



Contents

VEMP (Vestibular-evoked myogenic potentials)

- Brief introduction
- The Stimuli & Recording methods of c- & oVEMPs
- VEMPs in peripheral vestibular disorders
- VEMPs in central vestibular disorders
- Simultaneous recording of c- & oVEMPs

- 3rd most common presenting symptom in primary care centers
- 26% ER admissions
Herr et al., Ann Emg Med 1989
- Many neurotologic evaluation tools...

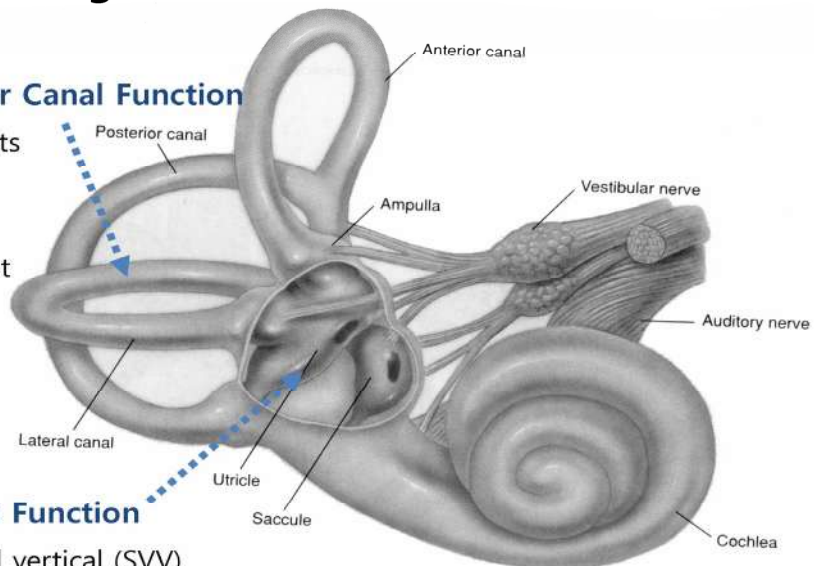
Routine neurotologic evaluation..

Tests of Semicircular Canal Function

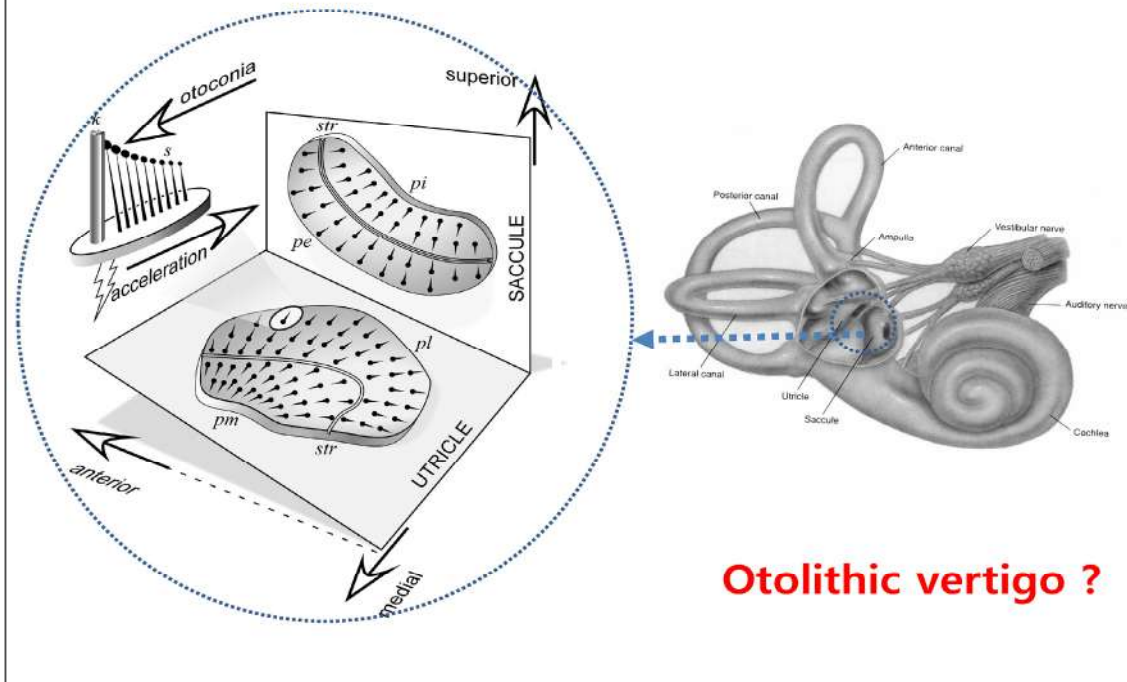
- Head impulse tests (bedside, video)
- Caloric test
- Rotation chair test

Tests of Otoliths Function

- Subjective visual vertical (SVV)
- Fundus photography
- VEMPs (cVEMP and oVEMP)



Otoliths: Utricle and Saccule

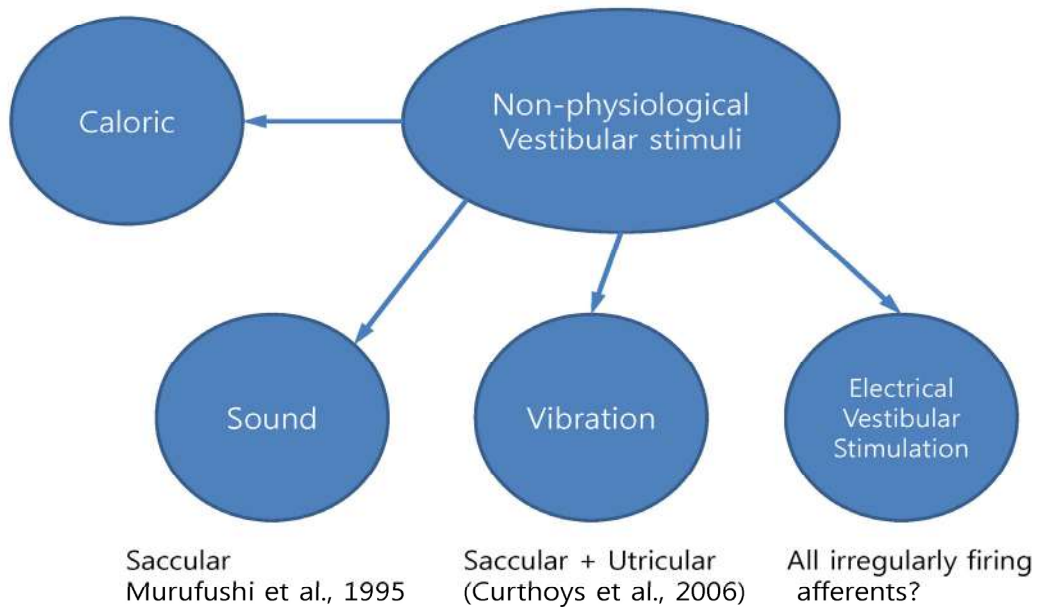


Otolithic Function : Evaluation

- **Clinical**
 - Ocular tilt reaction (OTR)
 - Head heave test
- **Laboratory**
 - Subjective visual vertical (SVV) / SVH
 - Vestibular myogenic evoked potential (VEMP)
 - cervical VEMP and ocular VEMP
 - Fundus Photography
 - Tilt suppression of post-rotatory nystagmus
 - Ocular counterrolling
 - Oculogravic illusion
 - OVAR
 - Eccentric rotation



The stimulus for VEMP



Stimulus for VEMP

- **Air-conducted sound (ACS)**
: Click, tone-burst



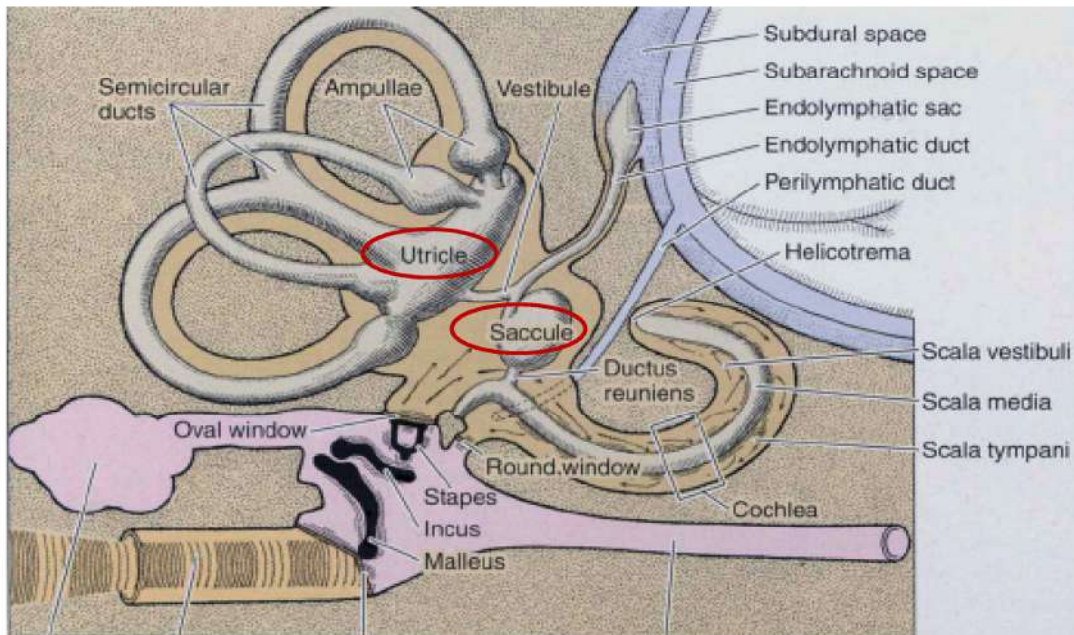
- **Bone-conducted vibration (BCV)**



- **Galvanic stimulation**



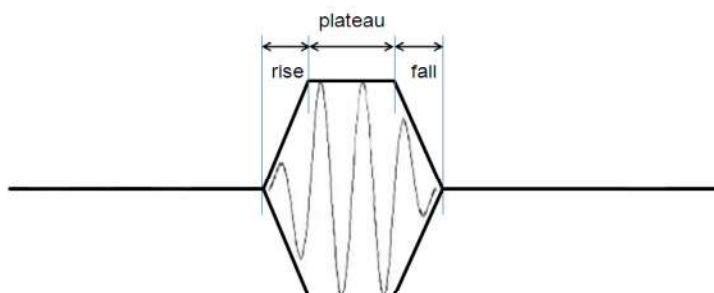
Air conduction stimulus



Air conduction stimulus

	Tone burst	Click
Duration	2-4-2 msec	0.1 msec
Frequency	500 Hz	All frequencies
Response rate	High	Higher
Amplitude	Slightly larger	Slightly smaller
Threshold	Slightly lower	Slightly higher
Latency	Slightly delayed	Slightly shorter

Stimulus and averaging



- Intensity: 90-100 dB nHL
- Duration
 - rise time 1-2 msec
 - plateau time 2-4 msec
 - fall time 1-2 msec
- Rate: 3-7 Hz
- Number of sweeps: 100-256

Stimulus and averaging

Table 1
Recommended cVEMP recording parameters.

cVEMP Recording parameters	
Number of channels	1 ^a or 2
Amplifier gain	5000x
Low pass filter	5-30 Hz
High pass filter	1000-3000 Hz
Sample rate	2500-10,000 Hz ^b
Sweep time	100 ms
Artifact rejection	Off
Number of sweeps	100-250
Active electrode	Midpoint to upper third of SCM muscle
Reference electrode	Sternoclavicular junction
Ground electrode	Forehead or upper chest

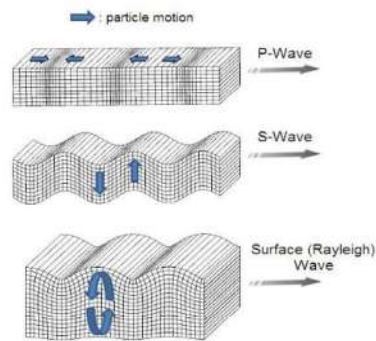
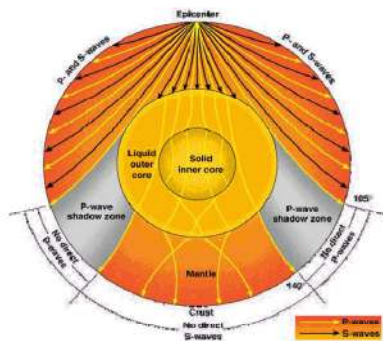
^a If one channel it must be the SCM ipsilateral to the stimulated ear.

^b Sampling rate should always be at least twice the High Pass Filter setting.

Papathanasiou ES, Clin Neurophysiol. 2014

Bone conducted vibration

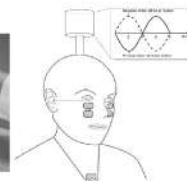
- A vibration or tap to the head
 - waves to travel around and through the head
 - linear accelerations at the mastoids



von Bekesy 1960

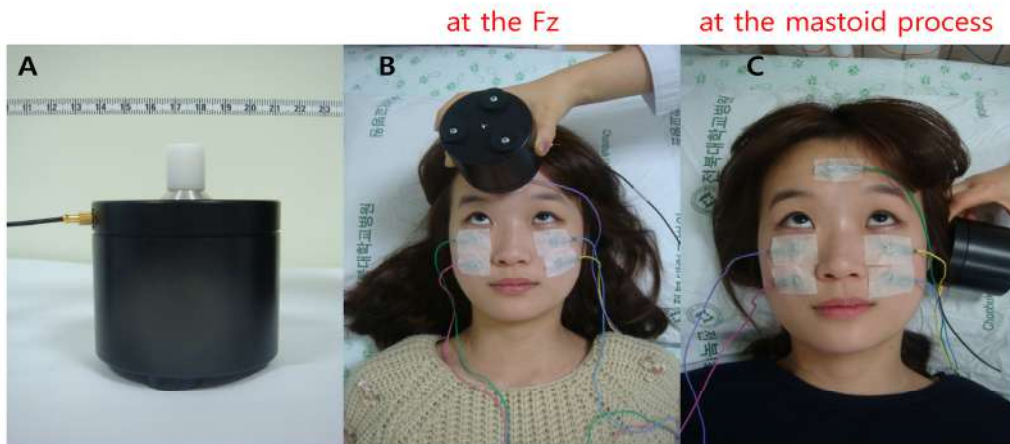
Bone conducted vibration

- **Radioear B-71**
 - Mastoid or Forehead: may be too weak
 - Small changes in the location, direction or force of B-71 on the mastoid cause substantial changes in the applied linear accelerations
- **Exciter Type 4810**
 - Bruel and Kjaer
 - Force Rating: 10 N
 - Frequency Range: DC to 18 kHz



Curthoys, Acta Otorhinolaryngol Ital. 2012
 Na BR & Park HJ, Korean J Otorhinolaryngol-Head Neck Surg 2011
 Holmeslet B, Clin Neurophysiol 2014

Bone conducted vibration



Mini-Shaker 4810 (Bruel and Kjaer, Naerum, Denmark)

Cervical and Ocular VEMP

(Vestibular Evoked Myogenic Potential)



Cervical VEMP

(Vestibular Evoked Myogenic Potential)

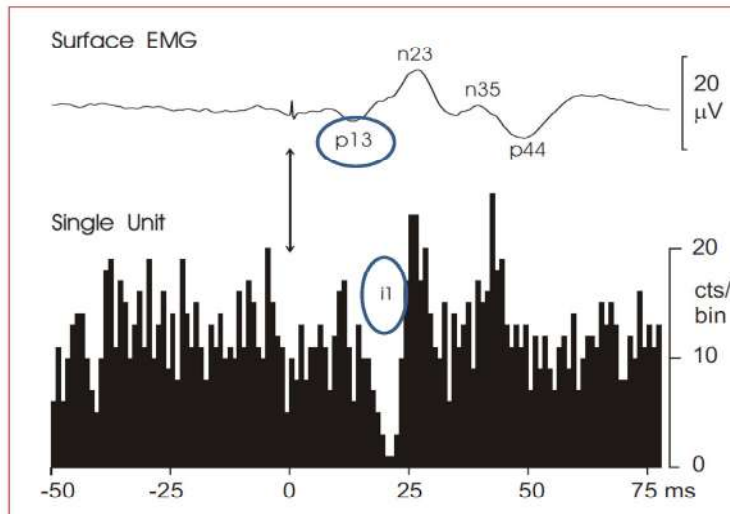
Cervical VEMP

(Vestibular Evoked Myogenic Potential)

- Sacculo-colic reflex
- Loud sound / bone vibration stimulation
- Inhibitory response of ipsilateral SCM muscle

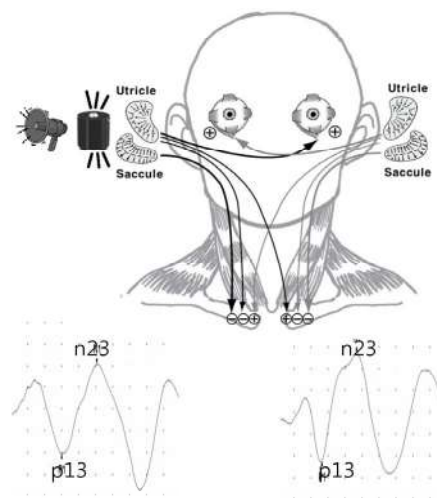
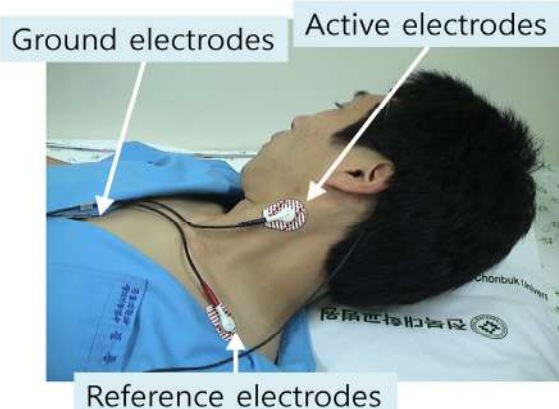


Simultaneous surface and single motor unit recordings in response to clicks

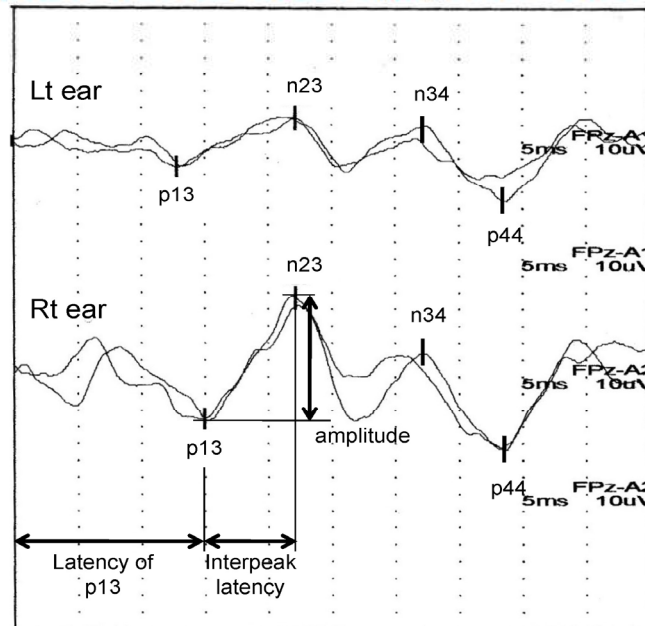


Colebatch et al., Clinical Neurophysiol 2004

Cervical VEMP (Vestibular Evoked Myogenic Potential)



Cervical VEMP (Vestibular Evoked Myogenic Potential)



Cervical VEMP: Parameters

1. Absence of response
2. Latency delay
3. Amplitude asymmetry
4. Threshold decrease

1. Absence of response

- Peripheral disorder
 - Meniere's disease (MD)
 - Vestibular neuritis (VN)
- Central disorder
 - Brainstem infarct
 - Vestibular schwannoma
- Subject factors
 - Old age
 - Inappropriate muscle contraction
 - Conductive hearing loss
 - Insufficient stimulus
 - etc.

2. Latency delay

- Central disorder
 - Multiple sclerosis
 - Vestibular schwannoma

Ferber-Viart, 1999; Mulch, 1979; Murofushi, 2001

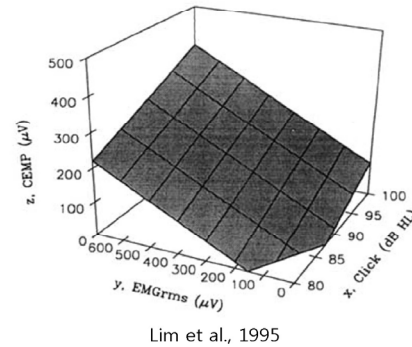
- Peripheral disorder
 - no delay in MD, VN
 - Delay can be detected

Murofushi, 2001

Cha, 2006

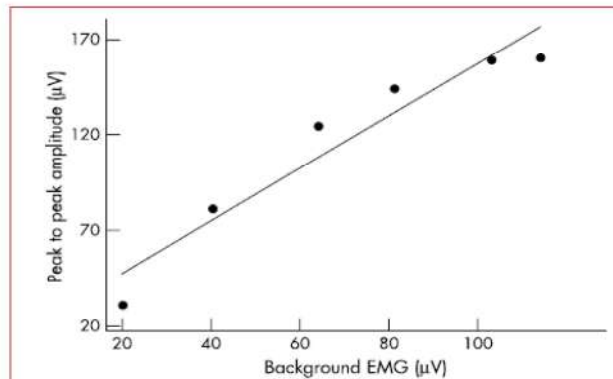
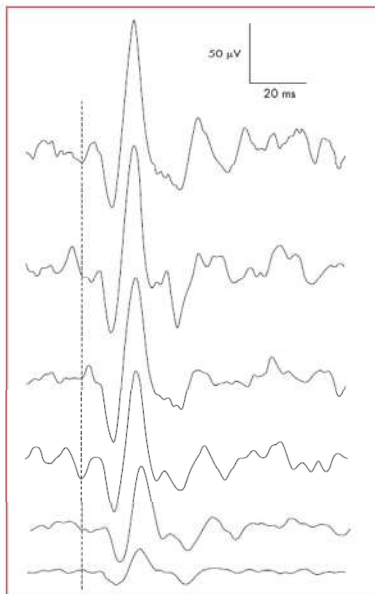
3. Amplitude asymmetry

- Dependent on many factors
 - Intensity of stimulus
 - Muscle contraction power
 - Evoked response system
 - Electrode resistance
 - Location of measurement
 - Age
 - etc.



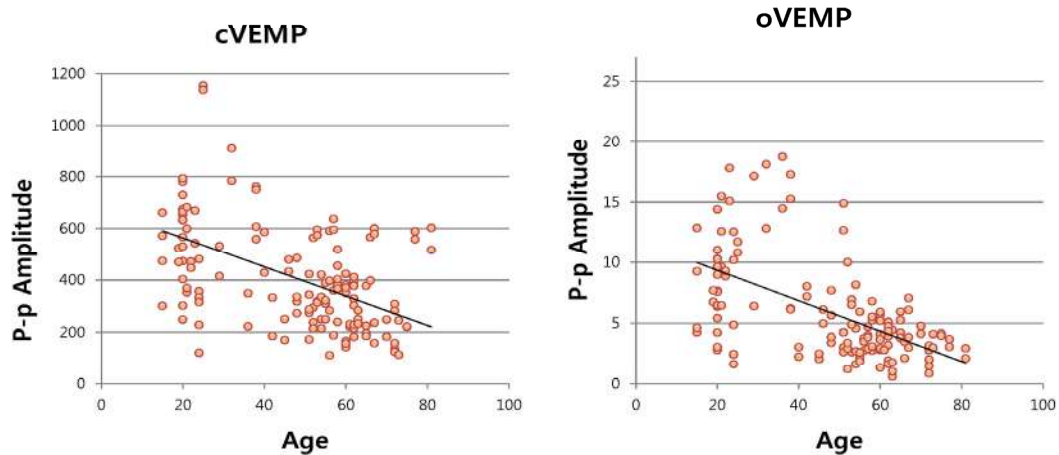
Colebatch et al., 1994a; Kim et al., 2003; Ochi et al., 2001

cVEMP amplitude is directly proportional to EMG activation



J Neurol Neurosurg Psychiatry 2003;74:771-778

Age-related VEMP amplitude changes



Oh et al., 2017

Asymmetry ratio (AR)

Interaural amplitude difference (**IAD**) = asymmetry ratio (**AR**)

$$AR = \frac{(Rt \text{ amplitude}) - (Lt \text{ amplitude})}{(Rt \text{ amplitude}) + (Lt \text{ amplitude})} \times 100$$

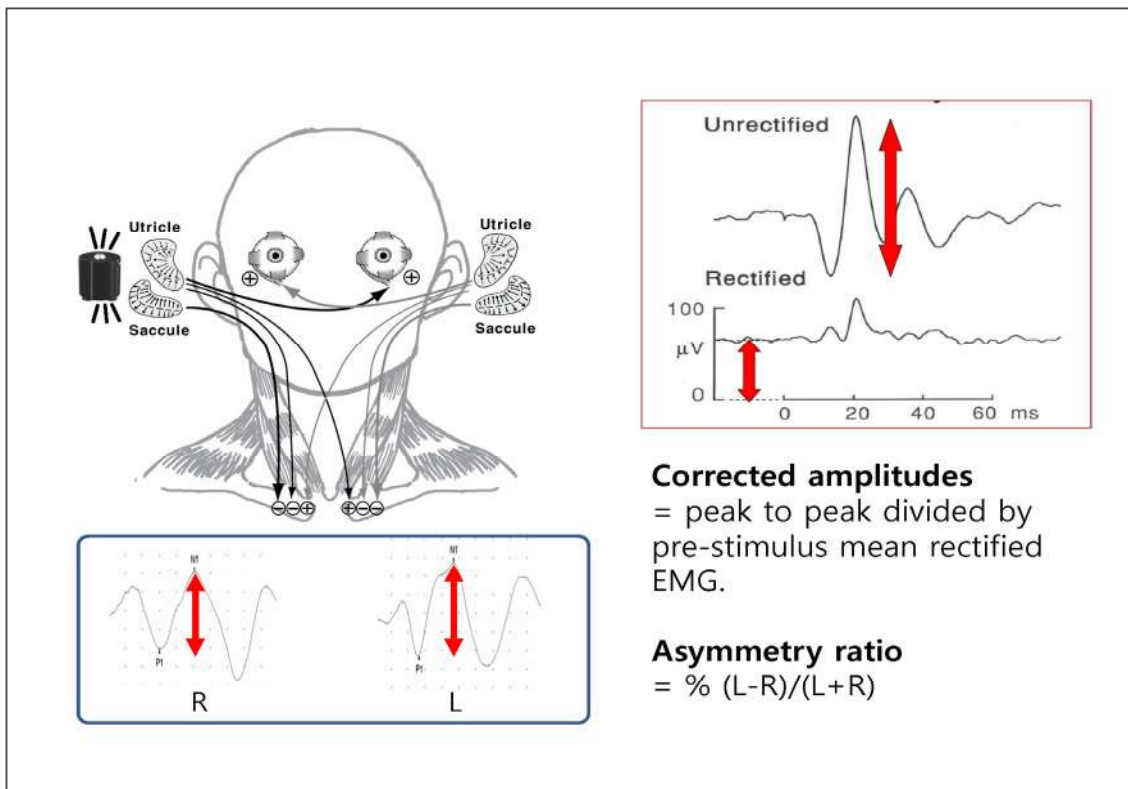
Papathanasiou ES, Clin Neurophysiol 2014

- May minimize inter-individual variance
- Normal criteria of IAD
 - Normal <25-39%
 - Normal <32%

Young and Kuo, 2004

Suh MW, Koo JW, Ann Otol Rhinol Laryngol 2009
Young, 2004

Papathanasiou ES, Clin Neurophysiol 2014
Wang et al., 2010



4. Threshold of cVEMP

- Usual threshold
 - Around 85-95 dB nHL
- Decreased threshold
 - Around 65-70 dB nHL
 - Thresholds greater than 10 dB below the limit of normal
 - Tullio phenomenon
 - Superior semicircular canal dehiscence
 - sensitivity and specificity of over 90%

Colebatch et al., 1994

Papathanasiou ES, Clin Neurophysiol 2014

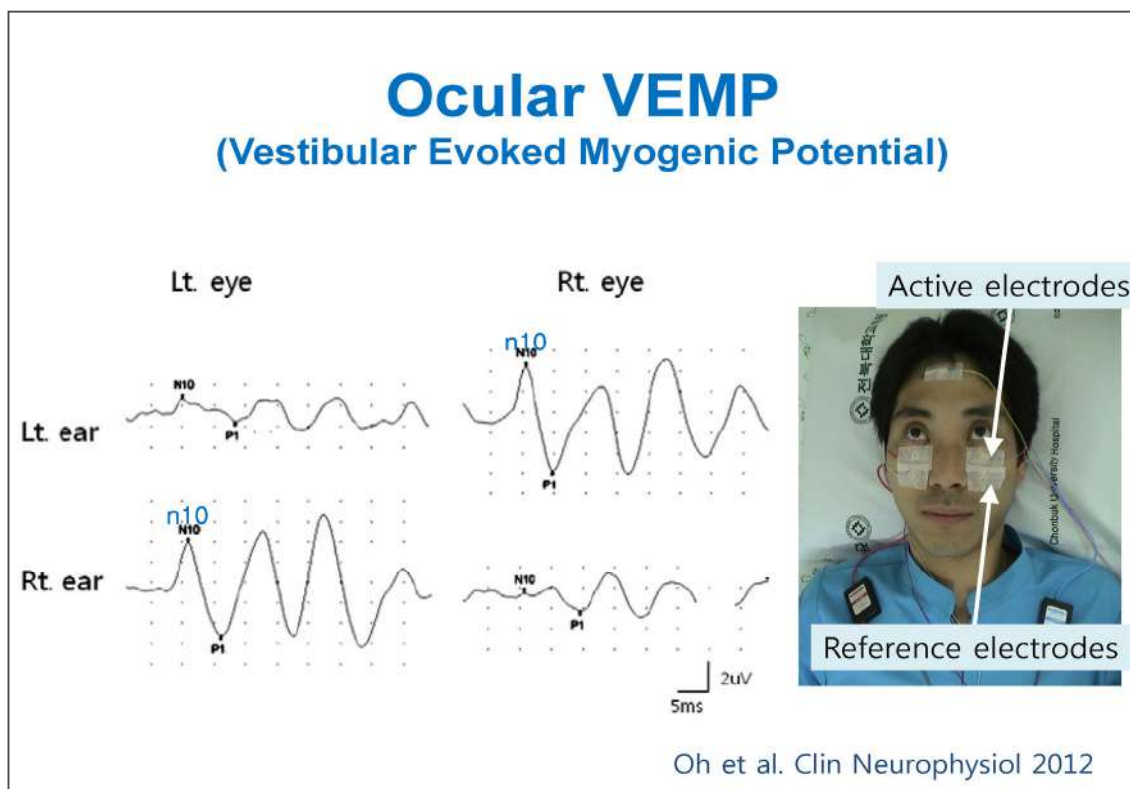
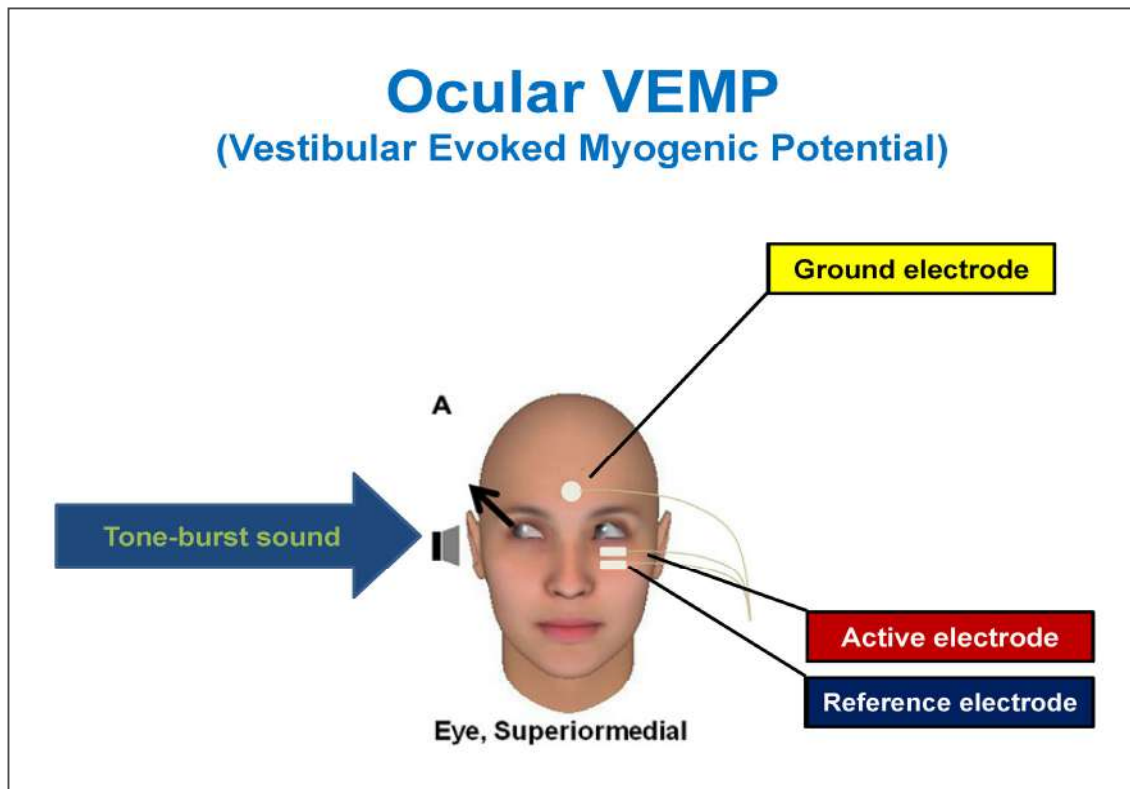
Brantberg and Verrecchia 2009; Zhou et al., 2007
 Colebatch, 1994; Rauch, 2006; Streubel, 2001

Reflex pathway of cVEMP

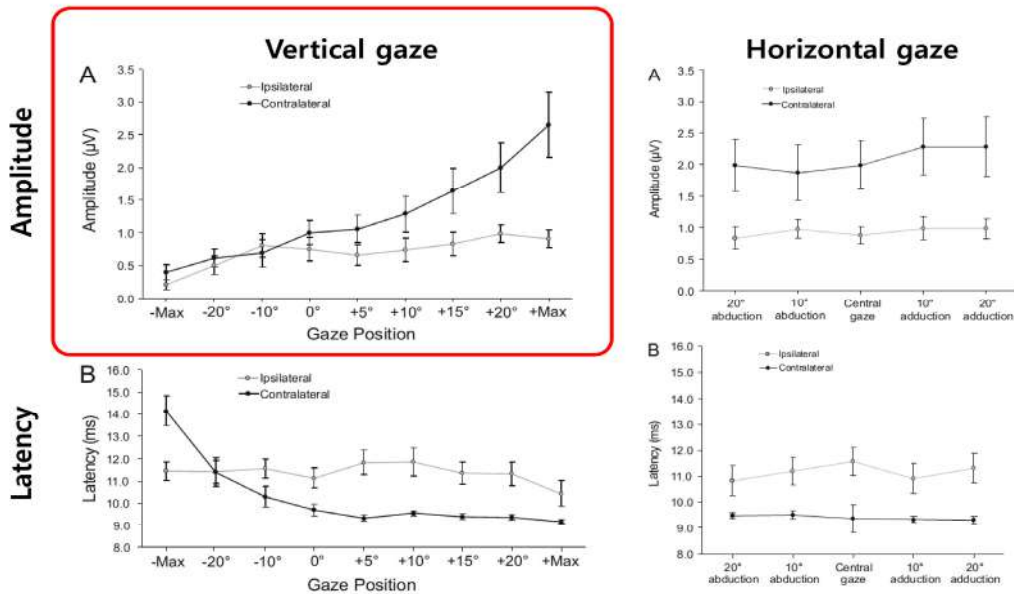
- **Sacculo-colic reflex**
 1. Middle ear
 2. Saccul (±utricle)
 3. Inferior vestibular nerve
 4. Vestibular nucleus
 5. Medial spinal vestibular track
 6. Accessory nuclei
 7. Sternocleidomastoid muscle (SCM)
- Contralateral response

Oh SY, Clinical Neurophysiology 2013

Ocular VEMP (Vestibular Evoked Myogenic Potential)



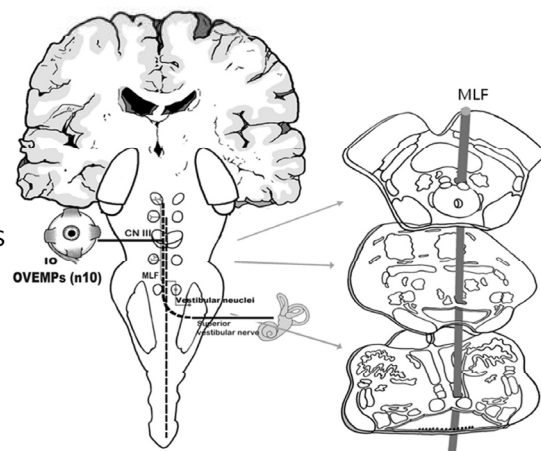
Ocular VEMP: effect of gaze



Clinical Neurophysiology 120 (2009) 1386–1391

Reflex pathway of oVEMP

- **Otolith-ocular reflex**
 1. Middle ear
 2. Utricle (\pm saccule)
 3. Superior vestibular nerve
 4. Vestibular nucleus
 5. Medial longitudinal fasciculus
 6. CN III
 7. Inferior oblique muscle
- **Contralateral response**



Oh SY, Clinical Neurophysiology 2013

Normal Response

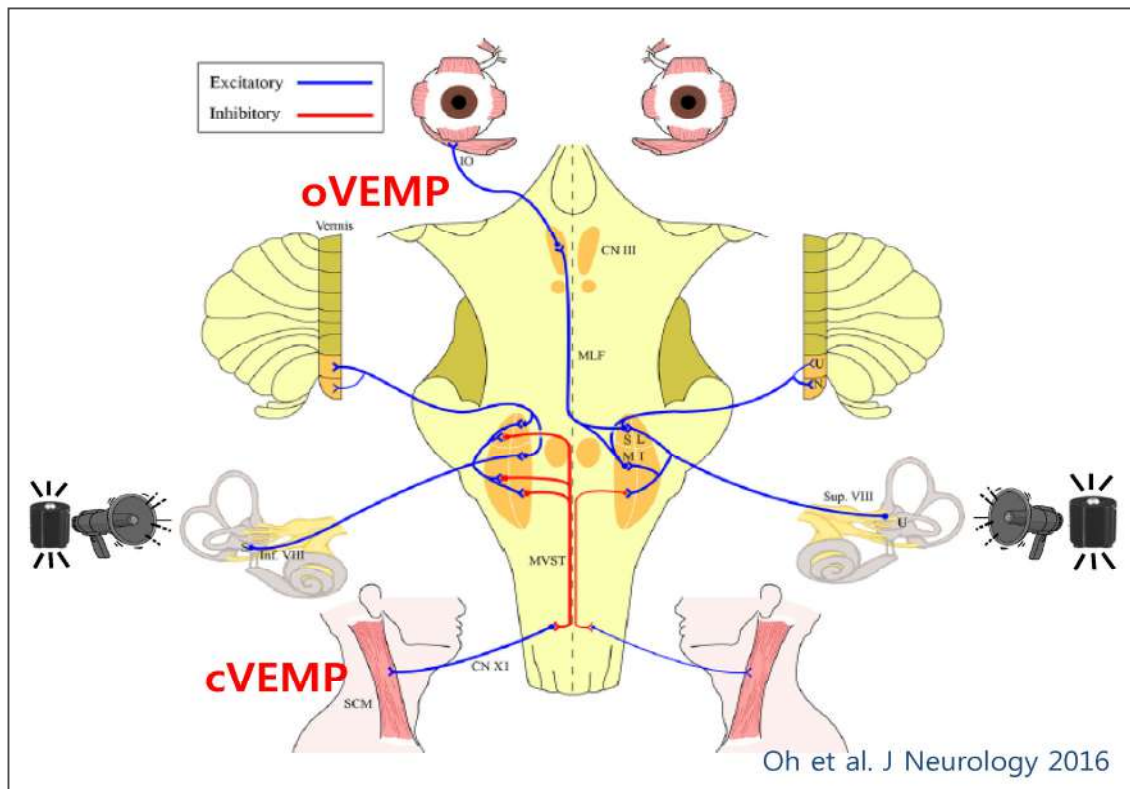
cVEMP	Latency of P13	12.8(\pm 2.5) msec
	Latency of N23	20.5(\pm 4.0) msec
	Amplitude (Peak to peak, μ V)	382.9(\pm 258.2) μ V
	Asymmetry Ratio (AR, %)	9.6(\pm 7.3)
oVEMP	N10 latency (ms)	9.4 (\pm 1.8) msec
	Amplitude (Peak to peak, μ V)	6.7 (\pm 5.2) msec
	Asymmetry Ratio (AR, %)	14.4 (\pm 11.3)

- Symmetry 1:2.5 or up to 35%
- Threshold 70-100 dB nHL

CBNUH 2011

Summary

	cVEMP	oVEMP
Response	Sacculo-colic reflex	Utriculo-ocular reflex (VOR)
	Inhibitory response	Excitatory response
Recording muscle	Ipsilateral SCM muscle	Contralateral IO muscle
Parameters	p13 n23 response	n10 p20 response
Interpretation	Stimulus intensity Contraction state of the SCM muscle Saccular function	Stimulus intensity Look up position (contraction state of IO muscle?) Utricular function



VEMPs in common peripheral vestibular disorders

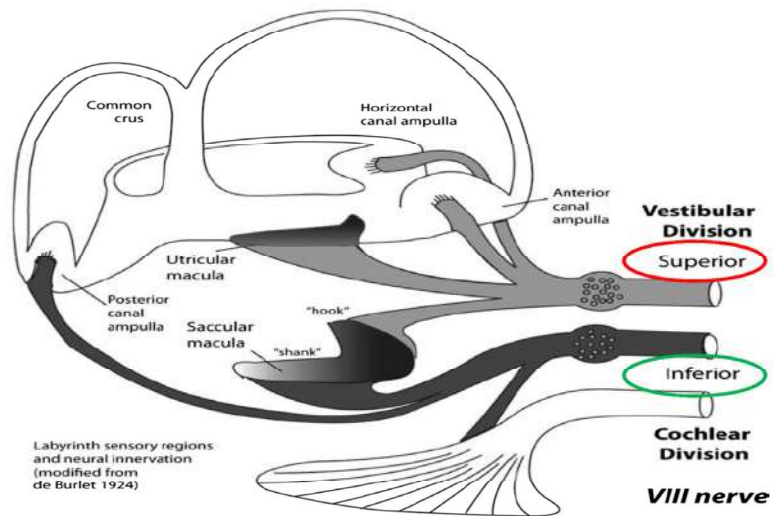
- Vestibular neuritis (VN)

Involvement of inferior division

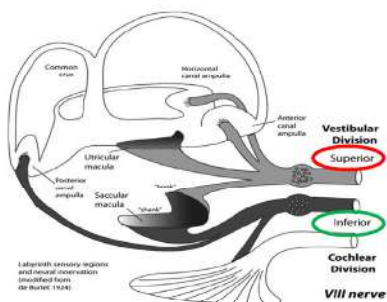
Development of BPV

- BPPV
- Meniere disease (MD)
- Superior canal dehiscence syndrome (SCD)
- Acoustic neuroma

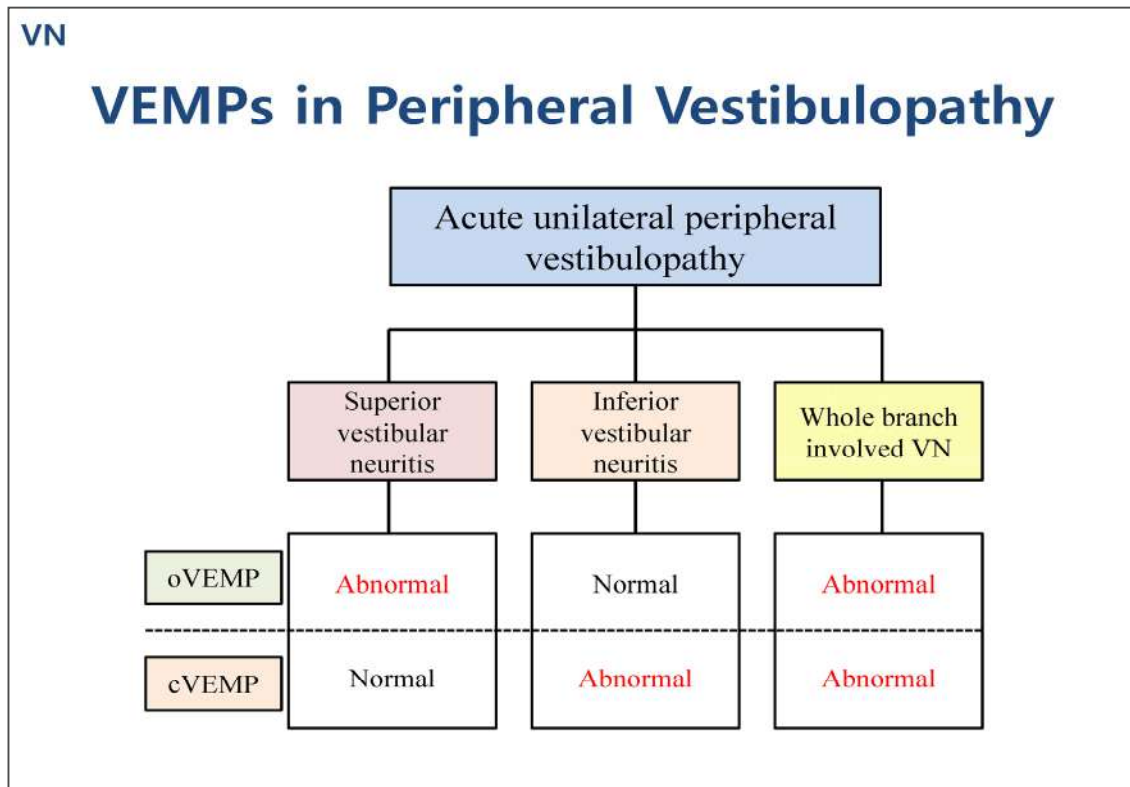
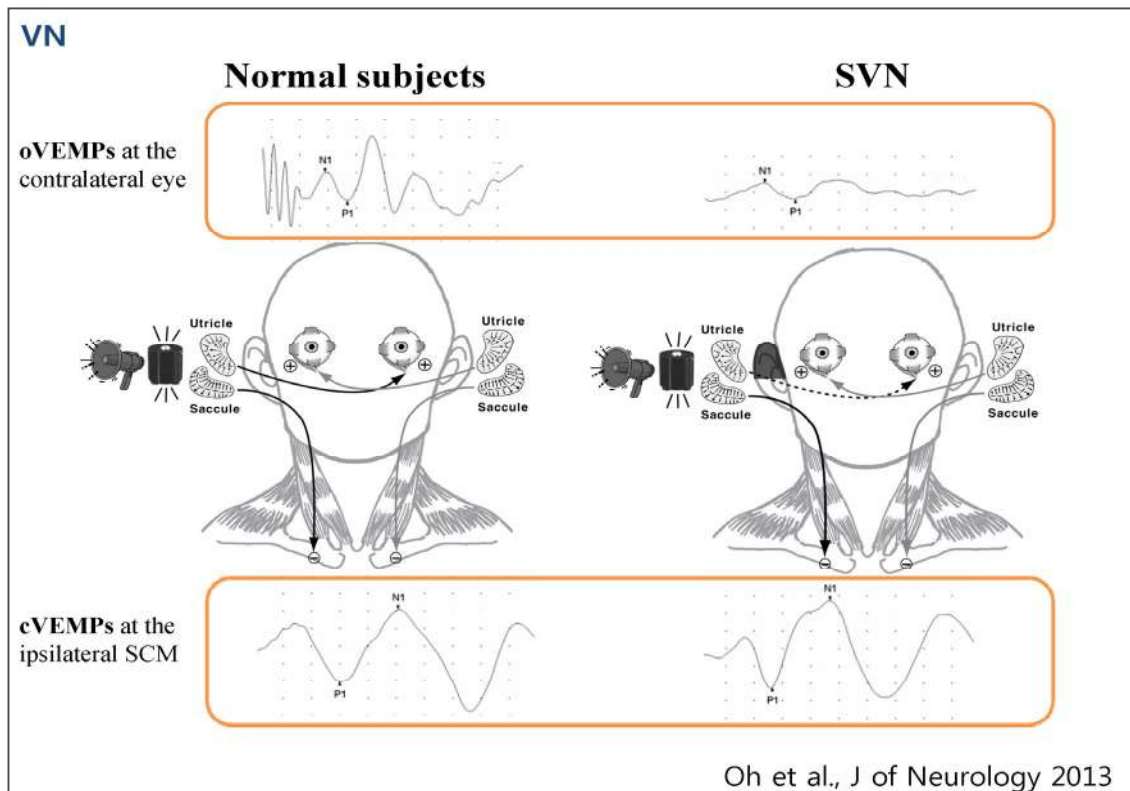
Vestibular neuritis



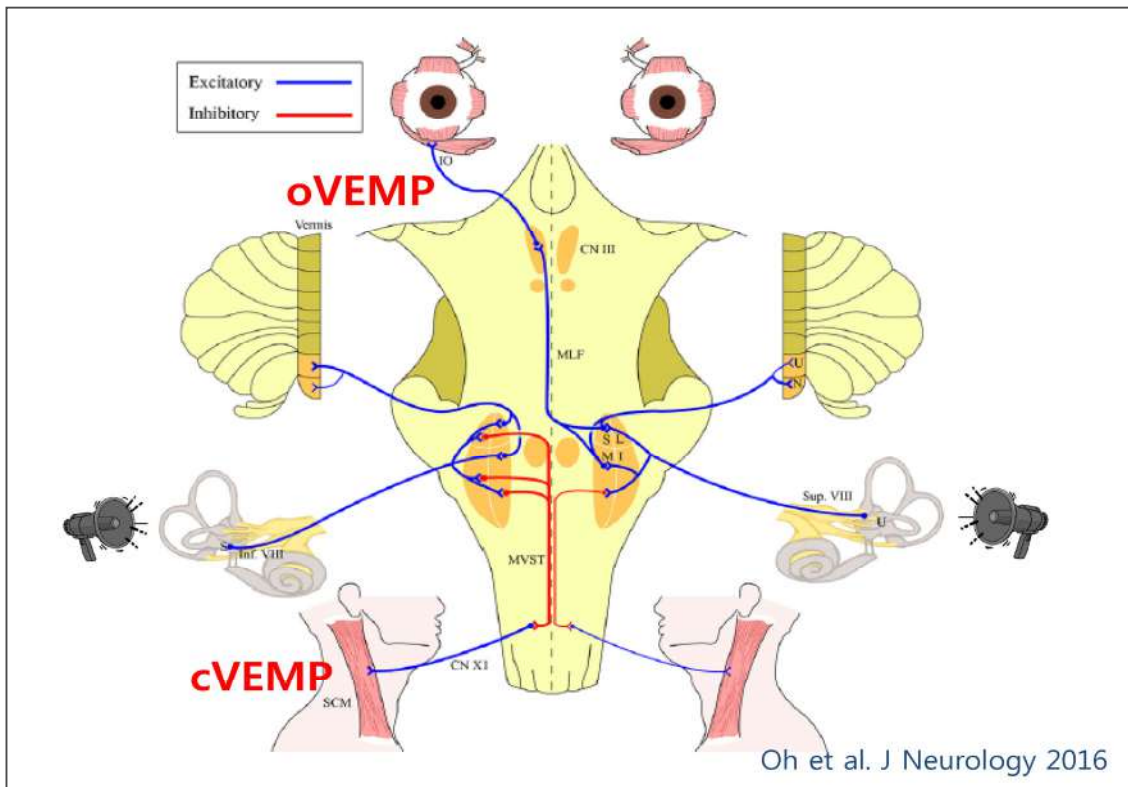
Vestibular neuritis (VN)

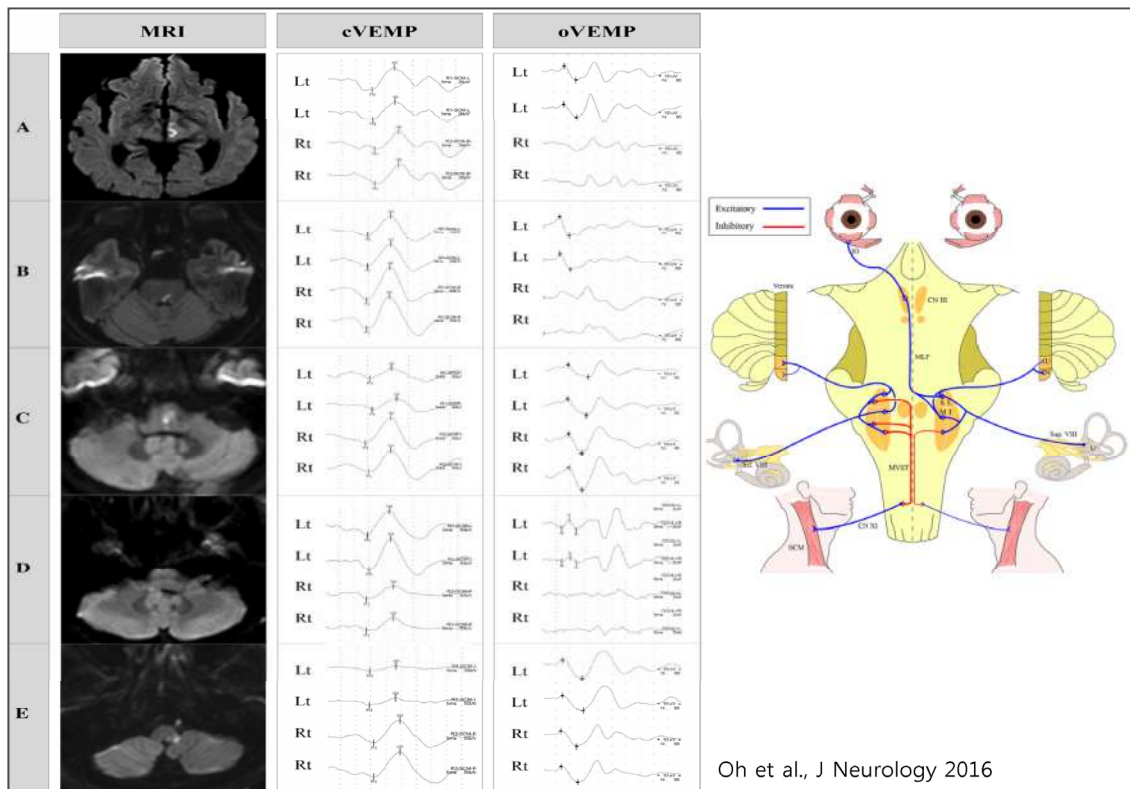


VN	Structures	Tests
Sup. VN	HSC	Caloric, HIT
	ASC	HIT
	Utricle	SVV, oVEMP
Inf. VN	PSC	HIT
	Sacculle	cVEMP
	Cochlea	PTA

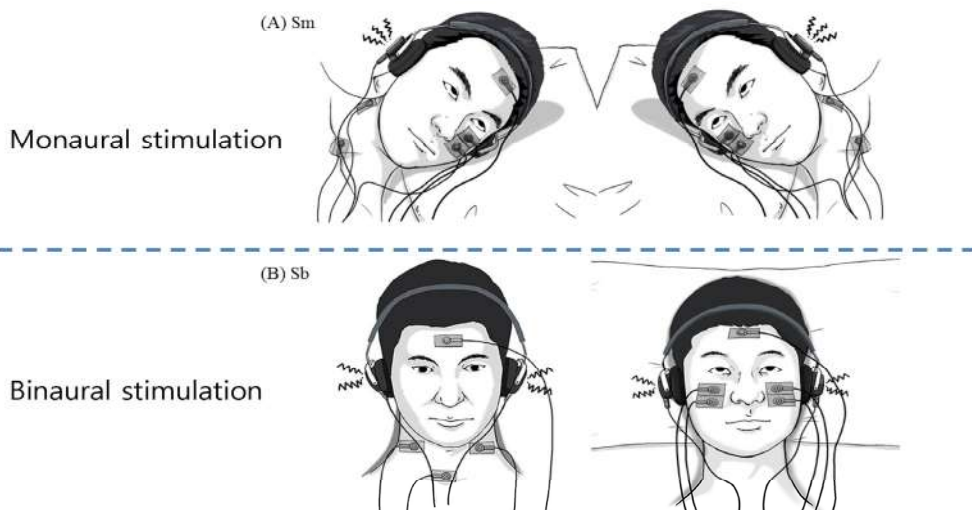


VEMPs in Central vestibular disorders

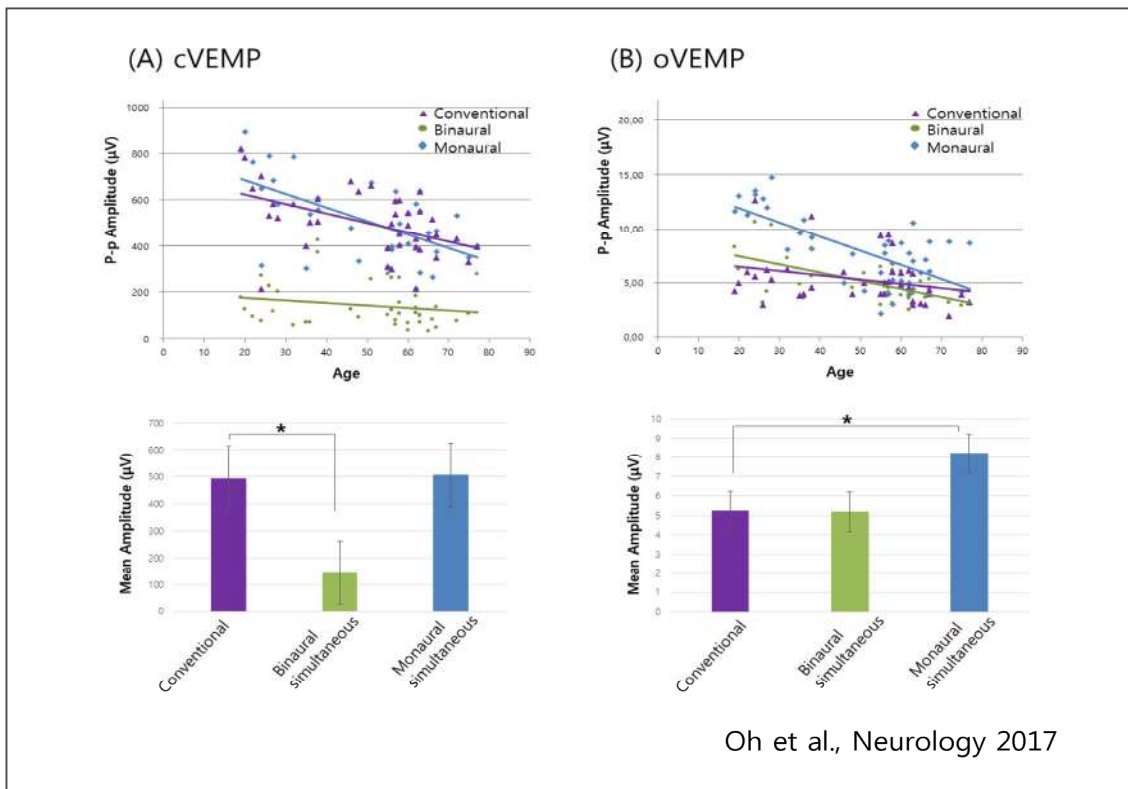




Simultaneous recording of c- & oVEMPs

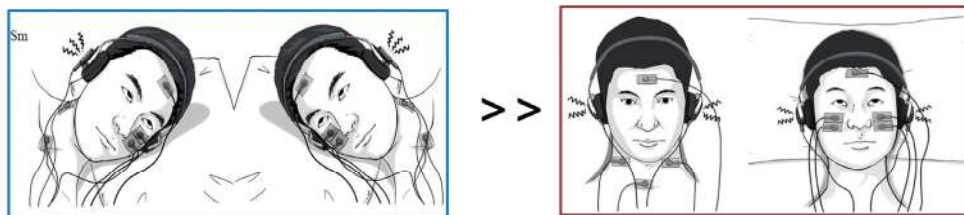


Oh et al., Neurology 2018



Simultaneous recording of c- & oVEMPs during monaural stimulation

- Simultaneous recording during monaural and binaural stimulation - reduced the recording time (55%)
- Simultaneous recording with monaural stimulation



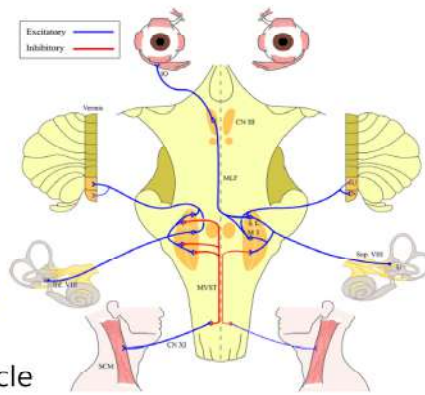
Summary

- **cVEMP (otolith-collic reflex)**

- Ipsilateral inhibitory response
- Ipsilateral SCM
- Inferior vestibular nerve
- Saccule

- **oVEMP (otolith-ocular reflex)**

- Contralateral excitatory response
- Contralateral inferior oblique muscle
- Superior vestibular nerve
- Utricle



Thank you for your attention!



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