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Original Article

Optimum Number of Sweeps in Clinical OVEMP Recording; How Many Sweeps are Necessary?

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OBJECTIVE: Ocular vestibular-evoked myogenic potentials (OVEMPs) in our hands provide us with reproducible and consistent results; however, it has been shown that the OVEMP amplitude decreases with increased stimulus duration. The exact number of stimuli for OVEMP recording is not consistent among the published papers describing this test. We aimed to determine the number of stimuli needed to produce a satisfactory OVEMP response and the consequences of a more prolonged stimulation to the OVEMP response.

MATERIALS and METHODS: We retrospectively analyzed 50 OVEMP patient recordings and found that the average number of sweeps carried out was 26. We carried out three different OVEMP recordings using our standard protocol of (1) a "standard" OVEMP protocol, in which we record until the OVEMP wave becomes obvious; (2) an OVEMP recording using our average of 26 sweeps; and (3) an OVEMP recording with twice as many sweeps.

RESULTS: OVEMP latencies did not change when using different number of sweeps; however, the amplitudes showed a significant decrease with an increasing number of sweeps.

CONCLUSION: OVEMPs can be completed in a satisfactory manner with a much lower number of stimuli than those usually carried out. Reducing the stimulus number reduces the time taken for the test, minimizes the cochlear insult while not reducing the valuable information obtained, and maximizes the amplitude of the stimulus, possibly increasing the accuracy of measuring interaural amplitudes and helping to measure asymmetry.

KEYWORDS: OVEMP, otoliths, vestibular, diagnostics

INTRODUCTION

Cervical vestibular-evoked myogenic potentials (CVEMPs) were first described in the 1960s and developed as a clinical test of otolithic function (specifically the saccule) in 1992 [1]. A test of utricular function, the ocular VEMP (OVEMP) was first described in 2005 [2]. The two tests are now part of the standard balance assessment of inner ear function. The stimulus for OVEMPs is either a sound of 97 decibels (dB) hearing level [HL] or a vibration. The advantage of a sound stimulus for OVEMPs (because of interaural attenuation) is that the ear that is stimulated is the ear from which the response arises, whereas with skull vibration (a much less specific stimulus), there is always a concern regarding the side from which the response has occurred.

Ocular VEMPs in our hands provide us with reproducible and consistent results. Recently, the effect of tone-burst stimulus duration on the OVEMP was studied, and it was shown that the amplitude decreased with increased stimulus duration [3]. There is a wide range of stimulus repetitions used by different investigators [4-11], and it became clear to us that the exact number of stimuli for OVEMP recording was not consistent among the published papers describing this test (Table 1). Our present protocol calls for recording to continue until an obvious reflex is elicited, and the visual inspection of the real time recording shows no change in the evoked waveform. This often calls for up to 40 or 50 sweeps, and if there is no indication of response after 40 sweeps, the trial is terminated. Considering that the OVEMP assessment requires an uncomfortable unnatural patient action that is aphysiological (i.e., it is not an action undertaken in everyday activities), we aimed determine the smallest number of repetitions required to produce a satisfactory OVEMP in a series of normal people. In addition, the consequences of using more stimuli were also investigated. We focused on studying the effect of the number of repetitions on the OVEMP amplitude. The present study was designed by the authors to fulfill the requirements of AK's research requirements in her medical studies. This study was designed in an attempt to minimize the amount of a stimulus while still producing a satisfactory OVEMP in a series of normal people and show the consequences of using a higher number of stimuli.

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Table 1. Number of OVEMP sweeps found in literature

Authors	Number of sweeps
Winters et al. [9] (2011)	50
Zuniga et al. [10] (2013)	100
Rosengren et al. [8] (2013)	200
Piker et al. [7] (2013)	150
Nguyen et al. [6] (2010)	100
Gozke et al. [4] (2010)	1500
Murofushi et al. [5] (2011)	100
Smulders et al. [11] (2009)	30

OVEMP: ocular vestibular evoked myogenic potentials

A single case of sensorineural hearing loss after VEMP testing has been reported in humans [12], although the noise exposure reported in the case report was greater than the exposure that a patient experiences in a standard VEMP assessment. However it was stressed by the authors that during VEMP testing, a significant amount of sound can be delivered to the cochlea, and certain individuals may be susceptible to acoustic trauma at these levels. The authors recommended "limits for VEMP stimuli levels and attention to total sound exposure when multiple trials are used." It has been shown in guinea pigs that the cochlea can exhibit temporary or permanent functional loss resembling hearing threshold shifts [13] following noise exposure.

The American standard for noise exposure requires that hearing protection be worn at 85 dB and that exposure should be limited to 8 hours. For every 3 dB increase in noise level, the duration of exposure allowed is reduced by 50%. When testing OVEMPs using our commercially available system (ICS Chartr EP 200; GN Otometrics; Schaumburg Il; USA), a warning is displayed stating: "The current stimulus intensity level of 97 dB nHL (128 dB SPL) can be hazardous if presented for over 15 minutes." It is agreed that impact noise is more deleterious. As OVEMP testing usually requires sound exposure totaling <3 minutes, patients we assess fall well within a safe level of noise exposure. However, with sounds at this loudness, it is still logical to minimize the stimulus while gaining the maximal clinical information. The present article addresses this issue by determining how many stimuli are needed to produce a satisfactory OVEMP response and the consequences of a more prolonged stimulation to the OVEMP response. In our hands, OVEMPs are a highly reproducible assessment routinely carried out in our lab on approximately 10 patients per week.

MATERIALS and METHODS

This study was approved by the Clinical Research Ethics Board of our institution (Approval number H15-00494) and is an ongoing study to develop different methods of interpreting and understanding VEMP recordings of patients in our clinic. It was deemed by the ethics board to be a "quality assurance and improvement study" under the auspices of our previously approved study. The ethics board clearly states that this is an "activity not requiring review." Thus, an expedited approval to this study was granted, and it was deemed that no consent form would be required.

In our main study, we enrolled 10 volunteers aged 22-71 years (5 males, 5 females). Subjects had no history of auditory, vestibular, neurological, or visual complaints or disorders. When conducting this experiment, the fact that the OVEMP is a delicate response (often a factor of ten less than a CVEMP response) was considered. Our clinical experience is that some individuals have robust responses, while others have responses that are less robust (but still fall within the parameters of normal). To conduct the experiment (and show a change in response amplitude), we elected to select subjects with well-formed and robust OVEMP waveforms allowing for clear and straightforward measurement. Because we used this protocol for acceptance, we disregarded the results of three normal subjects whose OVEMPs were present but less easily interpreted and quantified.

Corollary Experiment

We also designed a corollary experiment to eliminate the possibility that fatigue may play a factor in the results of our first experiment. In our corollary experiment, we assessed five subjects with repeated OVEMPs using the 26-sweep protocol. Each subject underwent the 26-sweep OVEMP protocol conducted sequentially (trials 1-3) with a maximum of 15 seconds between assessments. Subjects were then given a 5-minute rest period, followed by two further OVEMP assessments repeatedly with 15 seconds in between trials.

The subjects were assessed routinely in our institution using OVEMPs. Two disposable evoked potential Wet Gel Electrodes (ICS GN Otometrics; Schaumburg Il; USA) were positioned beneath each eye. The top electrode is the active electrode and is situated directly underneath the eye in line with the pupil as the subject gazes straight ahead. The reference electrode is situated 1 cm below. The ground electrode is placed in the center of the forehead (Figure 1). Impedances are kept below 5 KΩ. The patient is positioned leaning forward and is instructed to place his/her chin on a blood pressure cuff positioned on a cross-bed food table (Figure 2), and to gaze straight ahead at a target. The table is set at a predetermined height and the patient chair is situated at a fixed distance from the adjacent wall. A target is situated at an angle of 30-35° above the fixated center gaze. It is stated in the literature that controlling the level of gaze when recording OVEMP is of utmost importance and must be carefully controlled [14]. Because of this, our protocol includes placement of the assessor's hand at the back of the patient's/subject's head to prevent any movement (in particular neck extension). This ensures that the angle of eye elevation remains static. The patient is instructed to elevate gaze prior to the start of the recording, and when the fixation is established, the stimulus is started.

We used an air-conducted 500 Hz tone burst of 97 dB nHL delivered at 5.1 per second stimulation rate, using a Blackman window with 2-0-2 rise/plateau/fall pattern. The sound is delivered using 300 Ω OTOinsert earphones to each ear sequentially. During stimulation, the patient is instructed to elevate their eyes and fixate on the target. This upward gaze position has shown to be the most appropriate way for the tonic activation of the extraocular muscle for recording OVEMPs. Measurements are taken from the contralateral electrode. At least two traces of each recording are completed and averaged. A third (and sometimes even a fourth) run is completed if the responses are absent or judged not to be reproducible.

Clinical OVEMP analysis in our lab consists of calculating four parameters of the OVEMP response: the latency of the first positive peak (p1), latency of the first negative peak (n1), and amplitude

Figure 1. This demonstrates our ocular VEMP (OVEMP) and cervical VEMP (CVEMP) electrode array. All tests are conducted without the patient having to move from the initial test position, as shown in Figure 2.

*Subject's (who is also one of the co-authors of this article) consent was obtained for publication of this image.

Figure 2. The OVEMP test position is shown with the chin resting on a meal table. To undertake OVEMPs, the assessor's hand is placed on the back of head, while the subject is instructed to elevate gaze to a fixed target on the opposite wall at 30° to 35° above the center gaze

*Subject's (who is also one of the co-authors of this article) consent was obtained for publication of this image.

(p1-n1). The interaural amplitude ratio is defined as the difference of the amplitude of each ear divided by the sum of the amplitude of both ears.

As mentioned, there is no consensus in the literature regarding the number of sweeps that is optimum in the OVEMP recording. We retrospectively analyzed our previous 50 OVEMP recordings and averaged the number of sweeps used for recording the OVEMPs from those 100 ears. The average was 25.89±10.88. Therefore, for this research project we carried out three different OVEMP recordings;

1. A "standard" OVEMP recording (using our usual clinical protocol described above) without looking at the number of sweeps to test for the recordability of the OVEMP from the participant. As detailed above, our standard clinical protocol is to cease recording when the OVEMP wave becomes obvious.
2. OVEMP recording with the average of 26 sweeps.
3. OVEMP recording with twice as many sweeps (54 sweeps).

Table 2. OVEMP amplitudes recorded under three different parameters

Subject	Sex	Age, years	Standard (µV)	26 reps (µV)	54 reps (µV)
S1	F	27	L: 5.12	L: 5.00	L: 2.28
			R: 3.52	R: 5.69	R: 1.89
S2	M	64	L: 24.88	L: 21.64	L: 22.99
			R: 29.02	R: 28.86	R: 21.7
S3	F	27	L: 6.02	L: 6.01	L: 6.97
			R: 10.90	R: 9.45	R:13.05
S4	M	27	L: 13.29	L: 13.29	L: 17.82
			R: 11.81	R: 18.60	R: 13.67
S5	M	71	L: 6.95	L: 5.70	L: 5.89
			R: 8.94	R: 5.32	R: 4.12
S6	M	44	L: 9.53	L: 3.57	L: 3.08
			R: 10.03	R: 5.75	R: 7.16
S7	M	30	L: 6.14	L: 9.09	L: 7.21
			R: 8.13	R: 11.85	R: 8.81
S8	F	68	L: 10.52	L: 3.91	L: 2.50
			R: 3.33	R: 3.77	R: 1.45
S9	F	19	L: 16.26	L: 14.10	L: 11.41
			R:24.60	R: 21.68	R: 17.51
S10	F	22	L: 21.54	L: 23.83	L:14.37
			R: 7.59	R: 7.75	R: 6.33
MEAN		39.9	11.91	11.24	9.51

Ten healthy subjects (20 ears) were assessed. All subjects underwent sequential OVEMPs, with virtually no break in between, with the standard OVEMP carried out first, followed by the 26 sweep trials, and then the 54 sweep trials. Although not reported here, the onset latencies of n1 and p1 were measured using our standard protocol and a repeated measures ANOVA; neither of these latencies changed significantly between the recordings.

Statistical Analysis

All data were collected and organized using Statistical Package for Social Sciences for Windows version 23.0 (IBM Corp.; Armonk, NY, USA), and we measured the mean and standard deviation of the amplitudes and n1 and p1 latencies. For this study, we analyzed amplitudes between all subjects using a two-tailed paired *t*-test. We did not differentiate between ears (we analyzed all 20 recorded values for each of the three conditions).

In our corollary study, as discussed above, five subjects underwent our 26-sweep protocol with five successive runs.

RESULTS

We analyzed all amplitudes using a simple two-tailed paired *t*-test (available on line) for any significant differences between the three parameters. The amplitudes of the OVEMP recordings under each

Table 3. OVEMP amplitudes recorded in 5 successive trials (see discussion)

SUMMED AMPLITUDES in μV (R+L) FOR EACH TRIAL						
Name	**Age/sex**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**
S1	65M	34.51	55.86	44.77	49.44	61.94
S2	26F	38.10	45.49	40.54	43.31	42.56
S3	72M	10.67	6.37	10.48	16.07	8.23
S4	28F	23.14	25.78	28.38	15.75	48.28
S5	20F	7.08	21.44	14.78	17.35	12.02
TOTAL		113.50	154.94	138.95	141.92	173.03

ANOVA-p value 0.878; results not significant at $p<0.01$

ANOVA: analysis of variance; OVEMP: ocular vestibular evoked myogenic potentials

collection parameter are shown in Table 2. The mean amplitude was 11.917.51 μV in the standard recording. The 26-sweep protocol showed a mean amplitude of 11.24±7.73 μV. The 54-sweep recording showed a mean amplitude of 9.51±6.71 μV.

Paired t-test comparisons

1. Standard vs. 26-sweep protocol; not significant
2. Standard vs. 54-sweep protocol; significant at $p=0.008$
3. 26 sweep vs. 54-sweep protocol; significant at $p=0.03$

In our corollary experiment (Table 3), results were analyzed using an analysis of variance (ANOVA) test. We recorded and summed the amplitudes of the two ears in each subject for each trial, as we aimed to see any effect of fatigue brought on by successive trials. There was no significant difference between any trials, with a p value of 0.878.

DISCUSSION

The present study demonstrates that OVEMP latencies do not change when different numbers of sweeps are used. However, the amplitudes decreased with an increasing number of sweeps. Our usual OVEMP patient assessment is often about 30 sweeps (as discussed, our protocol is to stop recording when an obvious wave has been elicited). It appears logical that our standard assessment was not significantly different from the 26-sweep protocol. Our data have shown a decrease in the amplitude of the OVEMP response with an increased number of sweeps. It is unclear to us whether this represents some kind of central (peripheral) attenuation of the reflex or the difficulty in maintaining an elevated gaze during assessment (which is an unnatural task to perform). Our corollary experiment suggests that fatigue is not a factor. All five subjects in our corollary experiment were specifically asked if they felt any fatigue, and they all denied any such sensation.

Our concern with either explanation is that prolonged stimulus exposure (such as that reported by many other investigators [4-11]) could attenuate the reflex to the extent of rendering latency measurement much more challenging and amplitude interpretation less accurate. One study [4] used 1500 sweeps. Patients with diagnosed migraine and a fairly high rate of absent responses were included. We speculated if the active vestibular disease or perhaps the extremely long duration of the response may have been reflected in the high rate of absent responses in the mentioned study. In a diagnostic assessment, it is important to ensure that there is no "test effect" (e.g., fatigue factor) that can influence the results.

Our experiment has shown that it is possible to obtain a satisfactory response with many fewer stimulus repetitions than those generally conducted. It has also been shown in both guinea pigs [13] and humans [12] that there are potentially deleterious effects of prolonged noise exposure at the level required to perform the OVEMP assessment. As discussed in the methods section, our technical adaptation of a hand placed on the back of the patient's head to detect and prevent neck extension during testing is critical to the procurement of a valid response.

CONCLUSION

Based on the aim of getting an accurate and clinically reproducible response for the minimal stimulus amount to minimize cochlear insult [12], our study shows that OVEMPs can be completed in a satisfactory manner with much fewer stimuli than are usually carried out. This has three benefits; firstly, it reduces the time taken for the test. Secondly, it minimizes the cochlear insult, while not reducing the valuable information obtained. Thirdly, the OVEMP is a fragile, low amplitude reflex (often around 10 μV). Our corollary experiment rules out the possibility of a fatigue effect during OVEMPs. In this experiment, there was a slight variation in some of the OVEMP responses but this was in the magnitude of only 5 to 10 μV, which is an extremely small electrophysiological variation.

Our main study demonstrates that OVEMP amplitude is larger with fewer stimuli, and if comparative stimuli from side to side are used to measure asymmetry, this method is helpful in preventing attenuation and perhaps disappearance of the response due to overstimulation.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Vancouver General Hospital and the University of British Columbia (Approval No: H 15-00494).

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