VEMP

Vestibular Evoked
Myogenic Potentials

cVEMP • oVEMP • AC • BC

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audiology planet

inventis
Audiology & Balance

Starting With VEMP:

The Fastest Way to Level-Up Your Vestibular Clinic

A practical, evidence-based guide to integrating cVEMP and oVEMP into daily vestibular assessment.

- Otolithic Function
- Protocol Selection
- Clinical Applications
- Daily Integration

Continuing Education Webinar | Vestibular Electrophysiology Series

What We'll Cover Today

01 **VEMP Fundamentals**

02 **Clinical Value of VEMPs**

03 **Protocol Selection**

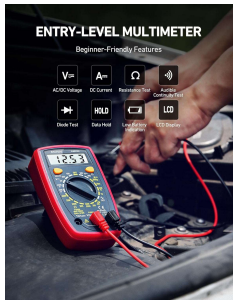
04 **Disease-Specific Applications**

05 **Work flow**

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testing



- 1970s Clinical electrophysiology is born
- 1980-1990 Refinement + commercial systems

> Science. 1970 Mar 13;167(3924):1517-8. doi: 10.1126/science.167.3924.1517.

Human auditory evoked potentials: possible brain stem components detected on the scalp

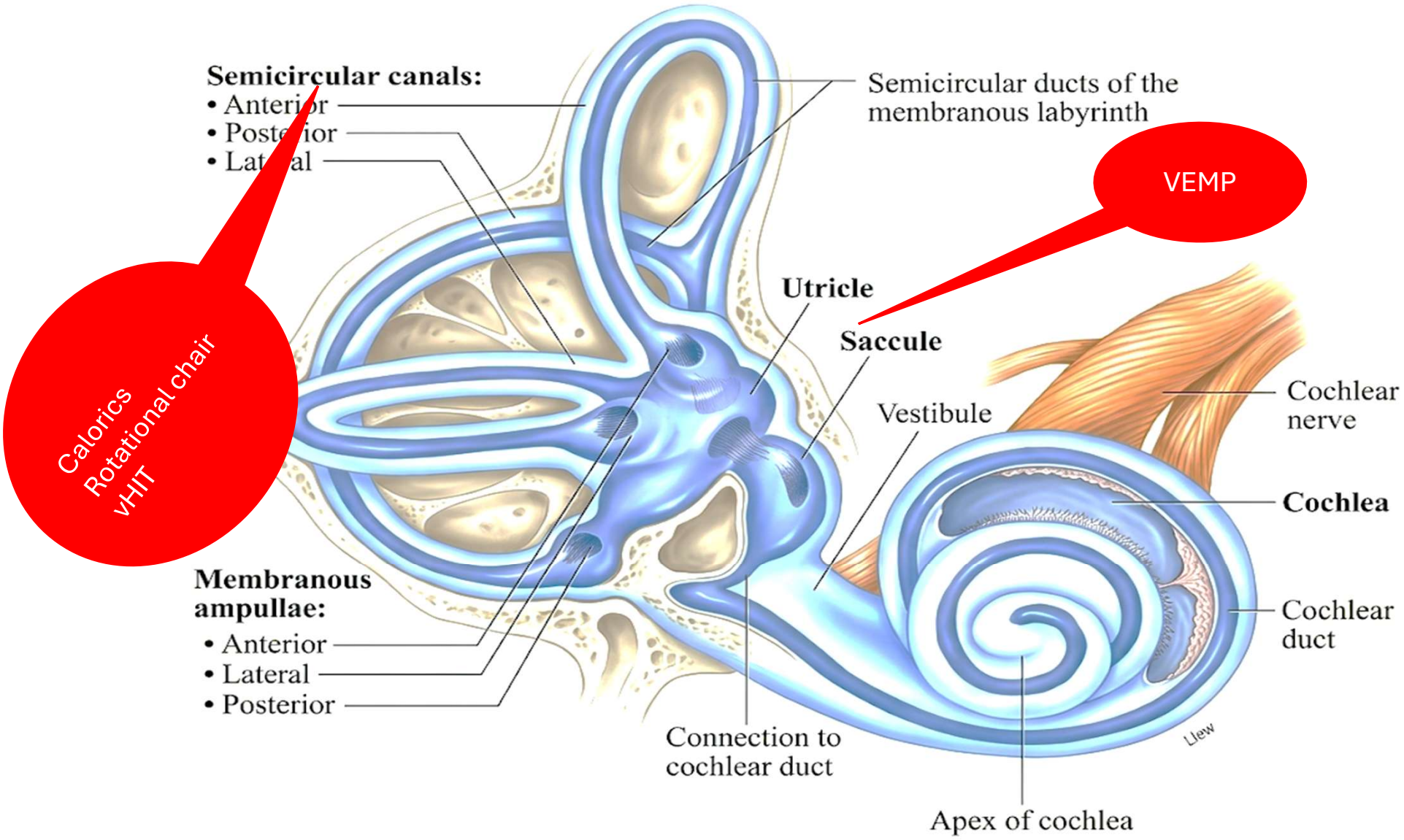
D L Jewett, M N Romano, J S Williston

PMID: 5415287 DOI: 10.1126/science.167.3924.1517

Abstract

Auditory potentials recorded from the vertex of humans by a modified averaging technique have very short latencies and are probably generated by brain stem structures located at a considerable distance from the recording point. The evoked waves, which shOW considerable detail and consistency within and across subjects, may be clinically useful in evaluating subcortical function.

Transistors made low-noise amplification possible → which enabled signal averaging → which made evoked potentials clinically usable


Semicircular canals:
• Anterior
• Posterior
• Lateral
Semicircular ducts of the membranous labyrinth
VEMP
Calorics
Rotational chair
vHIT
Utricle
Saccule
Vestibule
Cochlear nerve
Cochlea
Cochlear duct
Membranous ampullae:
• Anterior
• Lateral
• Posterior
Connection to cochlear duct
Apex of cochlea
Llew

Tests of Otolith Functions (Jacobson & Shepard

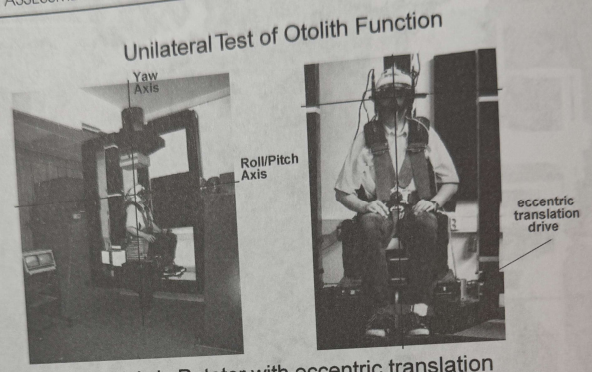


Figure 19–5. **A**. Subject seated on a yaw axis rotating chair. The chair is fitted with an eccentric translation drive that allows translation of the subject sideways to position one utricle on the rotational axis (**B**). This technique allows centrifugation of one utricle at a time and is currently the only test available for unilateral utricular examination. (Courtesy of A. Clarke)

arke & Engelhorn, 1998; Wuyts et al., 2001). sponses can be recorded as ocular torsion, for exam-, with 3-D video-oculography (Figure 19–5A), or as bjective visual tilt with a chair-mounted subjec- visual vertical system (see below).

It is important to note that when tion is generated by rotation, th can only be assessed either by su ponent due to angular motion (e.g eccentric response from head-

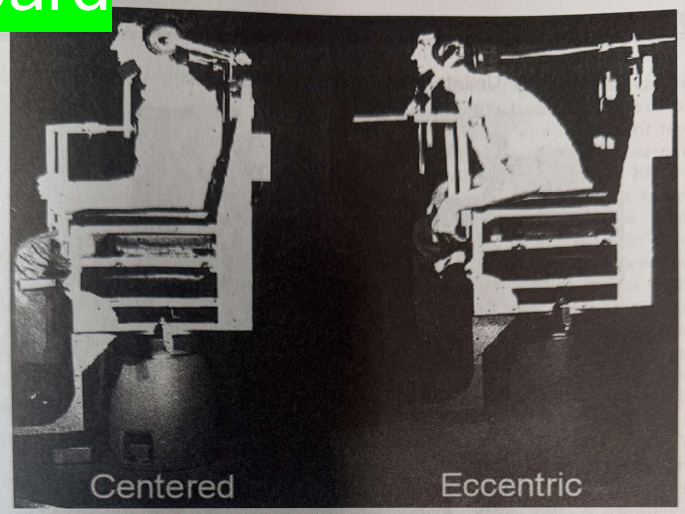


Figure 19–6. Off-vertical axis rotation (OVAR): Subject seated on a yaw axis rotating chair. The chair is tilted with respect to earth-vertical (*black line*) so that, during rotation, the otoliths are continuously stimulated as they are dynamically reoriented with respect to the gravity vector.

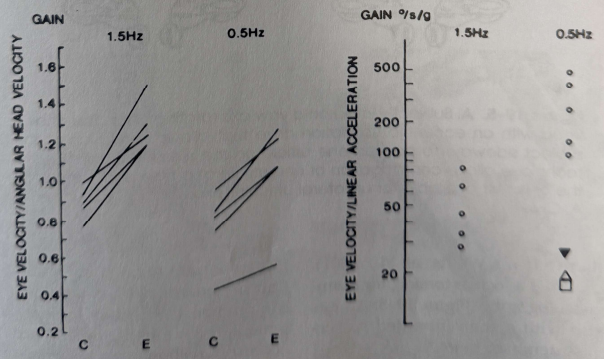
What physiologic responses can be measured to assess otolith function? The more common measure is the slow phase eye movement response, called linear or translational VOR or, more generally, otolith-ocular reflexes (Lempert et al., 1997). Recording of eye movements during otolith testing also poses technical problems. The forces involved usually generate more movement artifact than during conventional rotational or caloric procedures. In addition, the relatively small size of the otolith-ocular response, coupled with the fact that an important component of the otolith response is ocular torsion (not recorded by EOG), often requires three-dimensional oculography (video-oculography or scleral search-coil technique) (Clarke & Engelhorn, 1998). Another response, which can be measured during linear acceleration, particularly in centrifugation tests (Bohmer & Mast, 1999), is the subjective visual vertical (SVV) which largely follows ocular torsional position (Curthoys, Daf, & Halmagyi, 1991) (see below). Dynamic visual acuity, a measure of how much vision degrades, in this case, during linear acceleration, has also been used in bilateral vestibular patients but it is unlikely to be helpful in unilateral lesions (Lempert et al., 1997).



Figure 19–7. Controlled static tilt with precision gimbals system for eliciting ocular counter-rolling. The eye movements are usually recorded with 3-D VOG.



re 19–3. Subject positioned on the rotating chair for canal VOR testing (*centered*) or comb al-utricular VOR testing (*eccentric*). The eccentric position of the head adds a compone gential linear acceleration to the head. Subtraction of centered from eccentric ocular respo esents the utricular contribution.



gure 19–4. *Left:* ratio of slow phase eye velocity/angular head velocity in centered (C) ccentric (E) positions on the rotating chair as shown in Figure 19–3. Note the increase in eye velo the eccentric position due to additional otolith (utricle) stimulation. Also note the increase at hig equency of rotation. *Right:* shows the ratio of eye velocity attributed to otolith stimulation (i.e., h g subtracted the angular VOR) per unit of linear acceleration (deg/sec/g). For comparisons g btained during pure linear acceleration in the dark are provided (Steer, 1967, *filled triangle*; Cor nd Guedry, 1966, *open triangle*; Nyyen et al., 1966, *square*) at frequencies of about 0.5 to

Vestibular Battery Matrix

THE **COMPLETE** VESTIBULAR BATTERY **MATRIX**

TEST	TARGET ORGAN	NEURAL PATHWAY	STIMULUS	CLINICAL VALUE
Calorics	Horizontal Canal	Superior Vestibular Nerve	Thermal	Low-frequency unilateral weakness
vHIT	All 6 Canals	Superior & Inferior Nerves	Angular Head Impulse	High-frequency rotational deficits
cVEMP	Saccule	Inferior Vestibular Nerve	Sound / Vibration	Saccular & Inferior pathway integrity
oVEMP	Utricle	Superior Vestibular Nerve	Sound / Vibration	Utricular & Superior pathway integrity

Protocol Selection

Air Conduction (AC) vs Bone Conduction (BC) Stimulation

AIR CONDUCTION (AC)

Click or TB via insert earphone

Stimulus:	95-100 dB nHL clicks or 500 Hz TB with 2-1 Rise-fall. +1k if MD and +4k if SSCD
Rate:	5.1 Hz (optimal SNR)
Sweeps:	60-100 per average (10-1500 Hz filter)
EMG Target:	50–100 µV RMS tonic contraction
Ear:	Ipsilateral (cVEMP) / Contra (oVEMP)
Best For:	Threshold estimation, Menière's, SSCD screening
Limitation:	Middle ear pathology attenuates response

VS

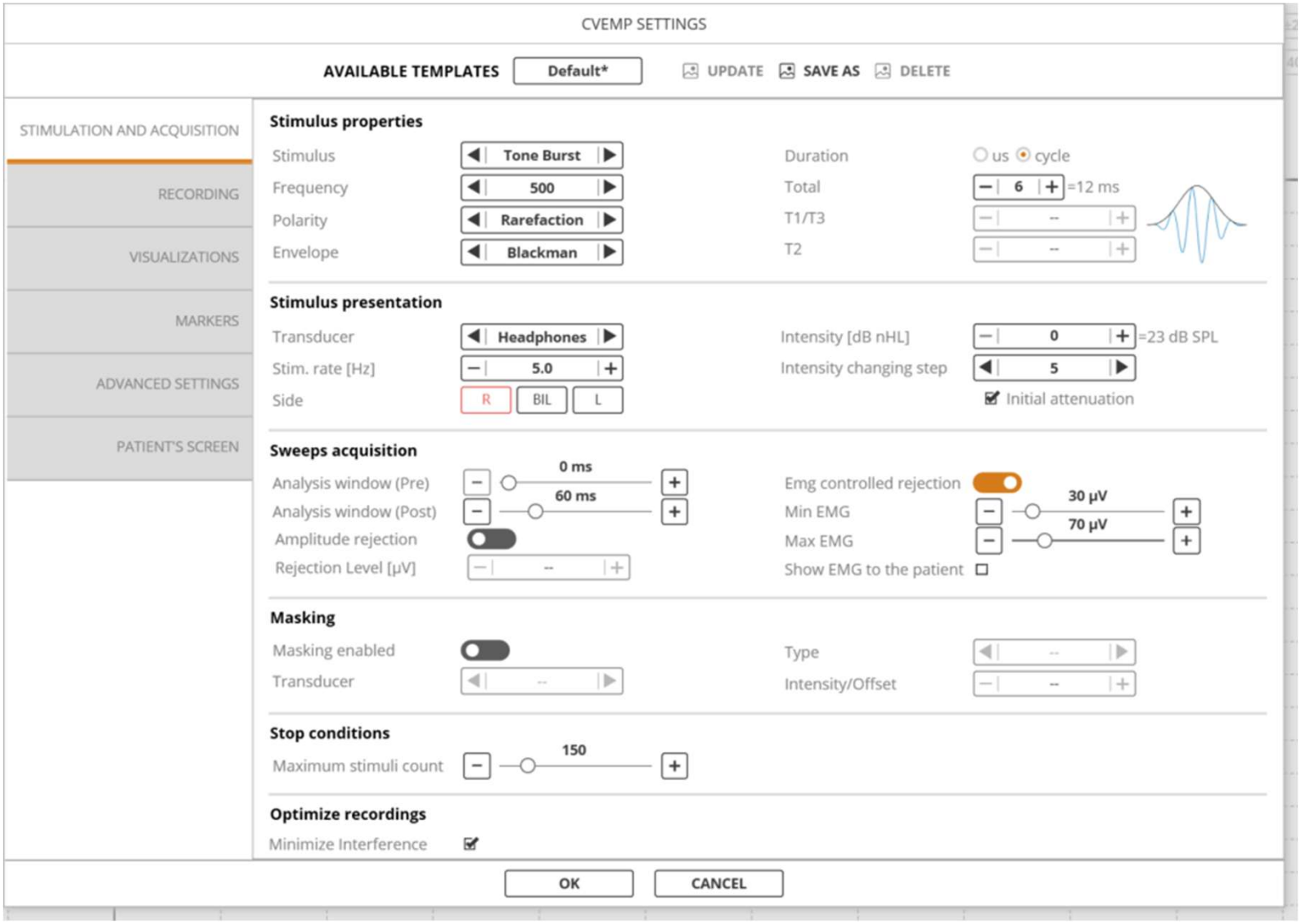
BONE CONDUCTION (BC)

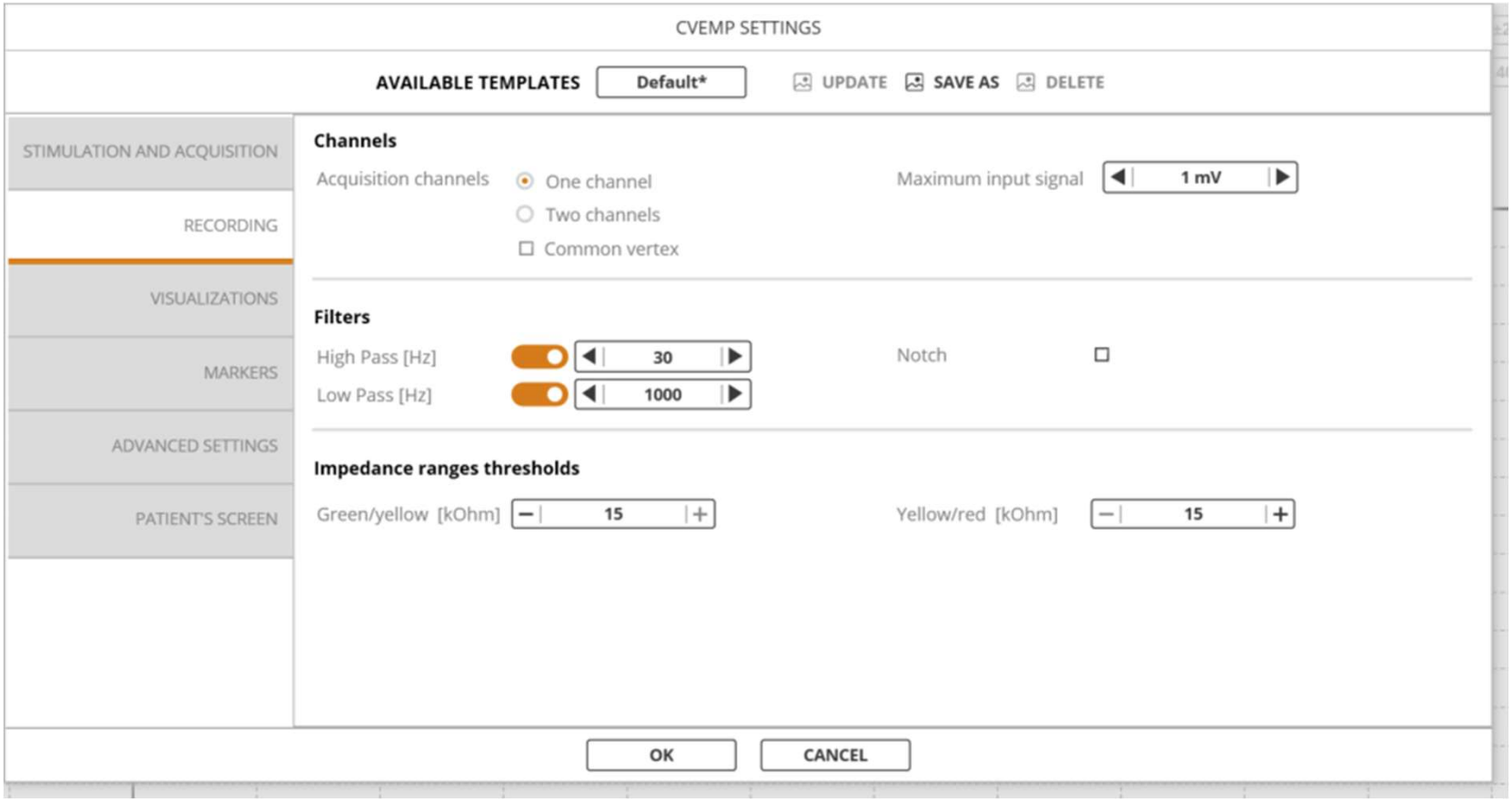
Mini-shaker or B71/81 transducer

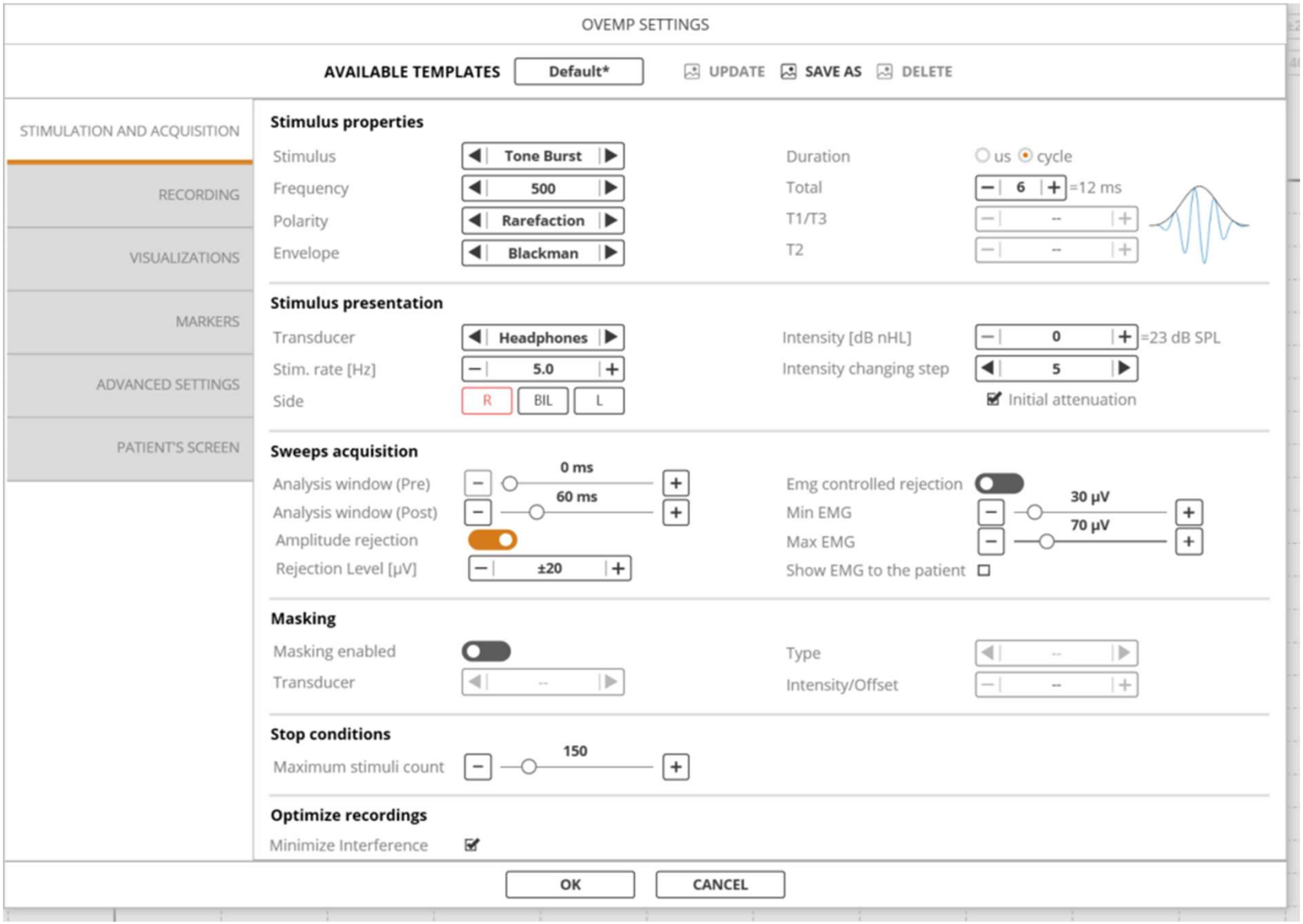
Stimulus:	Vibration burst (250-500 Hz, 4-8ms, 5.1/sec)
Force Level:	~140 dB re 1 µN (equivalent to around 70 dBnHL)
Rate:	5–13 Hz
Sweeps:	100–200 per average
Best For:	Bypasses ME pathology, oVEMP, conductive loss
Advantage:	Not affected by middle ear effusion
Limitation:	Placement-sensitive, less standardised

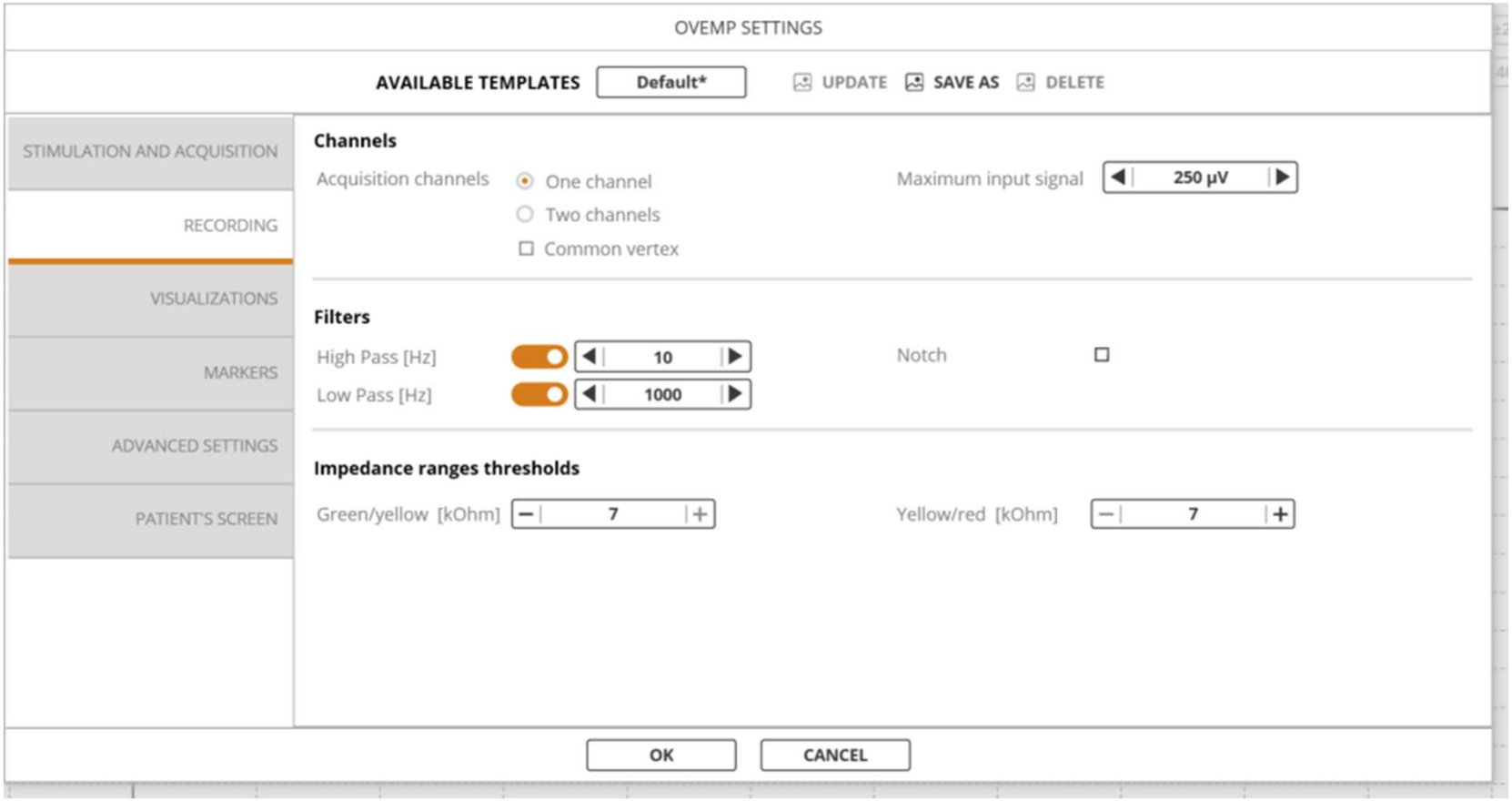
Stimulus considerations

Feature	Air Conduction (AC)	Bone Conduction (BC)
Calibration	Standardised and easy	Difficult and varies by placement
Middle Ear Influence	Blocked by conductive loss	Bypasses middle ear issues
Stimulus Specificity	Highly ear-specific	Often stimulates both ears
Comfort	Generally high	Can be uncomfortable due to headband pressure

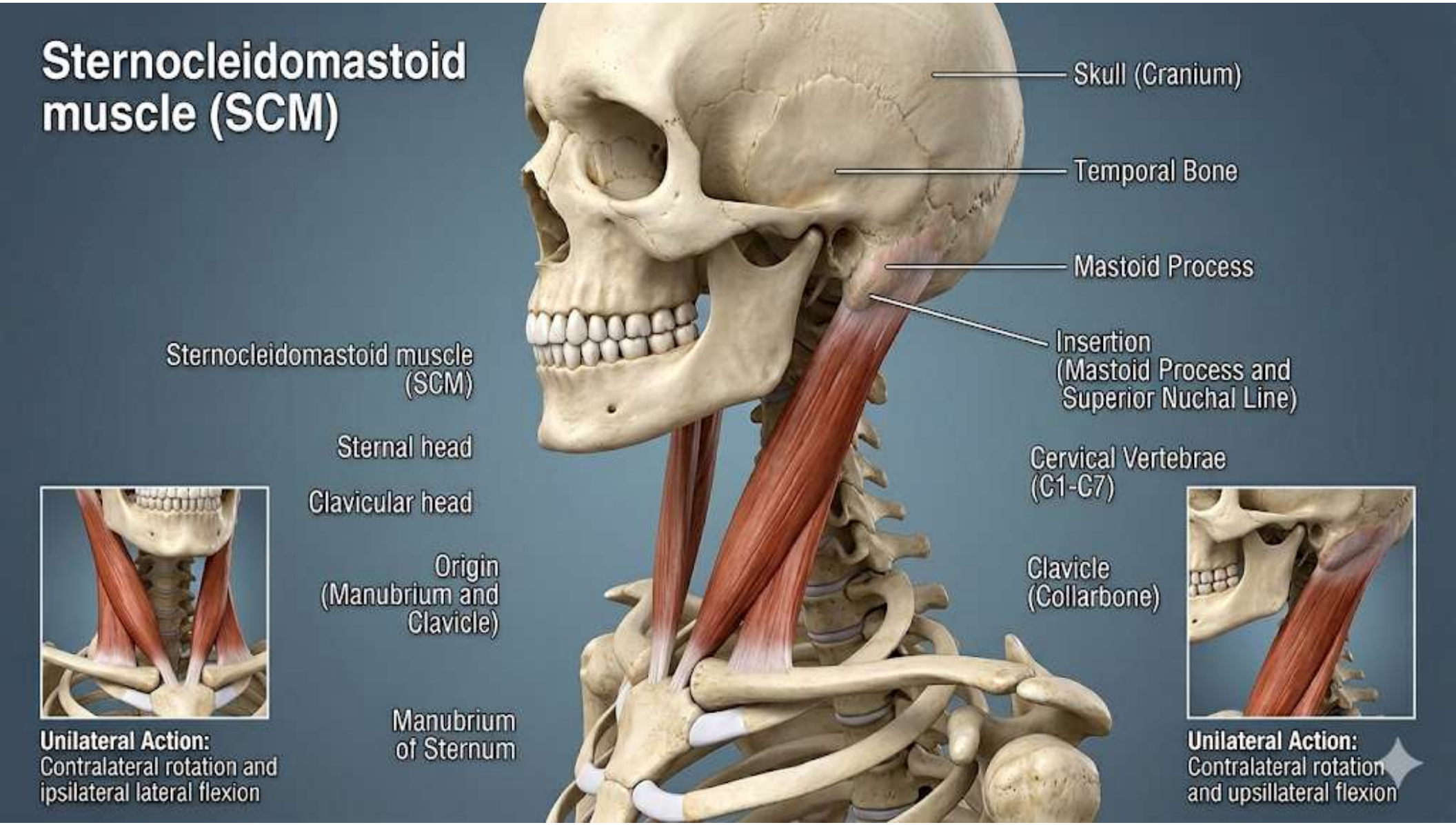

CVEMP SETTINGS
AVAILABLE TEMPLATES
Default*
UPDATE
SAVE AS
DELETE
STIMULATION AND ACQUISITION
RECORDING
VISUALIZATIONS
MARKERS
ADVANCED SETTINGS
PATIENT'S SCREEN
Stimulus properties
Stimulus
Tone Burst
Frequency
500
Polarity
Rarefaction
Envelope
Blackman
Duration
us
cycle
Total
6
=12 ms
T1/T3
T2
Stimulus presentation
Transducer
Headphones
Stim. rate [Hz]
5.0
Side
R
BIL
L
Intensity [dB nHL]
0
=23 dB SPL
Intensity changing step
5
Initial attenuation
Sweeps acquisition
Analysis window (Pre)
0 ms
Analysis window (Post)
60 ms
Amplitude rejection
Rejection Level [µV]
Emg controlled rejection
Min EMG
30 µV
Max EMG
70 µV
Show EMG to the patient
Masking
Masking enabled
Transducer
Type
Intensity/Offset
Stop conditions
Maximum stimuli count
150
Optimize recordings
Minimize Interference
OK
CANCEL


CVEMP SETTINGS
AVAILABLE TEMPLATES
Default*
UPDATE
SAVE AS
DELETE
STIMULATION AND ACQUISITION
RECORDING
VISUALIZATIONS
MARKERS
ADVANCED SETTINGS
PATIENT'S SCREEN
Channels
Acquisition channels
One channel
Two channels
Common vertex
Maximum input signal
1 mV
Filters
High Pass [Hz]
30
Notch
Low Pass [Hz]
1000
Impedance ranges thresholds
Green/yellow [kOhm]
15
Yellow/red [kOhm]
15
OK
CANCEL


OVEMP SETTINGS
AVAILABLE TEMPLATES
Default*
UPDATE
SAVE AS
DELETE
STIMULATION AND ACQUISITION
RECORDING
VISUALIZATIONS
MARKERS
ADVANCED SETTINGS
PATIENT'S SCREEN
Stimulus properties
Stimulus
Tone Burst
Frequency
500
Polarity
Rarefaction
Envelope
Blackman
Duration
us
cycle
Total
6
=12 ms
T1/T3
T2
Stimulus presentation
Transducer
Headphones
Stim. rate [Hz]
5.0
Side
R
BIL
L
Intensity [dB nHL]
0
=23 dB SPL
Intensity changing step
5
Initial attenuation
Sweeps acquisition
Analysis window (Pre)
0 ms
Analysis window (Post)
60 ms
Amplitude rejection
Rejection Level [µV]
±20
Emg controlled rejection
Min EMG
30 µV
Max EMG
70 µV
Show EMG to the patient
Masking
Masking enabled
Transducer
Type
Intensity/Offset
Stop conditions
Maximum stimuli count
150
Optimize recordings
Minimize Interference
OK
CANCEL


OVEMP SETTINGS
AVAILABLE TEMPLATES
Default*
UPDATE
SAVE AS
DELETE
STIMULATION AND ACQUISITION
RECORDING
VISUALIZATIONS
MARKERS
ADVANCED SETTINGS
PATIENT'S SCREEN
Channels
Acquisition channels
One channel
Two channels
Common vertex
Maximum input signal
250 µV
Filters
High Pass [Hz]
10
Notch
Low Pass [Hz]
1000
Impedance ranges thresholds
Green/yellow [kOhm]
7
Yellow/red [kOhm]
7
OK
CANCEL

Sternocleidomastoid muscle (SCM)



Unilateral Action:
Contralateral rotation and ipsilateral lateral flexion

Unilateral Action:
Contralateral rotation and upsillateral flexion


5.00 [uV/div]
40.00 [uV/div]
-16.0 -11.0 -6.0 -1.0 4.0 9.0 14.0 19.0 24.0 29.0 34.0 39.0
-21.0 -14.0 -7.0 0.0 7.0 14.0 21.0 28.0 35.0 42.0 49.0 56.0

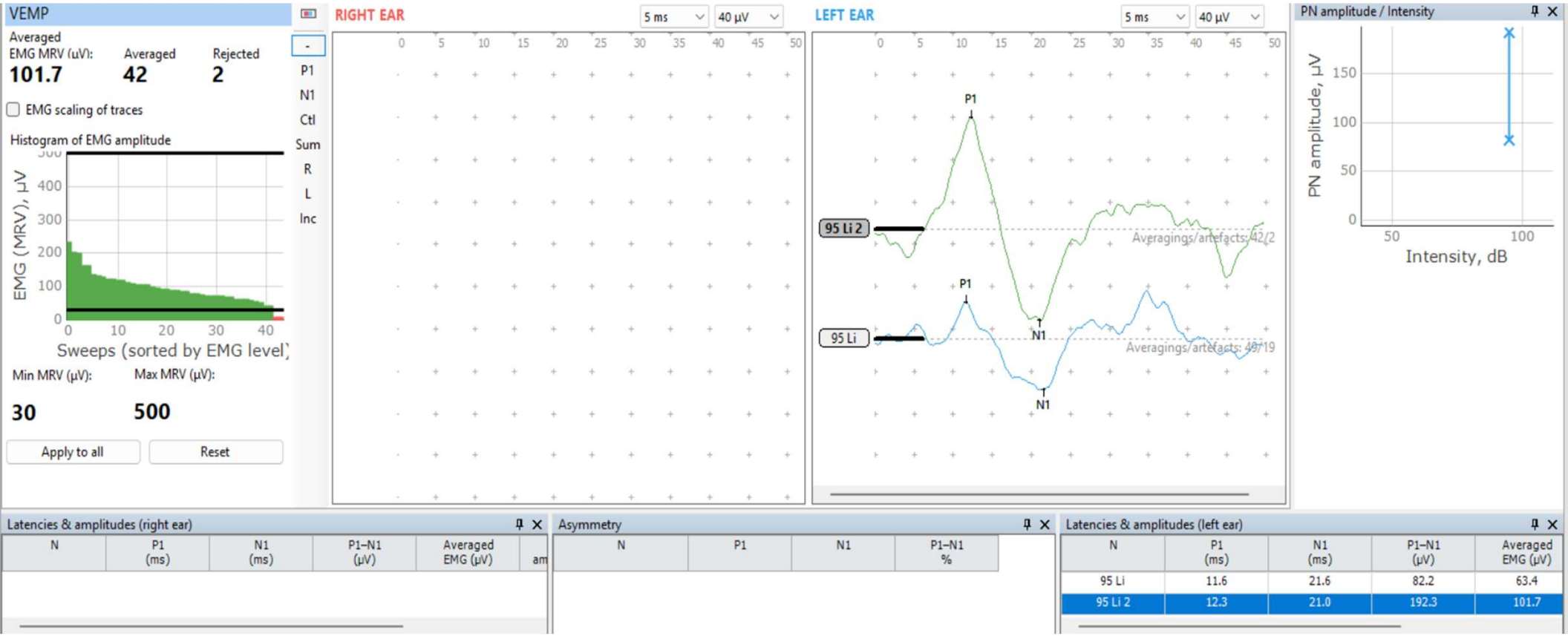
EMG

- Scaling or normalising- averages the absolute value of the pre-stimulus EMG (20 ms before stimulus onset) and divides response amplitude by this value.

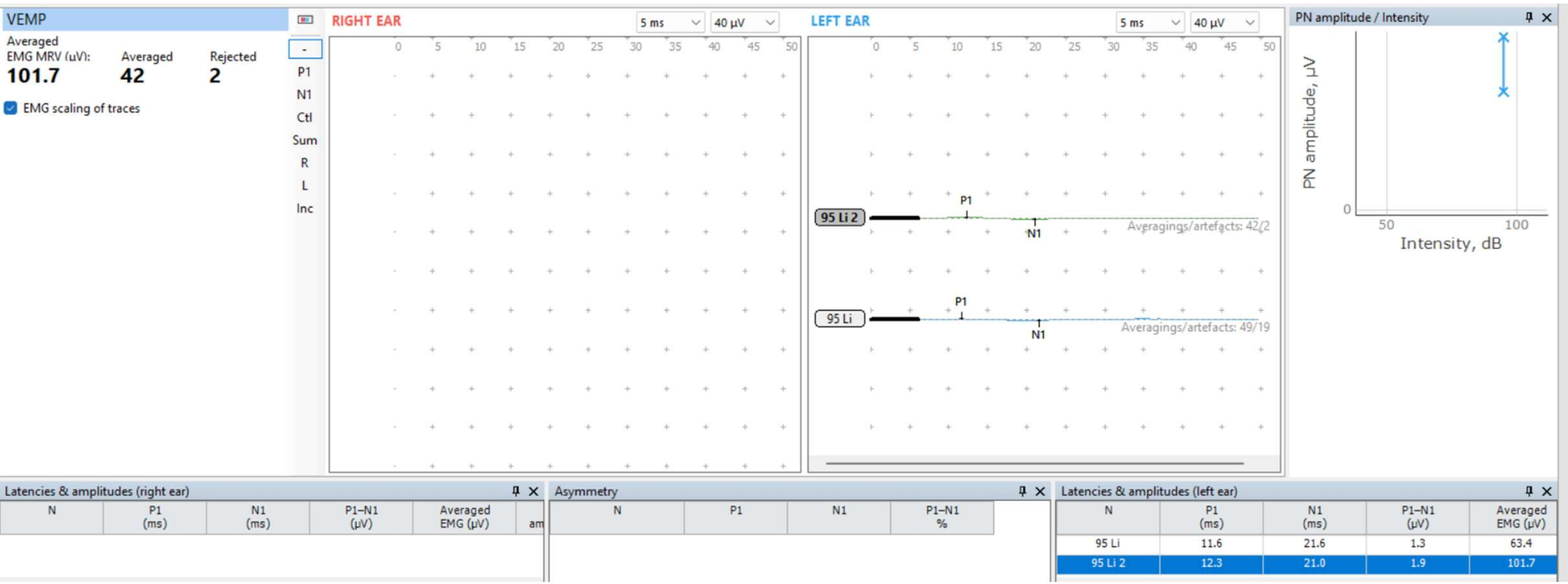
$$\text{Corrected Amplitude} = \frac{\text{Raw P13-N23 Amplitude}}{\text{Pre-Stimulus EMG RMS (Baseline Effort)}}$$

- Monitoring within a steady target window of 50-150 micro volts
- Can use the traffic light system in the machine or blood pressure cuff etc
- If EMG directly monitored- no need to normalise

Not scaled


VEMP
Averaged EMG MRV (uV):
101.7
Averaged
42
Rejected
2
EMG scaling of traces
Histogram of EMG amplitude
EMG (MRV), µV
Sweeps (sorted by EMG level)
Min MRV (µV):
30
Max MRV (µV):
500
Apply to all
Reset
RIGHT EAR
5 ms
40 µV
LEFT EAR
5 ms
40 µV
P1
N1
Ctl
Sum
R
L
Inc
95 Li 2
Averagings/artefacts: 42/2
95 Li
Averagings/artefacts: 48/19
PN amplitude / Intensity
PN amplitude, µV
Intensity, dB
Latencies & amplitudes (right ear)
N
P1 (ms)
N1 (ms)
P1–N1 (µV)
Averaged EMG (µV)
Asymmetry
P1–N1 %
Latencies & amplitudes (left ear)
95 Li 11.6 21.6 82.2 63.4
95 Li 2 12.3 21.0 192.3 101.7

Scaled


VEMP
Averaged
EMG MRV (µV):
101.7
Averaged
42
Rejected
2
EMG scaling of traces
-
P1
N1
Ctl
Sum
R
L
Inc
RIGHT EAR
5 ms
40 µV
LEFT EAR
5 ms
40 µV
0 5 10 15 20 25 30 35 40 45 50
95 Li 2
P1
N1
Averagings/artefacts: 42/2
95 Li
P1
N1
Averagings/artefacts: 49/19
PN amplitude / Intensity
PN amplitude, µV
0
50
100
Intensity, dB
Latencies & amplitudes (right ear)
N
P1 (ms)
N1 (ms)
P1–N1 (µV)
Averaged EMG (µV)
Asymmetry
N
P1
N1
P1–N1 %
Latencies & amplitudes (left ear)
N
P1 (ms)
N1 (ms)
P1–N1 (µV)
Averaged EMG (µV)
95 Li
11.6
21.6
1.3
63.4
95 Li 2
12.3
21.0
1.9
101.7

EMG and VEMP amp may not have linear relationship-particularly in disordered otolith organs

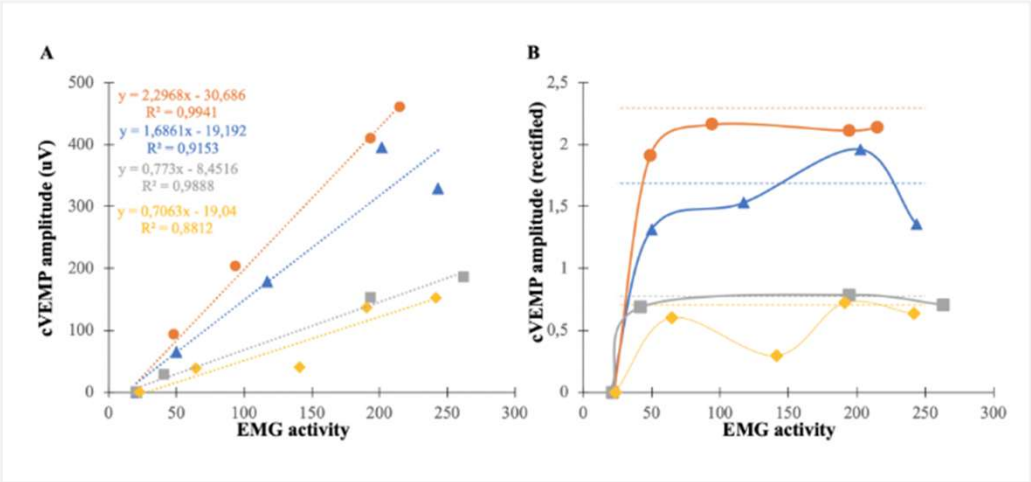


Figure 1. (A) Representation of the correlation between EMG activity and unrectified cVEMP amplitude. Dashed lines represent linear regression between EMG activity and unrectified cVEMP amplitude for each participant. Each participant is represented by a different color. (B) Normalized cVEMP amplitude (unrectified cVEMP amplitude/background EMG activity) with the different EMG activity levels. If rectified cVEMP amplitude is appropriate (linear correlation) each point should be close to the dashed line.

Normalisation? May be not enough data
However, one strong recommendation is to control for the level of EMG activation to reduce misinterpretation of asymmetry ratio and to ensure better test-retest variability.

Normative Values & Clinical Reference Ranges

cVEMP Reference Values

Parameter	Normal Range	Abnormal
p13 Latency	11–15 ms	>15 ms
n23 Latency	20–26 ms	>26 ms
p13-n23 Amplitude	50–370 µV*	<50 µV or absent
Asymmetry Ratio (AR)	<35%	>35%
Threshold (AC)	85–100 dB nHL	<75 dB nHL (↑) or absent
Interaural Latency Diff.	<2 ms	>2 ms

** Raw amplitude without EMG normalisation — always normalise in clinical practice*

oVEMP Reference Values

Parameter	Normal Range	Abnormal
n10 Latency	8–12 ms	>12 ms
p15 Latency	12–18 ms	>18 ms
n10-p15 Amplitude	5–15 µV	<3 µV or absent
Asymmetry Ratio (AR)	<35%	>35%
Threshold (AC)	90–105 dB nHL	Absent at max level
Recording Side	Contralateral	Ipsilateral = error

Norms

	Parameter	Mean	SD	Range	95% CI
cVEMP	p13	13.81	1.03	11.44–15.12	13.26–14.36
	n23	21.80	2.59	17.41–25.74	20.42–23.18
	ILD	8.03	2.19	4.27–11.87	6.86–9.19
	μV	53.34	44.05	11.44–178.09	29.86–76.81
	IAD	32.51%	24.62%	1.86%–68.52%	11.92%–53.09%
oVEMP	n10	8.47	1.35	6.79–10.75	7.68–9.25
	p16	12.31	2.37	9.81–17.41	10.94–13.68
	ILD	3.84	1.47	2.19–7.29	2.99–4.69
	μV	5.46	3.55	1.52–14.34	3.41–7.51
	IAD	32.03%	25.23%	0.00%–63.10%	8.70%–55.37%

Test Type	Metric	Combined Normative Range (5th – 95th)
C-VEMP	Amplitude (P1-N1)	45.68 – 93.04
	P1 Latency (ms)	11.32 – 23.00*
	N1 Latency (ms)	21.30 – 51.82*
O-VEMP	Amplitude (N1-P1)	13.12 – 18.58
	N1 Latency (ms)	0.92 – 11.10
	P1 Latency (ms)	13.20 – 15.00

Wackym PA, Ratigan JA, Birck JD, Johnson SH, Doornink J, Bottlang M, Gardiner SK, Black FO. Rapid cVEMP and oVEMP responses elicited by a novel head striker and recording device. Otol Neurotol. 2012 Oct;33(8):1392-400. doi: 10.1097/MAO.0b013e318268d234. PMID: 22935811. N=20 + 5 with confirmed SSCD

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Some references for the normative data

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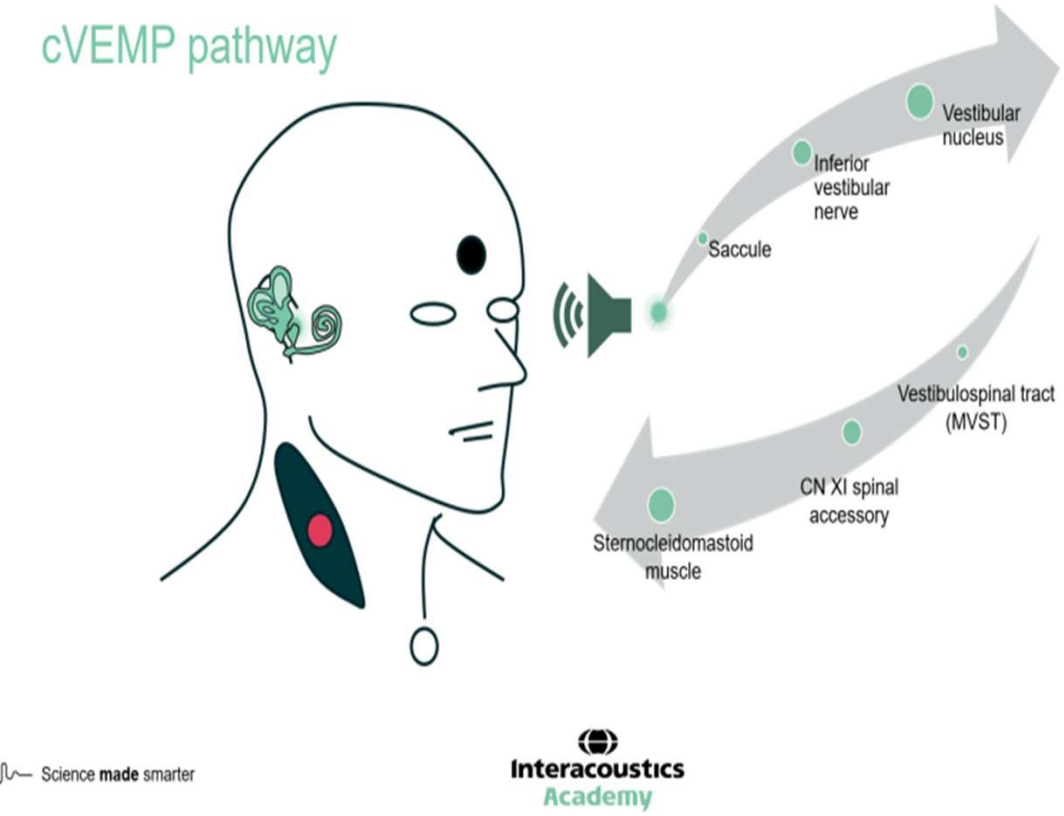
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Widely proposed neural pathway



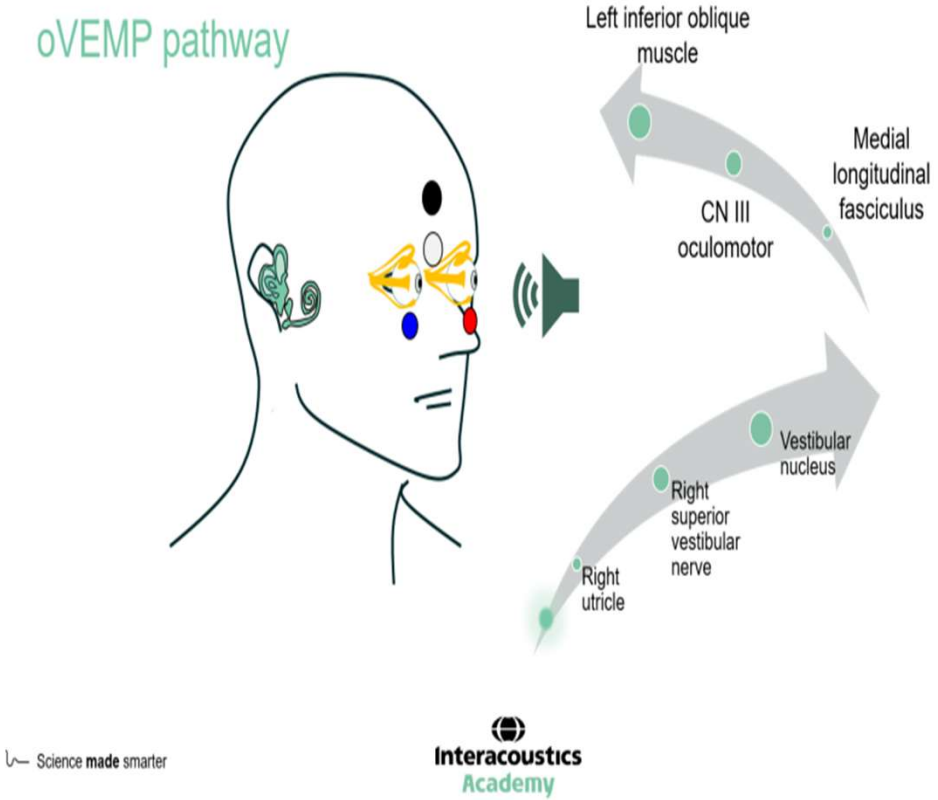
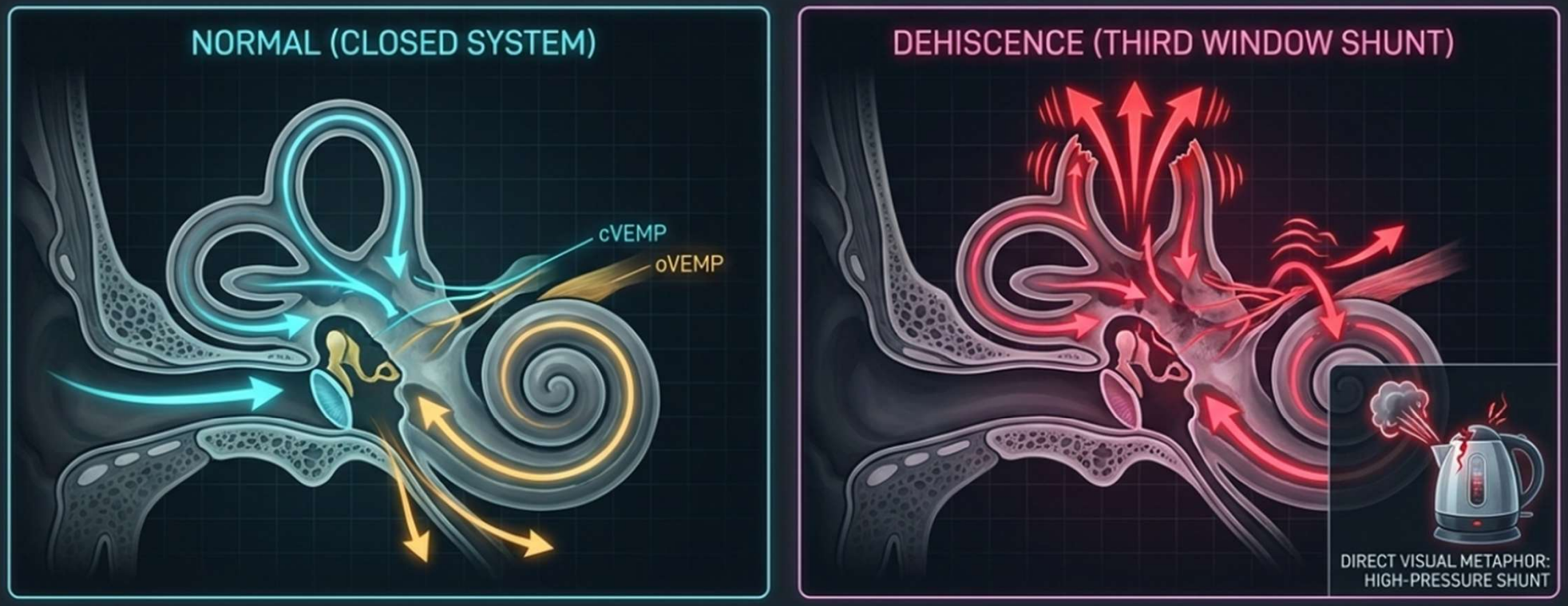


Image reference: https://www.interacoustics.com/academy/evoked-potentials/vemp/vestibular-evoked-myogenic-potentials

CLINICAL SIGNATURES: SUPERIOR CANAL DEHISCENCE (SCD)

A dehiscence creates a low-impedance third window in the bony labyrinth. Acoustic energy is shunted away from the cochlea (creating a pseudo-conductive hearing loss) and directly into the vestibular system, creating profound hyper-sensitivity.

THE THIRD WINDOW FLUID DYNAMICS MODEL



THE SCD ACOUSTIC PROFILE

SCD causes dramatic, **hyperactive** VEMP responses to Air-Conducted stimuli.

Audiol Res. 2022 Aug 24;12(5):457–465. doi: 10.3390/audiolres12050046

A Single Fast Test for Semicircular Canal Dehiscence—oVEMP n10 to 4000 Hz—Depends on Stimulus Rise Time

Ian S Curthoys [1,*], Ann M Burgess [1], Leonardo Manzari [2], Christopher J Pastras [3]

Editor: Dong-Hee Lee

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PMCID: PMC9498918 PMID: 36136853

Abstract

As previously reported, a single test measuring oVEMP n10 to 4000 Hz stimuli (bone-conducted vibration (BCV) or air-conducted sound (ACS)) provides a definitive diagnosis of semicircular canal dehiscence (SCD) in 22 CT-verified patients, with a sensitivity of 1.0 and specificity of 1.0. This single short screening test has great advantages of speed, minimizing testing time, and the exposure of patients to stimulation. However, a few studies of the 4000 Hz test for SCD have reported sensitivity and specificity values which are slightly less than reported previously. We hypothesized that the rise time of the stimulus is important for detecting the oVEMP n10 to 4000 Hz, similarly to what we had shown for 500 and 750 Hz BCV. We measured oVEMP n10 in 15 patients with CT-verified SCD in response to 4000 Hz ACS or BCV stimuli with rise times of 0, 1, and 2 ms. As a result, increasing the rise time of the stimulus reduced the oVEMP n10 amplitude. This outcome is expected from the physiological evidence of guinea pig primary vestibular afferents, which are activated by sound or vibration. Therefore, for clinical VEMP testing, short rise times are optimal (preferably 0 ms).

THE THRESHOLD MARKER:

cVEMP responses remain robustly present at abnormally low thresholds (often < 70-75 dB nHL). Normal ears yield no response at these levels.



THE AMPLITUDE MARKER:

oVEMP peak-to-peak amplitudes exceeding 17.1 µV yield 100% sensitivity and 98% specificity for SCD.

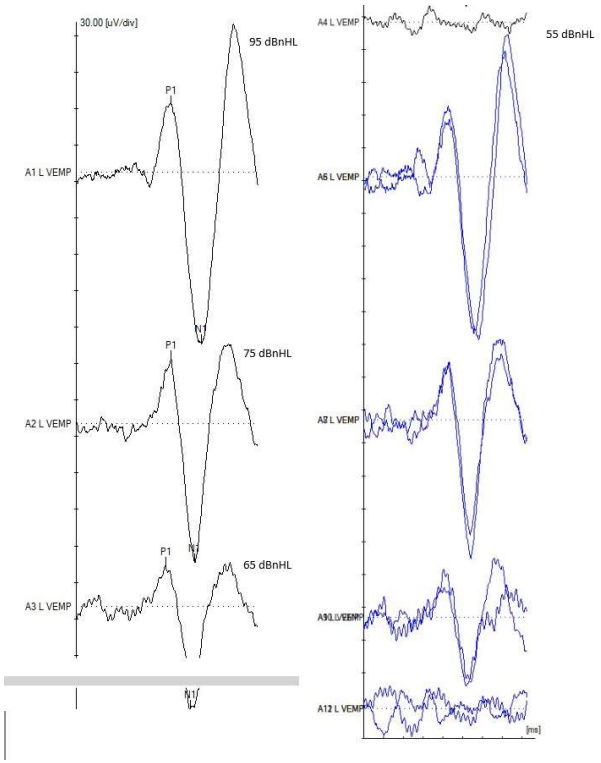


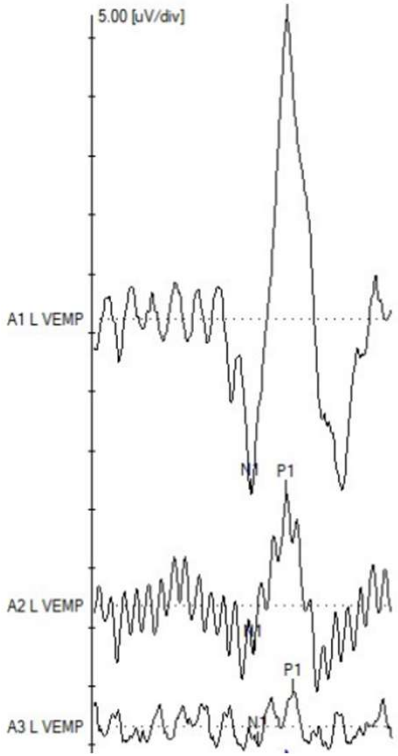
THE 4000 HZ PROTOCOL:

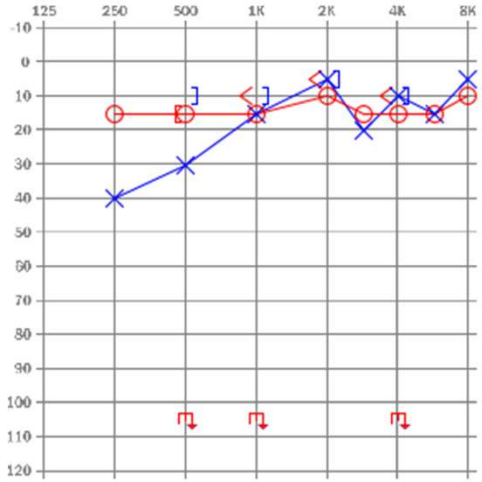
Sane ears do not generate oVEMPs to 4000 Hz tone-bursts. The presence of a 4000 Hz oVEMP is a highly specific, one-trial indicator of a third-window syndrome.



SSCD 47 yo female







› Neurology. 2008 Feb 5;70(6):464-72. doi: 10.1212/01.wnl.0000299084.76250.4a.

Vestibular-evoked myogenic potential thresholds normalize on plugging superior canal dehiscence

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Affiliations + expand

PMID: 18250291 DOI: 10.1212/01.wnl.0000299084.76250.4a

Abstract

Background: Diagnosis of the superior canal dehiscence syndrome (SCDS) relies on symptoms such as sound- or pressure-induced vertigo or oscillopsia, demonstration of sound or pressure-evoked vertical/torsional eye movements, and the presence of a defect in the bony roof overlying the superior semicircular canal. Lowered thresholds for eliciting vestibular-evoked myogenic potentials (VEMPs) provide additional conformation.

Objective: To examine VEMP characteristics before and after canal plugging for SCDS.

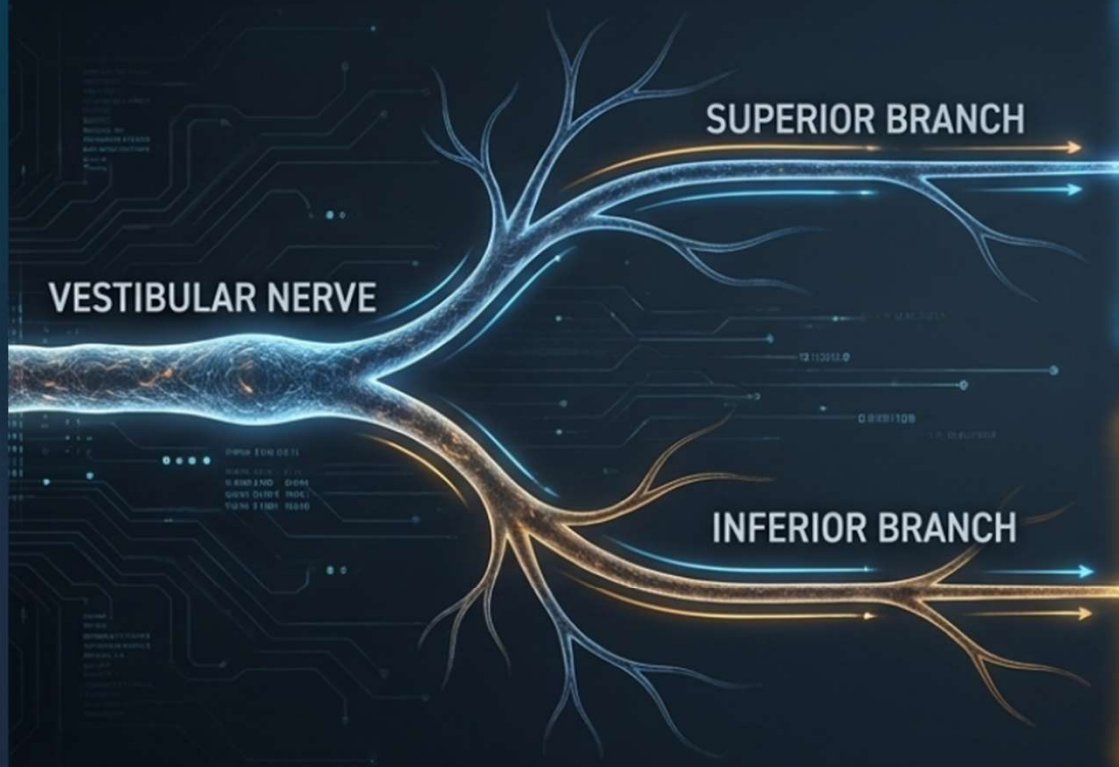
Methods: VEMPs evoked by air- and bone-conducted tones were measured from the sternocleidomastoid muscles (cVEMP) and periocular sites (oVEMP) of 20 normal volunteers, 10 newly diagnosed subjects with SCDS, and 12 subjects who underwent successful superior canal plugging.

Results: In all SCDS ears, thresholds for evoking VEMP using air-conducted tones were pathologically lowered, with average values of 83.85 +/- 1.40 dB sound pressure level (SPL) for cVEMP and 85.38 +/- 1.32 dB SPL for oVEMP, 20 to 30 dB below those of controls. Successful canal plugging resulted in normal reflex thresholds. For bone vibration, average thresholds in SCDS ears were 114.62 +/- 1.54 dB FL (force level) for cVEMP and 116.0 +/- 1.52 dB FL for oVEMP, 10 to 20 dB below controls, yet three SCDS ears had normal thresholds.

Conclusions: Ocular and cervical vestibular-evoked myogenic potentials evoked by air-conducted sound are equally useful in the diagnosis and follow-up of superior canal dehiscence syndrome. Stimulus thresholds are consistently lowered upon presentation and normalize after corrective surgery. Thresholds for bone vibration, in contrast, have a lower diagnostic yield.

CLINICAL SIGNATURES: VESTIBULAR NEURITIS

Neuritis rarely affects the entire system equally. VEMP allows us to execute precise topological pinpointing of the viral damage.



SUPERIOR VESTIBULAR NEURITIS (Most Common)

Signature:

✗ Absent oVEMP | ✓ Normal cVEMP

Corroboration:
Abnormal anterior/lateral vHIT; abnormal Calorics

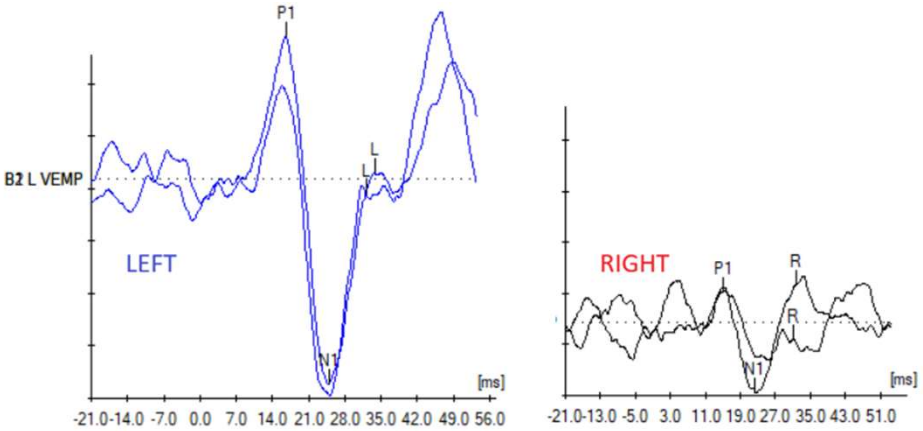
INFERIOR VESTIBULAR NEURITIS (Rare)

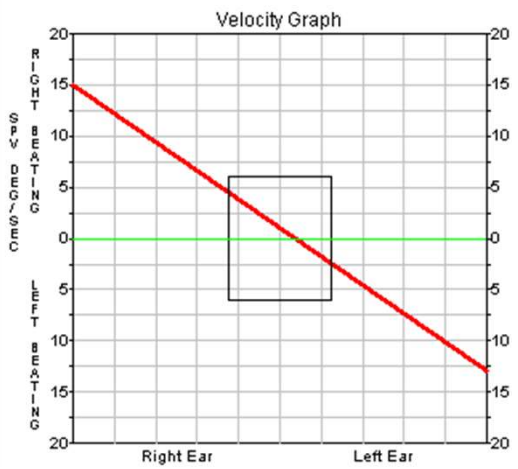
Signature:

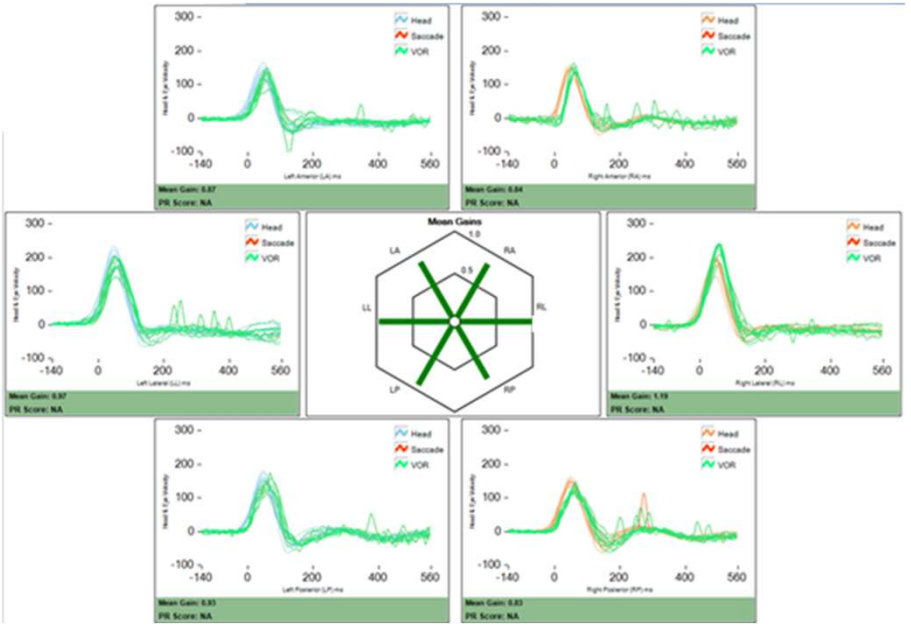
✗ Absent cVEMP | ✓ Normal oVEMP

Corroboration:
Abnormal posterior vHIT; normal Calorics

Right inferior vestibular neuronitis







Vestibular Rehabilitation

1. **Vertical motion habituation**
2. **Balance training**
3. **Head/body control- VCR related work**
4. **Dynamic gait with vertical challenge**



CLINICAL SIGNATURES: **MENIERE'S DISEASE**

VEMP responses alter dynamically based on the stage of endolymphatic hydrops.

EARLY STAGE

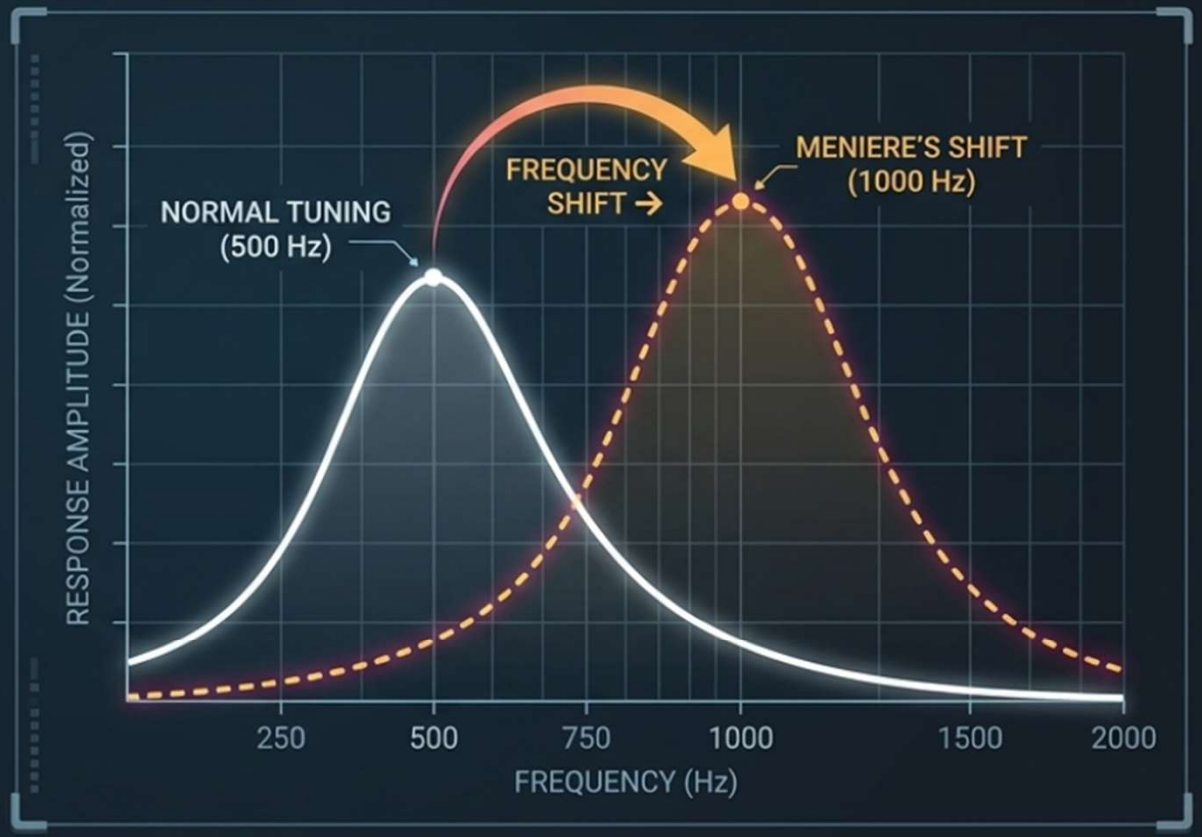
VEMPs may be augmented due to increased saccular sensitivity from hydrops pressure.

LATE STAGE

VEMPs become decreased or absent due to macular atrophy.

THE FREQUENCY SHIFT

Healthy otoliths are tuned to **500 Hz**. In MD, altered mechanical dynamics within the saccule frequently **shift the optimal tuning frequency to 1000 Hz**. A larger response at 1000 Hz vs 500 Hz is a strong indicator of MD.



Comparing the cVEMP 1,000 and 500 Hz amplitude ratio in ears with MD and non-MD vertigo, and in active versus stable MD.

Sensitivity, Specificity, and Positive Predictive Value of Diagnostic Tests in Differentiating Active Versus Stable Meniere's Disease.

	Caloric Paresis >30%	ECOG SP/AP >45%	Absent or >47% Reduced cVEMP at 500 Hz	1,000/500 Hz ratio >1.04
Sensitivity (95% CI)	41.9% (24.5–60.9)	65.22% (42.73–83.6)	74.2% (55.4–88.1)	67.8% (57.7–88.9)
Specificity (95% CI)	50% (24.6–75.3)	33.33% (15.6–55.3)	50 (24.6–75.4)	81.2% (35.4–84.1)
Positive predictive value (95% CI)	61.9% (46.1–75.5)	48.4% (34–64)	74.2 (62.8–83.1)	87.5% (68.3–88.9)

Open in a new tab

AP = action potential; cVEMP = cervical vestibular-evoked myogenic potentials by tone-bursts using 500 and 1,000 Hz stimuli; ECOG = electrocochleography; SP = summating potential.

Angeli SI, Goncalves S. Cervical VEMP tuning changes by Meniere's disease stages. Laryngoscope Investig Otolaryngol. 2019 Sep 18;4(5):543-549. doi: 10.1002/lio2.309. PMID: 31637299; PMCID: PMC6793602.

N= 47 MD patients and 30 control

VEMP Interpretation Framework

A structured approach to interpreting VEMP results in clinical context

Normal Bilateral VEMPs

Both cVEMP and oVEMP present, symmetric, normal latency and amplitude. Rules out significant otolith end-organ pathology.

Absent cVEMP (Ipsilateral)

Saccular dysfunction or inferior vestibular nerve lesion. Check: Menière's (late), inferior VN, cochlear hydrops.

Absent oVEMP (Ipsilateral)

Utricular/superior vestibular nerve lesion. Check: superior VN, utricular damage, early Menière's.

Enhanced cVEMP + Low Threshold

Third mobile window physiology. High suspicion for SSCD — correlate with CT temporal bone. Also possible in early Menière's.

High Asymmetry Ratio (>35%)

Significant interaural amplitude asymmetry. Side of lower amplitude suggests dysfunction. AR alone has moderate specificity.

Absent Bilateral VEMPs

Bilateral otolith dysfunction, bilateral end-organ loss, or technical failure. Verify EMG effort. Consider bilateral Menière's.

THE VESTIBULAR FINGERPRINT DASHBOARD

How isolated data points combine to form undeniable diagnoses.

DISEASE	vHIT	cVEMP	oVEMP	CORROBORATION
Superior Canal Dehiscence	✓ Normal	↑↑ Hyperactive (Up)	↑↑ Hyperactive (Up)	+ Air-Bone Gap
Superior Neuritis	Abn. Lateral	✓ Normal	✗ Absent (X)	
Inferior Neuritis	Abn. Posterior	✗ Absent (X)	✓ Normal	
Advanced Meniere's	✓ Normal	✗ Absent (X)	✗ Absent (X)	+ Low-freq SNHL
Bilateral Vestibulopathy	Abn. All	✗ Absent (X)	✗ Absent (X)	

Integrating VEMPs Into Everyday Clinical Practice

1 Referral & Triage

Screen referrals: dizziness + Tullio's, aural fullness, positional symptoms → prioritise VEMP

2 Protocol Selection

Select AC vs BC based on conductive status. Choose cVEMP for saccular pathway, oVEMP for utricular pathway

3 Electrode Setup & EMG

SCM electrodes (cVEMP) or infraorbital (oVEMP). Confirm EMG target 50–100 µV before stimulation

⏱ **Typical VEMP battery time: 15–20 minutes (bilateral cVEMP + oVEMP) — can be bundled with vHIT in a 60-minute comprehensive vestibular appointment.**

Common Pitfalls & Troubleshooting

⚡ Poor EMG Effort

Problem:

Inadequate SCM contraction → falsely absent or small cVEMP

Fix:

Biofeedback screen, head rotation toward contralateral shoulder, verbal coaching

📍 Electrode Placement Error

Problem:

Electrodes not on SCM belly or infraorbital rim → attenuated responses

Fix:

Palpate SCM during contraction; place oVEMP electrode 1cm below lid margin

🔊 Middle Ear Pathology

Problem:

Conductive hearing loss attenuates AC cVEMP threshold and amplitude

Fix:

Switch to bone conduction (BC) stimulation; document tympanogram

👁 Gaze Angle (oVEMP)

Problem:

Insufficient upward gaze reduces inferior oblique recruitment → poor oVEMP

Fix:

Instruct 30–35° upward gaze; use fixation target at correct elevation

📶 Noise & Artefact

Problem:

High background noise from clothing, movement, or mains interference

Fix:

Remove jewellery/clothes near electrodes; use shielded cables; 60 Hz notch filter OFF

🔄 Asymmetry Misinterpretation

Problem:

AR >35% attributed to pathology when due to effort asymmetry

Fix:

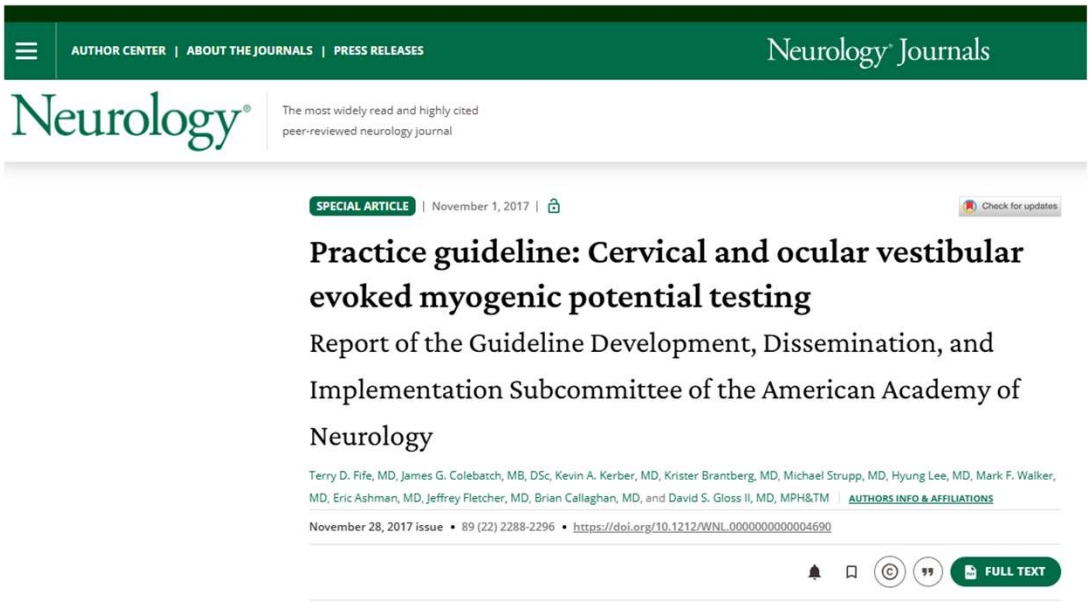
Always normalise amplitude to EMG level; ensure equal contraction bilaterally

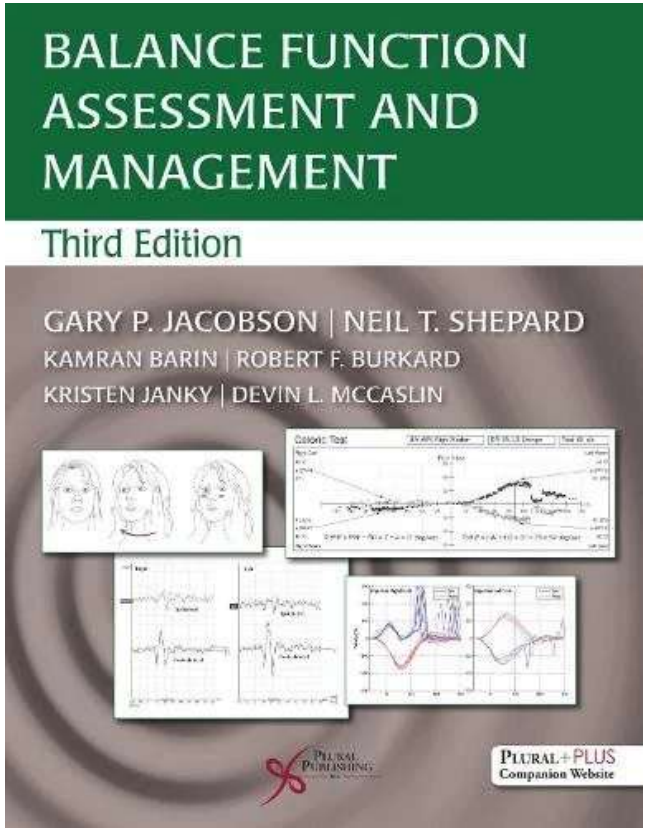
Key Takeaways

What to implement in your vestibular clinic starting tomorrow

01	cVEMP tests the saccule via the inferior vestibular nerve — preserved in superior VN, absent in inferior VN.
02	oVEMP tests the utricle via the superior vestibular nerve — absent in superior VN, preserved in inferior VN.
03	VEMPs fill the otolith gap — vHIT and caloric testing miss saccular and utricular function entirely.
04	SSCD produces enhanced cVEMP amplitude and lowered threshold (≤75 dB nHL) — a near-pathognomonic pattern.
05	Menière's disease progresses from enhanced → absent cVEMP — serial testing tracks disease stage.
06	Always normalise cVEMP amplitude to EMG level and use asymmetry ratio (>35% = significant) for clinical decisions.
07	A complete VEMP battery takes 15–20 minutes — integrate bilaterally with your existing vHIT workflow.

Self reading and cross references





Thank you

Extra: https://canadianaudiologist.ca/striking-the-right-balance-feature-07-03/

By Brahim Kaci Mujda Nooristani, MPA Maxime Maheu, PhD

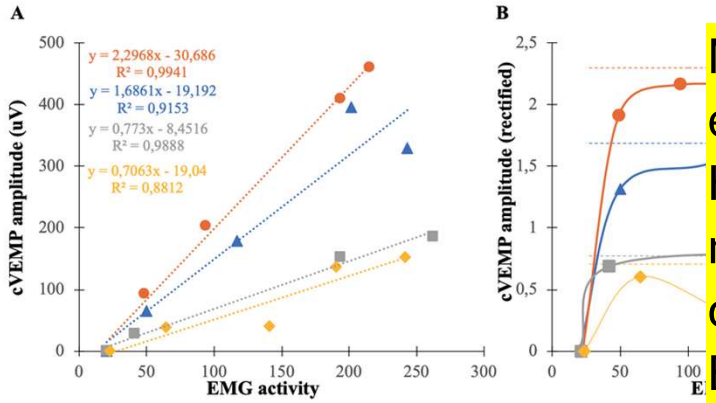


Figure 1. (A) Representation of the correlation between EMG activity and un
Dashed lines represent linear regression between EMG activity and unrectif
each participant. Each participant is represented by a different color. (B) No
(unrectified cVEMP amplitude/background EMG activity) with the different
rectified cVEMP amplitude is appropriate (linear correlation) each point sho
line.

Normalisation? Not enough data

However, one strong recommendation is to control for the level of EMG activation to reduce misinterpretation of asymmetry ratio and to ensure better test-retest variability.

Normalisation pre-supposes that a linear relationship exists between contraction and response. But that may not be as clean as that

- Therefore, the relationship between EMG activity and cVEMP amplitude could lead to an increase in the variability of the results and could potentially mislead the interpretation of the results. For example, it is known that a significant asymmetry in contraction level can produce a clinically significant amplitude asymmetry in normal healthy participants. To overcome this problem two options are available: (1) EMG contraction monitoring or (2) normalization.
- EMG contraction level monitoring aims at recording cVEMP response when EMG reaches a given pre-determined contraction level. EMG monitoring can be done using a simple blood pressure cuff or using an EMG monitor associated with visual feedback usually built-in in your VEMP equipment. The blood pressure cuff requires the individual to be tested to push their chin against the cuff to reach a certain level of pressure and maintain this contraction for the entire recording. On the other hand, an EMG monitor associated with a visual feedback system allows the individual to adjust the contraction level to be within a given range of EMG activity in real-time, during the recording. Usually, VEMP systems with EMG monitoring can be set up to reject responses that are not within the chosen EMG range.

- A second possibility is to normalize the cVEMP amplitude using pre-stimulus EMG activity. This method uses an algorithm that allows normalizing the cVEMP response by dividing its amplitude by the pre-stimulus EMG activity. This function averages the absolute value of the pre-stimulus EMG (20 ms before stimulus onset) and divides each one of the data points (response amplitude) by this value. This method of normalization is based on the fact that a linear relationship exists between the EMG contraction level and the cVEMP amplitude response,[4] which can be described by: y= ax+b (where y: cVEMP amplitude; a: slope of the regression; b: constant). The concept of linearity between EMG activity and cVEMP amplitude is crucial for normalization. However, cVEMP linearity remains a matter of debate in normal healthy individuals as some authors suggest a linear relationship[5–7] while others suggest a non-linear relationship at lower and higher EMG level.[8–10] To better demonstrate this concept, we replicated the graph found in Rosengren et al.[10] using preliminary data acquired by our group in normal healthy participants **(Figure 1)**. Panel A, on the left, demonstrates the correlation between EMG level measured before stimulation and the evoked (non-rectified) cVEMP amplitude. Panel B, on the right, shows the correlation between amplitude ratio (non-rectified amplitude/ EMG activity before stimulation) and EMG level. Panel A also shows the formulae that estimate the linear correlation between these variables for each participant. These results are similar to those reported by Rosengren et al. (2015),[10] where the constant (b) is always negative, indicating a possible overestimation of EMG activity. This would be a result of the surface electrode capturing EMG activity not only from SCM but other surrounding muscles. This seems to underestimate the cVEMP amplitude for lower contraction levels, as demonstrated in panel B - data points with lower contraction levels are under the dashed line. The graph shows that for some individuals the amplitude ratio is a good estimator of the slope (dashed line) across most EMG contraction levels. For these individuals, therefore, normalization would be appropriate. On the other hand, the amplitude ratio was not a good estimate of the slope in two other participants (blue and yellow). Finally, panel B demonstrates that at the highest level of EMG contraction, the amplitude ratio decreased for most participants suggesting a saturation effect. This saturation effect may potentially explain the results of a study conducted by our group investigating the test-retest reliability of cVEMP amplitude in normal healthy participants.[11] We compared VEMPs obtained in normal healthy participants at two different sessions. We concluded that to minimize test-retest variability it was best to monitor EMG activity and to normalize the amplitude. This allows keeping EMG activity within an acceptable range, increasing the chances to have a linear relationship and making the normalization process more efficient.