CERVICAL VESTIBULAR EVOKED MYOGENIC POTENTIALS: A REVIEW

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Abstract

Vestibular evoked myogenic potential is a recent tool to assess the sacullocollic pathway. The sacullocollic pathway includes the saccule, the vestibular nuclei and the medial vestibulo spinal tract. In the literature the studies done on vestibular evoked myogenic potentials have used different recording protocols. Various databases such as Medline, Pubmed, Google and Google scholar were searched for the references related to the vestibular evoked myogenic potentials. The different recording procedures from the literature have been summarized in the present article.

Key Words*: Vestibular evoked myogenic potentials, Click, Tone burst, Muscle tension*

Vestibular evoked myogenic potentials (VEMPs) were first described by Bickford, Jacobson, and Cody (1964), and have been suggested as a trustworthy clinical test to evaluate the functioning of saccular or inferior vestibular nerve (Cloebatch, 2001). VEMPs are electromyogram (EMG) with short latency and are evoked by higher-level acoustic stimuli. .Surface electrodes placed over the tonically contracted sternocleidomastiod (SCM) muscle elicit VEMPs. According to the neurophysiological and clinical data, VEMP pathway includes the saccular macula, inferior vestibular nerve, the medial vestibular nucleus, the medial vestibulospinal tract, and the motorneurons of the ipsilateral SCM muscle (Halmagyi & Curthoys, 2000).

Short latency responses to auditory clicks at the inion recorded by Geisler, Frishkopf, and Rosenblith (1958) recorded were initially considered to be cortical in origin. Later, Bickford, Jacobson, and Cody (1964) described the characteristics of these responses and ascertained their vestibular origin. Cody and Bickford (1969), and Townsend and Cody (1971) provided further evidence suggesting the mediation of these responses from the vestibular end organ, specifically the saccule.

In 1994, Colebatch, Halmagyi, and Skuse established a reliable procedure to record the myogenic potentials evoked by the clicks. These authors modified the previous recording procedures by incorporating the placement of surface electrodes on the sternocleidomastoid (SCM) muscles. Normal VEMP responses are characterized by biphasic (positive – negative) waves. In a majority of studies, labelling of the peaks and troughs is done with the lower case letters ‘ p’ (for positive) or ‘ n ‘ (for negative) followed by the mean latency in milliseconds (Yoshie and Okodaira, 1969). This is done to distinguish them from neurally generated evoked potentials. The first positive- negative complex is often labeled as p13-n23. A second wave complex (n34-p44) has also been reported to be present in 68% of the participants (Robertson and Ireland, 1995). Figure -1 shows the waveform obtained for the Vestibular evoked myogenic potentials from a normal hearing individual.

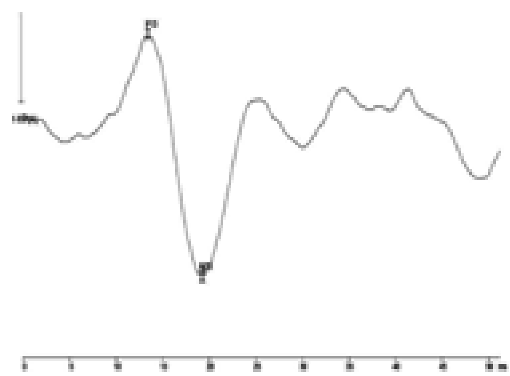

Figure-1: *Typical waveform obtained for Vestibular evoked myogenic potentials*

VEMPs Analysis Strategies**:** Record optimal response from each side. Calculate P1 latency, N1 latency and P1 —N1 amplitude. Compare the normative data to that of the patient data. It is very important to calculate inter aural amplitude of P1-N1 complex. The calculation of interaural amplitude is an important parameter in unilateral vestibular lesions. The interaural amplitude parameter is calculated as:

- Amplitude Ratio (%) = (AL-AR)/ (AL+AR) X 100, where L= left ear, R= right ear

The amplitude ratio is considered to be normal if it is less than 0.35, and if greater than 0.35, it is considered to be abnormal.

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Need for the present review: In the literature, there are few review articles on VEMP (Ferber-Viart, Dubreuil, & Duclaux, 1999; Welgampola & Colebatch, 2005; Rausch, 2006; Honaler & Samy, 2007; Renato & Fayez, 2009; Mudduwa, Kara, Whelan & Banerjee, 2010; Eleftheriadou & Koudounarakis, 2010) none of which explain the method of recording procedure, stimulus variability, and stimulus parameters in greater detail. An attempt is to review these articles on the method of recording procedure and other stimulus parameters in greater detail for the benefit of the readers.

ROADMAP of the review:
Recording protocol:
Methods of recording
Type of stimuli
Intensity
Monaural and binaural stimulation
Stimulus polarity
Presentation rate
Transducer

1. **Methods of recording Vestibular Evoked Myogenic Potentials:** There are four methods by which the vestibular evoked myogenic potentials are recorded:
a. Air Conducted VEMP
b. Bone Conducted VEMP
c. Skull Taps
d. Galvanic Stimulus

1. a. Air conducted *VEMP:* Intense clicks of about 95 to 100 dB nHL are required to evoke VEMPs and are at the limit of what is considered generally well tolerated, However, an uncomfortable level should be elicited from the client before undergoing this test.. Stimuli of 95 db NHL and 0.1-millisecond duration are used in routine clinical tests performed.

1. b. Bone conduction VEMP: Bone-conducted tones bypass the middle ear conductive apparatus and can evoke VEMPs inspite of conductive hearing loss.

1. c. Skull Taps: A forehead tap, delivered at Fpz (International 10–20 System) via a tendon hammer, evokes a vestibular dependent short-latency p1n1 response in both sternocleido mastoid muscles. The technique is operator dependent and does not deliver a calibrated stimulus. VEMp elicited by the skull taps are generally 1.5 to 3 times larger compared to the air conducted VEMP elicited through head phones or insert ear phones.

1. d. Galvanic VEMP: A short-duration (2-millisecond) pulsed current delivered via electrodes attached to the mastoid processes evokes a p13n23 response on the side ipsilateral to cathodal stimulation similar to that evoked by sound. Galvanic VEMP is a retro labyrinthine response, which actually bypasses the peripheral structures and it stimulates the vestibular nerves directly. A combination of galvanic and air conducted VEMP can indicate whether the lesion is in the peripheral structure or in the vestibular nerve.

2. **Stimulus type:** Clicks, short duration tone bursts and logons have been used as stimulus both monaurally and binaurally to obtain VEMP recordings.

A. **Clicks:** The different parameters for click stimuli that have been investigated are as follows:
- Duration
- Repetition rate

Duration of click stimuli*:* Click stimuli with different durations have been used to record VEMP. Studies have revealed that longer duration gives better response rate but latencies are prolonged for longer duration clicks. A study by Huang; Su & Cheng, 2005 indicates that click duration of 0.2, 0.5 and 1.0 ms gives a 100% response rate, compared to 0.1 ms. Increase in the click duration from 0.1 to 1 ms lead to prolongation of p13 and n23 latencies respectively. This prolongation was attributed to longer duration of stimulus. Highest amplitude was seen for 0.5 and 1.0 VEMPs which decreased with decrease in duration of click. Since the smallest interaural latency difference was obtained with 0.5 VEMP and lesser sound energy exposure is required for 0.5 VEMP compared to 1.0 VEMP, 0.5 VEMP is recommended to be the optimum duration for VEMP elicitation (Cheng, et al., 2005).

Repetition rate: In a study by Wu and Murofushi (1999), VEMP recordings with repetition rate of 1Hz, 5 Hz, 15 Hz and 20 Hz were compared and the results revealed that VEMPs for 1 Hz and 5 Hz stimuli showed the highest amplitude which tends to decrease as repetition rate increases. Variance in measurement of latencies was reported to be largest with 20 Hz and smallest with 1Hz but with 1Hz stimuli neck muscles had to be contracted for longer. Hence, 5 Hz is considered to be the optimal stimulation rate for the clinical use of VEMP (Wu, et al., 1999).

B. **Short duration tone bursts:** Better VEMP responses are expected using low frequency tone bursts and logons, which can be attributed to high sensitivity of single afferent saccular nerve fibre to low frequency acoustic stimulus as indicated in various animal studies (McCue and Guinan, 1994; Murofushi et al, 1995). The tone-burst-evoked responses showed no latency effect whereas the amplitude was largest when 500 and 1000 Hz tone bursts were used compared to higher frequency tone bursts (Welgampola and Colebatch, 2001).

Different parameters that have been studied using tone bursts are as given below:

- Plateau time
- Rise/fall time
- Frequency of the stimulus

Rise/fall time: Studies reveal that latencies are prolonged with increase in rise/fall time keeping the plateau time constant at 2 ms. When rise/fall time of 0.3ms, 1ms, 3ms and 10ms were compared, it was found that rise/fall time of 1 ms produced the largest amplitude compared to 0.3, 3 and 10 ms. The amplitude drops drastically if 10 ms rise/fall time is used (Cheng and Murofashi 2001). Hence 500Hz of STB frequency having rise/fall time of 1ms with plateau of 2ms was concluded to be the optimal stimulation pattern as the waveform morphology obtained with this combination was most constant and marked.

Plateau time: Cheng and Murofashi (2001) studied the effect of different plateau times on the tone burst evoked VEMPs. They found that any plateau time (1ms, 2ms, 5ms or 10ms) is sufficient enough to elicit VEMPs but the latency of P1 and N1 increased with increase in the plateau time; further the peak to peak amplitude was smallest at 1 ms. Reduced peak to peak amplitude was observed if 10 ms plateau time is used and could be as a result of stapedial reflex.

Frequency of the stimulus: Generally, VEMP has been recorded using 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz tone burst frequencies. The responses elicited using the 500 Hz tone burst are generally larger compared to the other frequencies. The larger amplitude of the VEMP with 500 Hz tone burst has been attributed to the band-pass tuning of utricle which is best at 400 and 800Hz (Todd,2009) and band pass tuning of saccule which responds to a well-defined frequency tuning of 300 to 350 Hz (Todd,2000).

C. ***Logon:*** Recently, logon has also been considered as a stimulus to evoke VEMP. Logon is a pure tone, amplitude modulated by a Gaussian function; and has been considered as the best compromise between a rectangular wave and a continuous pure tone (Davis, 1976). Trivelli, Vicini, Ascanio, Greco & Salvinelli (2007) found that logon evoked VEMP presented a P1 latency of 15.58 ms, N1 latency of 26.12 ms, P1N1 interval of 10.54 ms and P1N1 amplitude of 129.27 μV.

Comparison of VEMP responses elicited by Click, Tone burst and Logon stimulus:

Click vs. tone bursts: Akin, Murnane and Proffitt (2003) reported that although the amplitude of response increased as a function of both clicks and tone burst level, the tone burst evoked VEMP amplitudes were larger than click-evoked amplitudes when compared at equal peak SPLs. As the tone burst frequency decreased, the amount of amplitude differences between tone-evoked and click evoked VEMPs increased. Their study also revealed that 500 Hz and 750 Hz tone bursts produced more robust responses compared to clicks. In a recent study by Kumar, et al. (2011), VEMP recordings were obtained with shorter latencies using click stimuli compared to tone bursts but the amplitude of responses was greater in a tone burst evoked VEMP. Hence, click stimuli may be more beneficial than short duration tone burst for clinical identification of abnormality due to its lesser variability whereas, tone bursts would be a better choice while assessing the presence and absence of VEMP responses.

Click vs. logon: Trivelli, et al., (2007) compared clicks and logon as a stimulus to evoke VEMP and found that there was a significantly higher P1/N1 amplitude in comparison with click evoked VEMP for both air and bone-conducted stimuli. The study also revealed that lesser intensity of logon is needed to evoke VEMP responses as compared to click and that logon evokes larger and more robust VEMP responses.

3. **Stimulus intensity:** Like other parameters, stimulus intensity also has an effect on VEMP response amplitudes. A common reason reported for failing to obtain robust responses is inadequate stimulus intensity (Akin & Murnane, 2001; Colebatch, 2001). Few studies have reported the intensity in terms of sound pressure level whereas others in normalized hearing level (nHL). The use of different decibel reference units can be a cause of confusion clinically, as most of the equipment are calibrated for the clicks and/or tone bursts using different decibel scales (Colebatch, 2001). Lowest intensity at which repeatable VEMP waveforms can be obtained is termed as VEMP threshold which lies between the range of 80dBnHL to 100dBnHL with a mean of 91dBnHL (Akin, et al., 2003).

4. **Monaural or binaural stimulation:** VEMP has been recorded using monoaural and binaural stimulation. VEMP using the monoaural stimulation method with ipsilateral recording is considered to be a more reliable technique that provides the closest to normal p13–n23 amplitudes and p13 and n23 latencies (Eleftheriadou, et al., 2008). Wang and Young (2003) recorded VEMP using a binaural stimulation. Wang and Young (2003) reported that there was no difference in the latencies of p13 and n23 with binaural or monoaural stimulation. However, the relative amplitude of binaural VEMP was reduced compared to the monoaural stimulation. Although, the monoaural recording of VEMP is considered to be more reliable, it has a major disadvantage. This method requires a sufficient level of muscle tension from the clients, which may not be feasible in the elderly or very young clients. Thus, in this group of clients, VEMP can be recorded using a binaural stimulation rather than monoaural stimulation, which would require less muscular effort, providing similar information as that of monoaural stimulation of VEMP.

5. **Electrode montage:** Back in 1969, Cody and Bickford measured vestibular responses from inion with reference electrode on the nose or earlobe and inverting electrode on the forehead; but this montage, did not elicit responses from all normal individuals. Viart, Duclaux, Colleaux and Dubreuil (1997) compared VEMP responses from sternomastoid and trapezius muscles. With reference electrodes in the middle of the anterior edge of the clavicles and a medial frontal electrode as ground, Ag/AgC1 surface electrodes placed over the SM halfway between the mastoid and clavicle evoked shorter latencies and lower amplitude responses compared to the trapezius muscles placement irrespective of type of stimulation. .

Colebatch, (2001) modified the montage with active electrode on the upper third of the SCM muscle, and the reference electrode on the muscle tendon just above the sternum. This montage elicited repeatable p13-n23 waveforms from all participants. Sheykholeslami, Murofushi, and Kaga (2001) recommended recording from the middle part of SCM as it provided the most consistent results.

Rudisill and Hain, (2008) recorded lower extremity myogenic potentials from gastrocnemius with noninverting electrodes placed on the right and left gastrocnemius; inverting electrodes, on the right and left medial malleolus; and the ground electrode, on the right or left lateral malleolus. Both ipsilateral and contralateral responses to acoustic stimulus were obtained with gastrocnemies placement. Responses were in the form of biphasic waves with P1-N1 and P2-N2 but not all subjects showed both components. When compared to the SCM placement, responses were smaller and later with P2-N2 being the most reliable wave. The responses were compared to the responses from SCM and the results revealed that responses were obtained in the gastrocnemius, both ipsilateral and contralateral to the acoustic stimulus. The response consisted of 2 biphasic waves (P1-N1 and P2-N2), although not all subjects exhibited both components. The most reliable wave was P2-N2 and the responses were smaller and later than those in the SCM.

To obtain the effect of different head positions on VEMP, recordings have been obtained with a surface electrode placement on the upper half of the left sternocleidomastoid muscle (SCM), a reference electrode on the medial end of the left clavicle and a ground electrode on the nasion (Ito, Karino, & Murofushi,2007).

6. **Effect of muscle tension on Vestibular evoked Myogenic potentials:** Muscle tension is an important factor in recording the Vestibular evoked. Myogenic potentials from the sternocleido mastoid muscles (SCM). As the muscle tension increases, the amplitude of the VEMP increases drastically. Therefore, it becomes very important to monitor the muscle tension during the recording of the VEMP from SCM. Based on the monitoring of muscle tension, there are two methods of recording-rectified and un-rectified methods of VEMP. In un-rectified method, a task is being given to move the neck up to a certain position but there is no monitoring of the EMG activity, whereas, in the rectified method, an EMG device monitors the activity of the muscles during the whole recording. Akin et.al (2003) recorded VEMP with both click and tone burst stimuli in nineteen individuals using rectified method and evaluated intensity and frequency effects. These subjects were given visual feedback of EMG in order to maintain tonic EMG at 50 mV during the testing. The authors hence concluded that the differences in VEMP amplitude were presumably due to the intensity and frequency and not due to the variations in EMG level. However, in another study by Bush, Jones and Shinn (2010), no significant effect on amplitude asymmetry was found with presence or absence of muscle tension monitoring.

Conclusions

The present review provided information on different recording procedures that have been used in order to obtain VEMP responses. The effect of different recording parameters on VEMP responses has also been discussed. Hence, all the above mentioned factors should be taken into consideration before choosing the appropriate protocol for VEMP recording.

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