

Critical reevaluation of methods of recording and assessing c-VEMPS

Abstract

The cervical Vestibular Evoked Myogenic Potential (c-VEMP) investigates otolith and vestibular nerve function. Dysfunction is characterized by feeling similar to being on a boat or an elevator. It may be a spinning sensation when people say that they are dizzy. The c-VEMP is a short-latency electromyographic (EMG) potential and it is evoked in response to high-level acoustic stimuli. The responses are mediated by the vestibular system. Clinical applications go beyond dizziness. Defining normative data is a first and crucial step to before implementing a new technique in the clinic for applications in patients.

Keywords: vestibular, dizziness, diagnosis, potential

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Introduction

The cervical Vestibular Evoked Myogenic Potential (c-VEMP) is generally assumed to provide information about a different part of the vestibular system compared to the more routinely applied rotation, head impulse and caloric tests and can provide valuable additional diagnostic information.¹ Defining normative data is a first and crucial step to before implementing a new technique in the clinic for applications in patients.

In most papers different protocols were used in those days describing various stimulation types (tone burst, clicks etc), stimulus intensities and frequencies, head and body positions, electrode positions, data-acquisition and signal processing, and output parameters like latencies, threshold and amplitude and symmetry of the responses.

In the following discussion it is presented in details the optimal protocol to apply in this test, according current literature.

Stimulation type

Various types of stimuli have been used to evoke c-VEMP responses. They include air and bone-conducted tone bursts, air-conducted clicks, forehead taps, and galvanic stimulation (short-duration transmastoid direct current stimulation).²⁻⁵

A click stimulus is a block function containing a wide spectrum of frequencies. A short tone burst (STB) stimulus can be described as a short pure tone, predominantly containing one specific stimulus frequency. Clicks and STB are conducted through the middle ear and are still believed to activate - among others - saccular hair cells via movement of the endolymph near the oval window by the stapes. Bone conducted stimuli produce a wave of vibration that bypasses the middle ear and directly activate the vestibular apparatus on both sides simultaneously. Galvanic stimulation is assumed to act upon the distal part of the primary vestibular afferents. Fore head taps are shown also to be effective in eliciting c-VEMP's. However, like bone-conducted stimulation, galvanic stimulation and fore head taps, induce worse signal to noise ration as compared to air-conducted sound stimulation. Bone conduction stimulation is limited as the current available stimulators and provide still limited and often sub-threshold stimuli intensities, between 60-70 dBnHL.^{6,7}

STB evoked C-VEMPs and click-evoked responses can be induced with good signal to noise ration, but STB require lower absolute

stimulus intensities.^{8,9} Based on these findings we choose for the STB type as a relatively easy and effective stimulus in the routine clinical application for C-VEMP's and this is still the case at current in most clinics worldwide.

Stimulus intensity and frequency

The c-VEMP can be induced in animals by tone burst stimuli ranging from 100 to 3200 Hz with a greater sensitiveness towards the lower frequencies.¹⁰⁻¹² The low frequency sensitivity in humans is even more pronounced maybe due to the larger otoconia mass in the human sacculus, compared to that in smaller animals such as a cat.^{10,13}

Remarkably, in our hands, the responses we obtained with 1000 Hz toneburst were more clear than with 500 Hz tone burst. As it is not in line with the literature this could at least partly be due to the limitations of our equipment used those days.

At lower amplitudes and at 500 Hz we observed no clear and reproducible responses in quite a number of healthy subjects. At current specific equipment have been developed for c-VEMP which provide even a response with a better signal to noise ratio even when using much less intense stimulus amplitudes of 95 dBnHL at various frequencies. The advantage of these lower amplitudes is a better comfort for patients; less fatigue while still good responses can be obtained. It is applied as an advice - in line with the current opinion and in case of using c-VEMP amplitudes as output parameters - the use of 95 dBnHL tonebursts at 500 Hz for routine application.

Head and body positions

A constant muscular tension is a prerequisite to a reliable recording of c-VEMP. If the muscle is not contracted sufficiently, the c-VEMP responses may be absent.⁸ The response can be measured on several neck muscles, also. So both electrode position and contraction state of the muscle are crucial. Colebath et al.,¹⁵ described a valid method recording response from the sternocleidomastoid (SCM) muscle and proposed this as optimal.

The many different methods of SCM activation make it difficult to compare findings across studies and thus to determine the optimal VEMP test protocol. The various methods used to obtain a tonic contraction of the SCM muscle throughout C-VEMP recording include: 1) lifting the head off the support surface to bilaterally activate the SCM muscles while in supine position (supine elevation method),¹⁶ 2) pressing the fore head against a padded bar,^{17,18} pushing

with their jaw against the hand-held inflated cuff to generate specific cuff pressures,¹⁹ pressing the chin against an adjustable stand,²⁰ or squeezing a rubber ball placed between the chin and the manubrium,²¹ to bilaterally activate the SCM muscles while in the sitting position (sitting forward flexion method), 3) rotating the head to the side opposite the stimulated ear to unilaterally activate the SCM on the side of the test ear while sitting,^{22–24} (sitting rotation method) or supine,²⁵ (supine rotation method) positions, and 4) simultaneously lifting and rotating the head to the side opposite the stimulated ear to unilaterally activate the SCM on the side of the test ear while in the supine position,²⁶ (supine elevation rotation method). Few studies have compared different methods of SCM activation to determine those positions that yield the most robust and reliable VEMP responses.^{25–27}

When the c-VEMP data were collected in our studies, the patient was seated with the head turned in the opposite direction of the neck muscle contraction to be induced and the stimulated labyrinth. At that time, it was not completely clear how latencies and amplitudes were affected by different head and body positions.

Nowadays, conclude based in the current literature that head and body position significantly affected the amplitude of the VEMP, but had no significant effect on latency. Although there is still no consensus all over the world regarding the optimal head-body position, there is a tendency in favor of using the supine position with the head in flexion without rotation but with visual feedback to control muscle contraction for routine application.

Electrode position

Electrode position is another variable in recording the c-VEMP. Sheykhleslami et al.,¹¹ sought to determine the optimal electrode sites. The optimal ground electrode was considered to be at the forehead, and the reference (indifferent) electrode was positioned on the sternum.¹⁰ Like indicated in the introduction of this thesis, results from the Sheykhleslami study suggested that the active electrode placed on either the upper or middle portion of the SCM produced the clearest waveforms with largest amplitudes. This electrode configuration became more or less the standard.^{24,28,29}

Electromyography (EMG) level

C-VEMP can be considered as a modulation of an existing tonic neck muscle contraction. The c-VEMP amplitude was shown and is known to increase with tonic muscle contraction.³⁰ So, it is necessary to define the contraction state of the neck muscle to standardize the method and to overcome the large variation in c-VEMP amplitudes when muscle contraction is not kept constant during the measurements. To achieve a constant EMG level and thus comparable physiological conditions, a manual or automatic feedback mechanism is needed. Several devices monitor the tonic muscle activity itself and visualize the level of activation, including visual feedback of tonic EMG displayed via a LED array,³¹ or small monitor,⁸ auditory feedback,³² or visualize head pressure by pushing the jaw against a blood pressure manometer with inflatable cuff.^{19,33}

The set points of the directly monitored tonic EMG levels used as a feedback to maintain the SCM muscle activation within specific levels, varied among researchers: 30–50 μV ,⁸ 40–150 μV ,³⁴ and 50–200 μV .³⁵

It is recommended visual feedback to control tonic EMG activity as a routine technique to optimize c-VEMP amplitude and reproducibility.

Out parameters

Latency

Among others c-VEMP latencies vary with stimulus type (e.g. sound, galvanic, taps), amplitude, frequency, shape, duration and age. But as not all independent parameters are fully recognized and understood, and also identification of the peak on-set is done manually and arbitrary, it is best to establish the normal range of the latencies at each institution.

A significant delay of peak latencies P13 and N23 is considered pathological. The peak latencies P13 show a better reproducibility than that of N23.

We advise to acquire adequate normative data of C-VEMP before using it as a diagnostic tool.

Amplitude

As not all independent parameters are fully recognized and understood, and because the identification of the peaks is done manually and arbitrary, it is best to establish the normal range of peak amplitudes or thresholds at each institution separately and not rely too much upon the data provided by the manufactory.

The c-VEMP response occurs as a stimulus synchronized reduction in tonic EMG activity. As the sacculo-collic reflex is inhibitory to the SCM contraction, c-VEmps are therefore only detectable when the muscle is indeed contracted. The c-VEmps amplitude therefore increases when the force exerted increase by recruitment of more motor units. C-VEMP amplitude also increases with a longer stimulus duration leading to a more prolonged and intense period of inhibition. The effect of both parameters would be an increase in the likelihood of a given motor unit being affected by the stimulus and thus a larger number of units to respond to each stimulus, evoking a larger response.³⁵ Indeed, c-VEMP amplitude depends on the level of both the tonic SCM muscle activation and the stimulus intensity.^{21,26}

The absolute c-VEMP amplitudes show a high inter-subject variability. Ochi et al.,⁴¹ concluded that the SD of the C-VEMP amplitude was too large to be used in clinical evaluation, even when the amplitude was normalized with the absolute EMG values.³⁷ Therefore c-VEMP amplitudes are in principle less appropriate for use in clinical practice.^{8,37}

Nevertheless, many people used and still use the peak amplitudes because the total test duration is then shorter as compared to a threshold measurement. Some investigations show that amplitude asymmetries between the right and left ear stimulation could provide useful information in diagnosing audio vestibular and neurological disorders as well as in determine the likely side of pathology.³⁸ The upper limit of the c-VEMP asymmetry ratio varies from 20% – 36% in the literature.^{24,27,36,37}

Thresholds

The lowest stimulus intensity needed to evoke a c-VEMP response is called the threshold. They are all based on the fact that c-VEMP amplitudes increase with increasing stimulus intensity. The fundamental problem here is how to distinguish a small response from the background noise, which again is an arbitrary manual process.

VEMP thresholds in healthy subjects have been reported to range between 100–115 dBnHL,⁹ and 75–105 dBnHL,³⁹ in response to click

stimuli. For tone burst stimuli the thresholds ranges from 85–100 dBnHL at 1000 Hz (40) and from 60–75 dBnHL at 250 Hz.⁴¹

Although identifying c-VEMP thresholds seem to be a useful clinical approach for identifying peripheral vestibular diseases^{42,43} no literature was available to our knowledge at the start of our study in 2004 for normative data regarding application of the VEMP methodology for central diseases.

This application of threshold detection to quantify the VEMP responses is applied more widely, showing consistent and reproducible amplitudes and latencies. It is recommend the evaluation of VEMP thresholds and not VEMP amplitudes in investigations with central diseases.

Conclusion

More consensus have been obtained regarding the precise stimulus and peak detection protocols for c-VEMP application in Otoneurology.

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Conflicts of interest

The author declares there are no conflicts of interest.

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