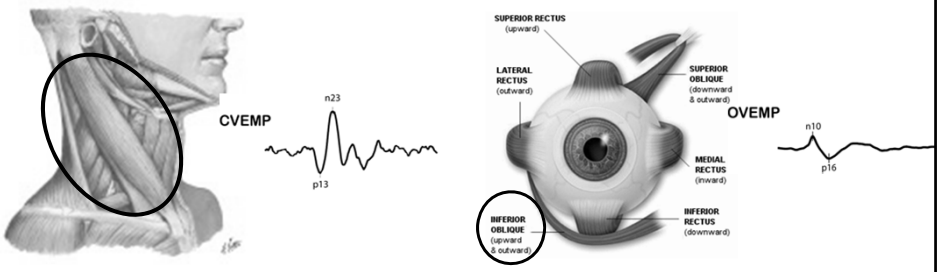
VEMP findings and suggested techniques per condition
- Control data
- Age effects
- Meniere's disease
- Vestibular migraine
- Third window: SCDS, LVA
- Vestibular schwanoma
- Vestibular neuritis
- Central neurological disorders

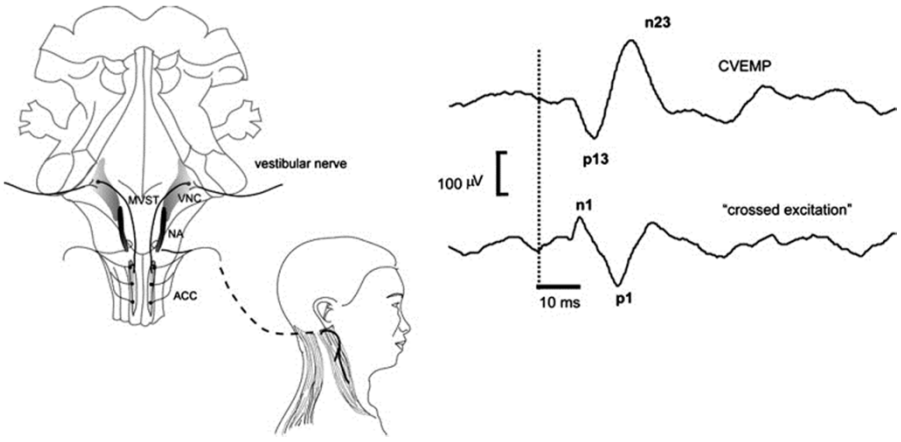
Summary

References/suggested readings

VESTIBULAR EVOKED MYOGENIC POTENTIAL (VEMP)

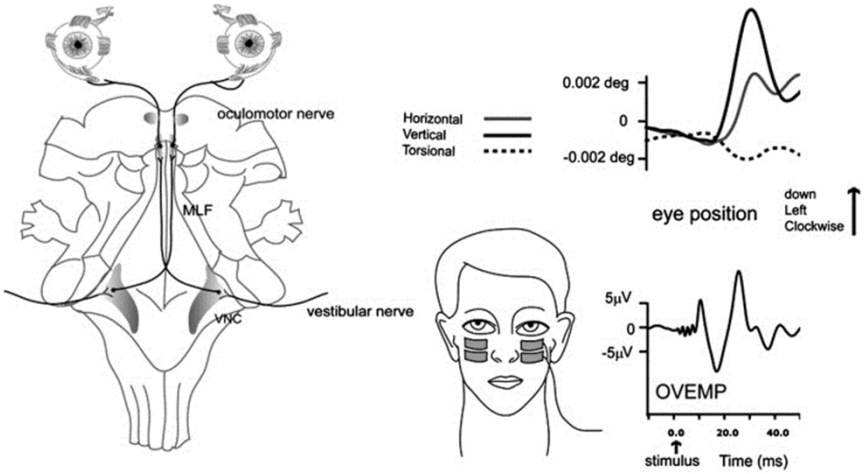
EMG: modulated by stimulating vestibular afferents





The suggested pathway for the sound-evoked cVEMP, consisting of the primary vestibular afferent, medial vestibulo-spinal tract (MVST) and spinal accessory nerve (ACC).

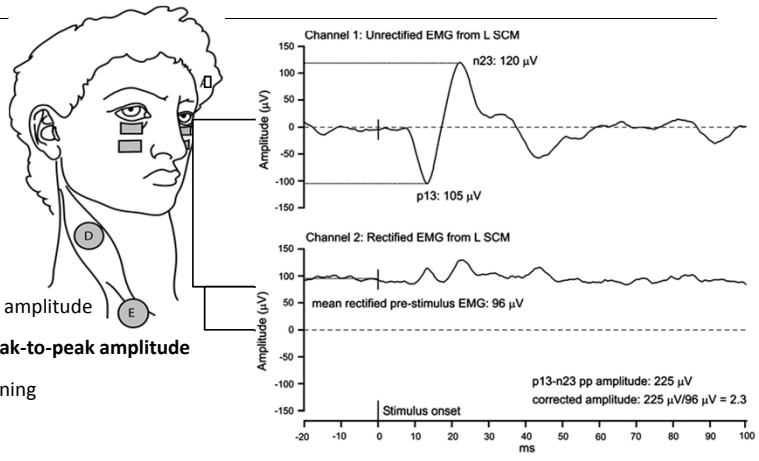
S.M. Rosengren , M.S. Welgampola , J.G. Colebatch. ***Vestibular evoked myogenic potentials: Past, present and future.*** Clinical Neurophysiology, Volume 121, Issue 5, 2010, 636 - 651



OVEMP pathway, consisting of the primary vestibular afferent, possibly the medial longitudinal fasciculus and the oculomotor nuclei and nerves.

S.M. Rosengren , M.S. Welgampola , J.G. Colebatch. ***Vestibular evoked myogenic potentials: Past, present and future.*** Clinical Neurophysiology, Volume 121, Issue 5, 2010, 636 - 651

What do we measure? CVEMP



1. Latency

2. Peak-to-peak amplitude

3. Corrected peak-to-peak amplitude

4. Frequency tuning

5. Thresholds

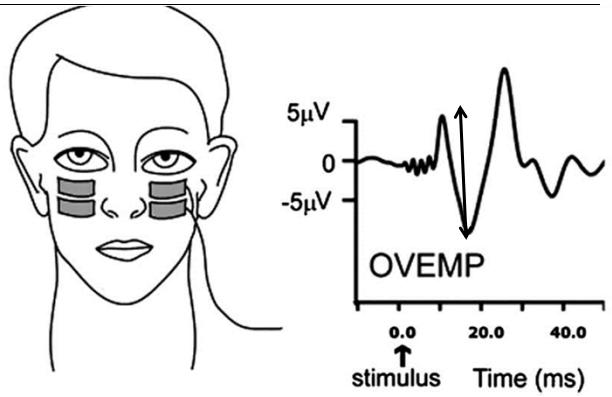
6. Asymmetry ratios

Threshold and tuning

Rosengren , S. et al. Colebatch. *VEMPs: Past, present and future.* Clinical Neurophysiology, 2010; 121(5): 636 – 651.

Modified from Welgampola MS, et al. VEMP thresholds normalize on plugging SCD. *Neurology*. 2008;70(6):464-72.

What do we measure? OVEMP



1. Latency

2. Peak-to-peak amplitude

3. N1 or n10 peak amplitude

4. Frequency tuning

5. Thresholds

6. Asymmetry ratios

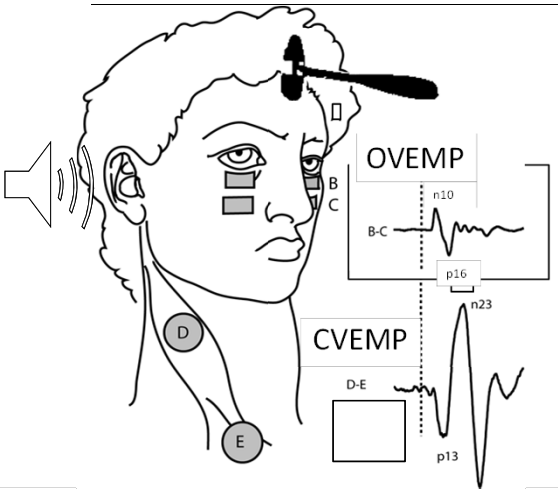
Sudden Bilateral Hearing Loss After Cervical and Ocular Vestibular Evoked Myogenic Potentials

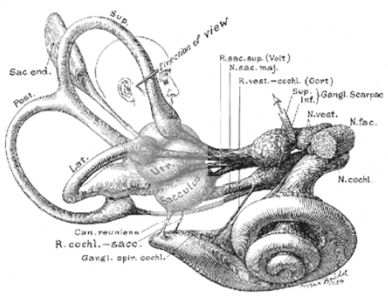
*Jameson K. Mattingly, †Cory D. F. Portnuff, ‡Brian M. Hondorp, and *Stephen P. Cass

Objective: Cervical and ocular vestibular evoked myogenic potentials (cVEMPs and oVEMPs) are commonly used in evaluation of neurotologic disorders. We present a case of sudden bilateral hearing loss immediately after oVEMP and cVEMP testing. The hearing loss did not recover. To our knowledge, no previous case reports discuss sudden hearing loss, especially bilateral, associated with VEMP testing.
Patient: A single patient with sudden bilateral hearing loss that has persisted after cVEMP and oVEMP.
Intervention: The patient had a history of chronic daily dizziness. She underwent vestibular function testing that included cVEMP and oVEMP testing. A significant bilateral sensorineural hearing loss was noted immediately after cVEMP and oVEMP testing and confirmed with audiometric testing. Despite the use of oral steroids, her hearing loss did not recover.
Main Outcome Measures: Serial audiograms, calculated maximum total sound energies to each ear.
Results: Pre-VEMP versus post-VEMP audiograms show increased thresholds and decreased word recognition scores; total sound energy delivered to each ear shows significant sound exposure.
Conclusion: Although VEMP testing is thought to be safe and well tolerated, a significant amount of sound can be delivered to the cochlea, and certain individuals may be susceptible to acoustic trauma at these levels. We recommend limits for VEMP stimuli levels and attention to total sound exposure when multiple trials are used. **Key Words:** Noise-induced hearing loss—Sudden hearing loss—Vestibular evoked myogenic potential.

Otol Neurotol **36:**961–964, 2015.

VEMP testing for evaluation of otolith function





Modified from Welgampola MS, et al. VEMP thresholds normalize on plugging SCD. *Neurology*. 2008;70(6):464-72.

In general (or for control data)

Saccular function

- Cervical VEMP in response to ACS
  - 500 Hz tone bursts
    - Robust responses with greater test-retest reliability
      - Nguyen et al 2010; Viciana et al 2012
  - Why?
    - ACS VEMPs show frequency tuning at around 400– 1000 Hz (Rosengren et al 2009)
    - Stimulus duration: 500 Hz TB = 4ms vs Clicks = 0.1ms
  - Outcome parameter → corrected peak-to-peak amplitudes

In general (or for control data)

Utricular function

- Ocular VEMP in response to midline taps
  - Reflex hammer
    - Better test-retest reliability vs Mini-shaker
      - Nguyen et al 2010
  - Outcome parameter → amplitudes

Age-matched results

With increasing age there is a decline in c- and oVEMP responses

- Decrease in peak-to-peak amplitudes, elevated thresholds

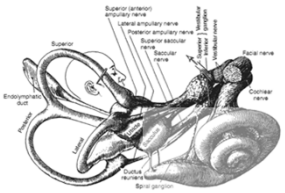
Consistent observation by different authors

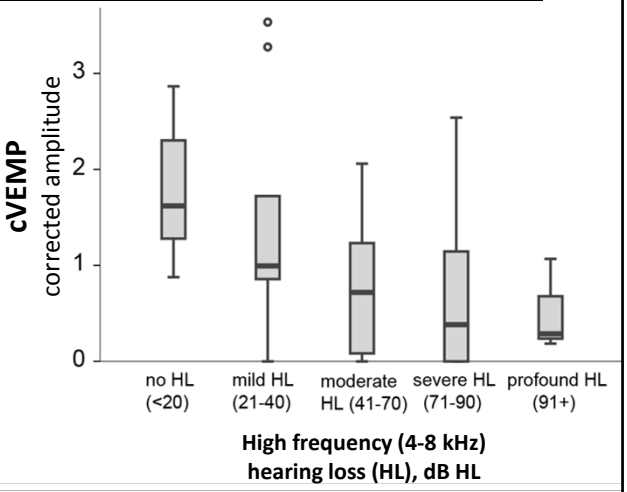
- Nguyen K et al. "Test-retest reliability and age-related characteristics of the ocular and cervical vestibular evoked myogenic potential tests". *Otol Neurotol*. 2010 Jul;31(5):793-802.
- Rosengren S et al. "Ocular and cervical vestibular evoked myogenic potentials produced by air- and bone-conducted stimuli: comparative properties and effects of age". *Clin Neurophysiol.* 2011 Nov;122(11):2282-9.
- Li C et al "Epidemiology of vestibular evoked myogenic potentials: Data from the Baltimore Longitudinal Study of Aging." *Clin Neurophysiol.* 2015 Jan 24 [Epub ahead of print]
- Piker et al. "Assessment of the Clinical Utility of Cervical and Ocular Vestibular Evoked Myogenic Potential Testing in Elderly Patients" *Otol Neurotol*. 2015 Jun 24. [Epub ahead of print]

VEMP in the elderly: screening tool for future fallers?

Cochlear & Saccular dysfunction

(r = -0.37, p < 0.0001)





Zuniga et al. Association between hearing loss and saccular dysfunction in older adults. *Otol & Neurotol.* 2012 Dec;33(9):1586-92.

Age-related slowing of gait speed is in part mediated by the decreased magnitude of saccular response associated with age.

- Layman and colleagues (2015)
  - 314 participants (mean age, 73.1 yr; range, 26-96 yr)
  - Greater cervical VEMP latency was associated with slower usual, rapid, and narrow gait speed in women but faster rapid gait speed in men.

Layman et al. "Association between saccular function and gait speed: data from the Baltimore Longitudinal Study of Aging." *Otol Neurotol.* 2015 Feb;36(2):260-6.

VEMPs in different pathologies

Meniere's disease

Vestibular migraine

Superior canal dehiscence syndrome

Enlarged vestibular aqueduct

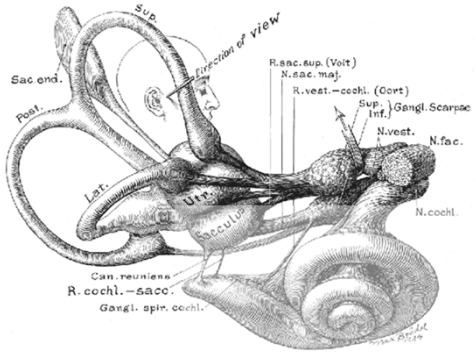
Vestibular neuritis

Vestibular schwanoma

Central Neurological disorders

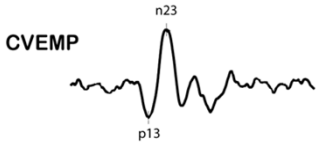
Meniere's disease

- Hydrops
  - After the cochlea, the sacculus is the second most commonly involved end organ



Meniere's disease

- Cervical VEMP →ABNORMAL



•Rauch and colleagues found in ears with MD
–VEMP thresholds increased & frequency tuning impaired

This protocol is time consuming and exhausting for patients

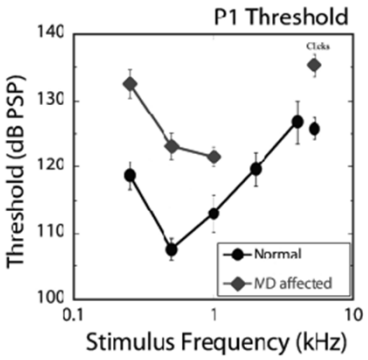


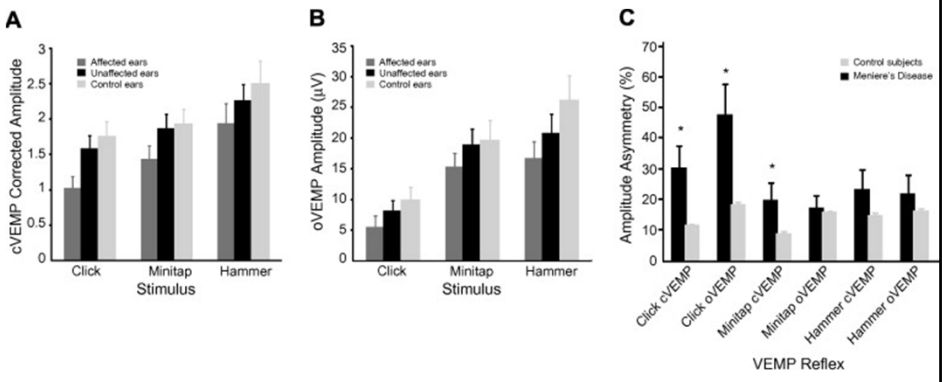
FIG. 3. Mean ± standard error of the mean VEMP thresholds for tone-burst and click stimuli in normal subjects' ears (n = 14) and affected and unaffected ears of subjects with unilateral Meniere's disease (n = 34).

VEMP show altered tuning in patients with Ménière's Disease. Rauch, et al. (2004) *Otol & Neurotol* 25:333–38

The vestibular evoked-potential profile of Ménière's disease

Rachael L. Taylor [a], Ayanthi A. Wijewardene [a], William P.R. Gibson [a], Deborah A. Black [b], G. Michael Halmagyi [a], Miriam S. Welgampola [a,*]

Clinical Neurophysiology 122 (2011) 1256–1263



VEMPs in MD

Take away message…

For MD a simple air conducted sound evoked (ACS) cervical VEMP measure of corrected amplitude is useful for diagnosing MD

Criteria for definite Vestibular Migraine (Radtke/Neuhauser)

A. At least 2 attacks of vestibular vertigo

B. Current or previous history of migraine headaches

C. Concomitant migrainous symptoms during at least 2 vertigo attacks

D. No evidence of other central or otological causes of vertigo

Pathophysiology of VM

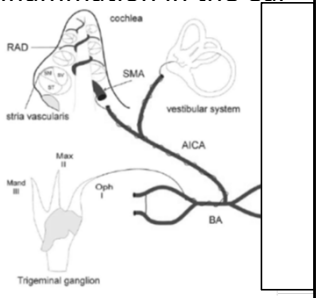
Central electrical disturbances

- Excitation/inhibition waves in brain affect central vestibular centers.

by Katie McMeans
web.mac.com/mcmeansk, with permission

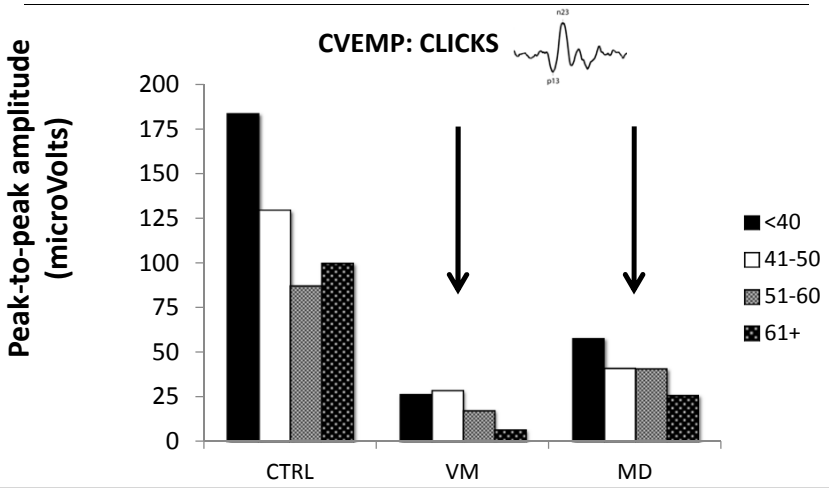
Peripheral trigemino-vascular efferent disturbances

- Trigeminal release of vasoactive peptides cause local inflammation in the ear



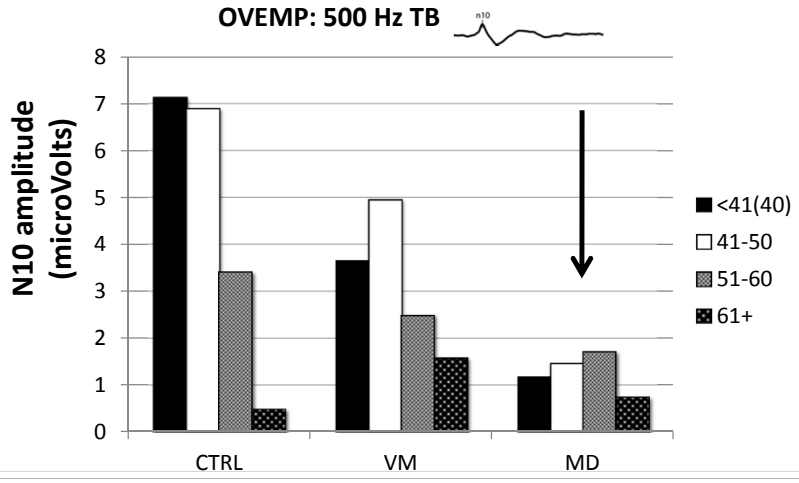
Z. Vass et al. Neuroscience 124 (2004) 919–927

Click-evoked cVEMP



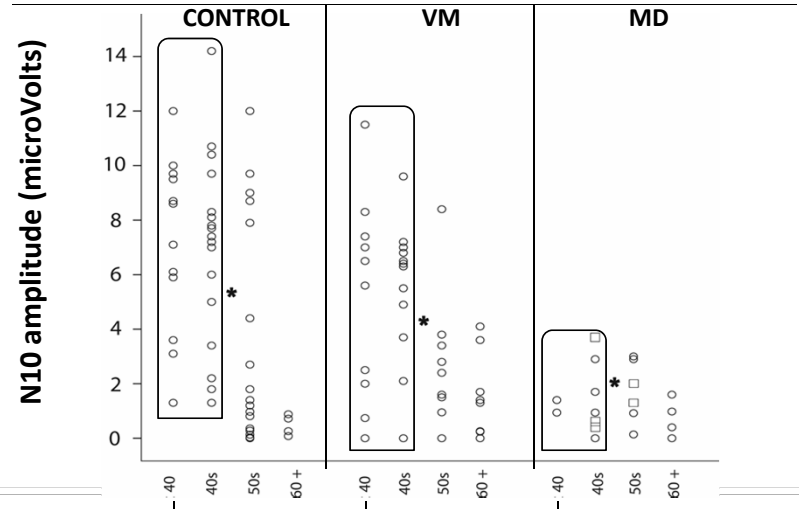
Modified from Zuniga et al (2012). *Otolaryngol Head Neck Surg. 2012;*146(5):788–796

500 Hz TB oVEMP



Modified from Zuniga et al (2012). *Otolaryngol Head Neck Surg. 2012;*146(5):788–796

500 Hz TB oVEMP



Modified from Zuniga et al (2012). *Otolaryngol Head Neck Surg. 2012;*146(5):788–796

VEMPs in VM

An abnormal VEMP result

- Does not equal MD
- Does not rule out VM

Cervical VEMP (500 Hz TB or Clicks)

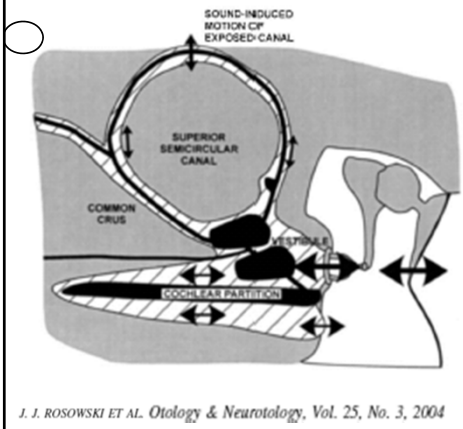
- help demonstrate peripheral hypofunction in VM relative to controls

Ocular VEMP: 500 Hz TB

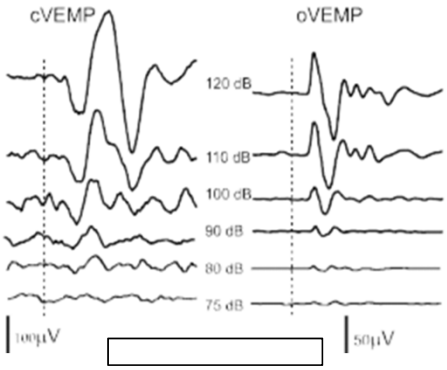
- A NORMAL response (n10 >4 μV), especially in patients younger than 40 years old point more to VM vs MD.

No current ROC curves to provide the sensitivity vs specificity

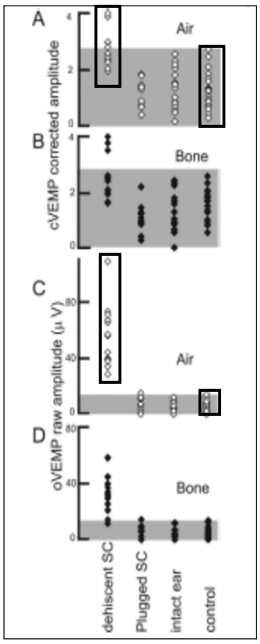
Superior Canal Dehiscence Syndrome



J. J. ROSOWSKI ET AL. *Otology & Neurotology*, Vol. 25, No. 3, 2004



Welgampola et al. VEMP thresholds normalize on plugging of SCD. Neurology (2008)



Welgampola et al., Neurology 2008

← OVEMP amplitudes have been described superior to CVEMP amplitudes for the diagnosis of SCDS

cVEMP thresholds

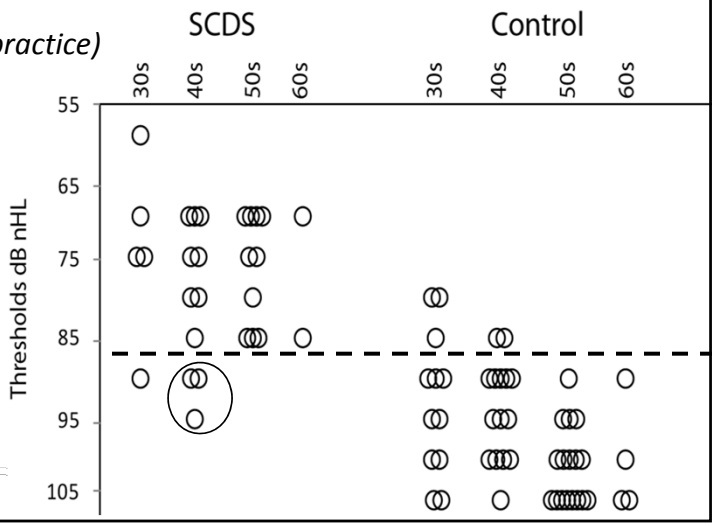
OR

oVEMP amplitudes …?

Click-cVEMP thresholds

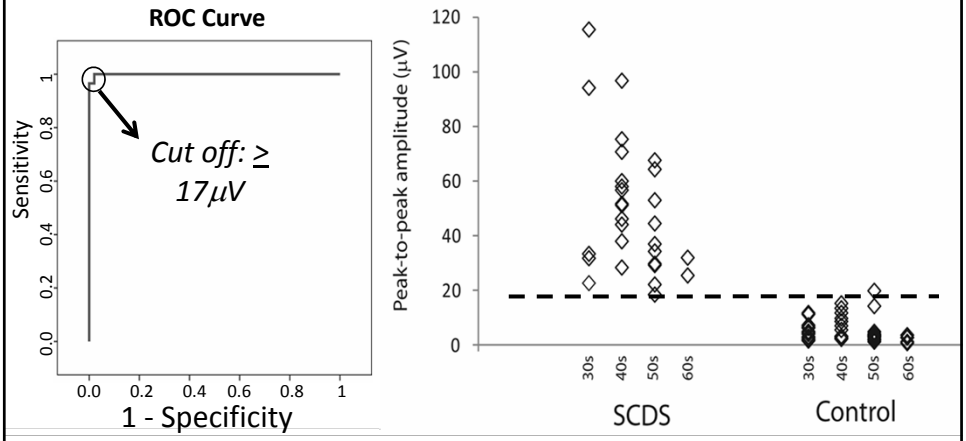
Cut-off value:
87.5 dB (85 dB in practice)

Sensitivity: 73%
Specificity: 87%



500 Hz tone-burst oVEMP amplitude

Sensitivity & Specificity: > 90% for all ages



Zuniga et al. (In press) CVEMP thresholds vs oVEMP amplitudes in SCD. *Otol & Neurotol.*

SCDS VEMP

☑ **OVEMP amplitudes**

in response to 500 Hz TB

Augmented Ocular Vestibular Evoked Myogenic Potentials to Air-Conducted Sound in Large Vestibular Aqueduct Syndrome

Rachael L. Taylor,[1] Andrew P. Bradshaw,[1] John S. Magnussen,[2] William P. R. Gibson,[1] G. Michael Halmagyi,[1] and Miriam S. Welgampola[1]

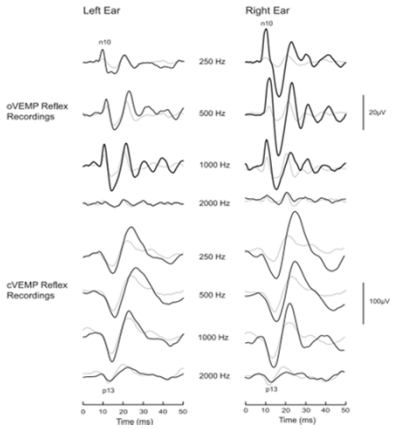
Objective: To demonstrate the value of recording air-conducted ocular Vestibular Evoked Myogenic Potentials (oVEMP) in a patient with bilaterally enlarged vestibular aqueducts.

Design: Cervical VEMP and oVEMP were recorded from a patient presenting with bilateral hearing loss and imbalance, attributable to large vestibular aqueduct syndrome. The stimuli were air-conducted tone bursts at octave frequencies from 250 to 2000 Hz. Amplitudes and thresholds were measured and compared with the normal response range of 32 healthy control subjects.

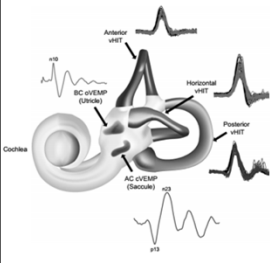
Results: oVEMP reflexes demonstrated pathologically increased amplitudes and reduced thresholds for low-frequency tone bursts. Cervical VEMP amplitudes and thresholds were within normal limits for both ears across all frequencies of stimulation.

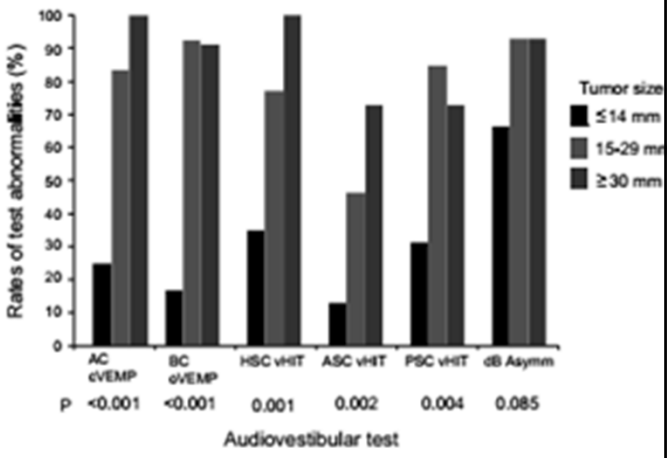
Conclusions: This study is the first to describe the augmentation of AC oVEMPs in an adult with large vestibular aqueduct syndrome.

(Ear & Hearing 2012;33;768–771)



Vestibular schwanoma





Taylor and colleagues. "Prevalence of vestibular dysfunction in patients with vestibular schwannoma using video head-impulses and vestibular-evoked potentials." *J Neurol* (2015) 262:1228–1237

Vestibular neuritis

Iwasaki et al. (2009) ACS cVEMP and BCS oVEMP in patients with superior vestibular neuritis (n=13)

- ACS cVEMPS : Normal
- 12/13 had absent or reduced BC oVEMPS

Vestibular neuritis

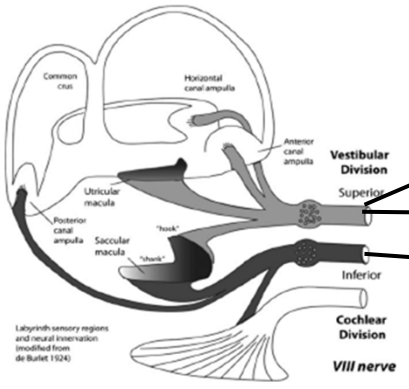


Fig. 1. Schematic illustration of the neural innervation of labyrinthine sensory regions, modified from de Burlet (1924). See text for details.

Curthoys et al. (2010) looked at ACS 500 Hz TB oVEMP

- ACS oVEMP decreased/absent response
- BCV oVEMP decreased/absent response
- ACS cVEMP

Central neurologic disorders

Demyelinating disease
- Multiple sclerosis

Cerebrovascular disease
- HINTS examination is of greater utility

Neurodegenerative disease

Tumors in the posterior fossa

Venhovens et al . "VEMPs in central neurological disorders" *Clin Neurophysiol.* 2015 Jan 16. [Epub ahead of print]

Central neurologic disorders

Table 1
Expected oVEMP and cVEMP abnormalities concerning neurovestibular disorders at different anatomical localizations.

Anatomical localization		Expected abnormalities	
		oVEMP	cVEMP
Peripheral labyrinth		Contralesionally absent responses or low amplitudes	Ipsilesionally absent responses or low amplitudes
Vestibular nerve		Contralesionally absent responses or low amplitudes ≫ latency prolongation (due to external vestibular nerve compression)	Ipsilesionally absent responses or low amplitudes ≫ latency prolongation (due to external vestibular nerve compression)
Brainstem	Pontine	Contralesionally or bilaterally absent responses, low amplitudes, or latency prolongation are all possible	Bilaterally normal responses are expected. However, with more caudal disease progression absent responses, low amplitudes, or latency prolongation, mostly ipsilesional or bilateral, are all possible
	Medulla	Bilaterally normal responses are expected. However, with more rostral disease progression absent responses, low amplitudes, or latency prolongation mostly contralesional or bilateral are all possible	Ipsilesionally or bilaterally absent responses, low amplitudes, or latency prolongation are all possible
Cerebellar		Normal responses or possibly contralesionally absent responses or amplitude differences (both decrease and increase are possible)	Normal responses or possibly ipsilesionally absent responses or amplitude differences (both decrease and increase are possible)

Venhovens et al . "VEMPs in central neurological disorders" *Clin Neurophysiol.* 2015 Jan 16. [Epub ahead of print]

Summary

Purpose	VEMP Reflex pathway	Stimulus and measurement
Saccular assessment	Cervical	500 Hz TB
Utricular assessment	Ocular	Reflex hammer
MD	Cervical	500 Hz TB (reduced amps)
VM	Cervical	Either Clicks or 500 Hz TB to differentiate from normal
VM	Ocular	500 Hz TB : differentiate from MD in <50 yo
SCDS	Ocular	500 Hz TB (increased amps)

Summary

Purpose	VEMP Reflex pathway	Stimulus and measurement
LVA	Ocular	500 Hz TB (increased amps)- third window effect
Vestibular schwanoma	O/Cervical	absent
Vestibular neuritis	Ocular	500 Hz TB or reflex hammer will be decreased
Central	O/Cervical	Delayed latencies; absent

Acknowledgements

- John P. Carey MD
- Devin McCaslin AuD PhD

Recommended readings

Rosengren SM, Welgampola MS, and Colebatch. "Vestibular evoked myogenic potentials: Past, present and future". Clinical Neurophysiology, Volume 121, Issue 5, 2010, 636 – 651

Weber KP and Rosengren SM. "Clinical Utility of Ocular Vestibular-Evoked Myogenic Potentials (oVEMPs)" Curr Neurol Neurosci Rep (2015) 15: 22 DOI 10.1007/s11910-015-0548-y.

Nguyen K et al. "Test-retest reliability and age-related characteristics of the ocular and cervical vestibular evoked myogenic potential tests". Otol Neurotol. 2010 Jul;31(5):793-802.

Rosengren S et al. "Ocular and cervical vestibular evoked myogenic potentials produced by air- and bone-conducted stimuli: comparative properties and effects of age". Clin Neurophysiol. 2011 Nov;122(11):2282-9.

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Piker et al. "Assessment of the Clinical Utility of Cervical and Ocular Vestibular Evoked Myogenic Potential Testing in Elderly Patients" Otol Neurotol. 2015 Jun 24. [Epub ahead of print]

Taylor et al. "The vestibular evoked-potential profile of Ménière's disease". Clin Neurophysiol. 2011 Jun;122(6):1256-63. doi: 10.1016/j.clinph.2010.11.009. Epub 2010 Dec 17.

Rosengren SM et al. "Why do oVEMPs become larger when you look up? Explaining the effect of gaze elevation on the ocular vestibular evoked myogenic potential." Clin Neurophysiol. 2013 Apr;124(4):785-91. doi: 10.1016/j.clinph.2012.10.012. Epub 2012 Nov 21.

Venhovens et al . "VEMPs in central neurological disorders" *Clin Neurophysiol.* 2015 Jan 16. [Epub ahead of print]