

The Usefulness of Rectified VEMP

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Objectives. For a reliable interpretation of left-right difference in Vestibular evoked myogenic potential (VEMP), the amount of sternocleidomastoid muscle (SCM) contraction has to be considered. Therefore, we can ensure that a difference in amplitude between the right and left VEMPs on a patient is due to vestibular abnormality, not due to individual differences of tonic muscle activity, fatigue or improper position. We used rectification to normalize electromyograph (EMG) based on pre-stimulus EMG activity. This study was designed to evaluate and compare the effect of rectification in two conventional ways of SCM contraction.

Methods. Twenty-two normal subjects were included. Two methods were employed for SCM contraction in a subject. First, subjects were made to lie flat on their back, lifting the head off the table and turning to the opposite side. Secondly, subjects push with their jaw against the hand-held inflated cuff to generate cuff pressure of 40 mmHg. From the VEMP graphs, amplitude parameters and inter-aural difference ratio (IADR) were analyzed before and after EMG rectification.

Results. Before the rectification, the average IADR of the first method was not statistically different from that of the second method. The average IADRs from each method decreased in a rectified response, showing significant reduction in asymmetry ratio. The lowest average IADR could be obtained with the combination of both the first method and rectification.

Conclusion. Rectified data show more reliable IADR and may help diagnose some vestibular disorders according to amplitude-associated parameters. The usage of rectification can be maximized with the proper SCM contraction method.

Key Words. Vestibular evoked myogenic potential, Rectification, Amplitude

INTRODUCTION

Vestibular evoked myogenic potentials (VEMPs) are mediated by the sacculocolic reflex arc, which initiates from the saccular macula and furthermore includes the inferior vestibular nerve, the lateral vestibular nucleus (Deiter's nucleus), the vestibulospinal tract and the motor neurons of the contracted ipsilateral SCM (1, 2).

VEMPs, measured from the contracted sternocleidomastoid muscle (SCM), are inhibitory myogenic potentials that result from ipsilateral saccular stimulation by means of loud clicks or tone bursts.

For determining right/left differences in the VEMP results, there are several methods or parameters, such as comparisons of

latency in early positive-negative p13-n23 component, peak-to-peak amplitude of the p13-n23 waveform complex, its interaural amplitude difference ratio (IADR) and threshold for the appearance of VEMP waves according to sound intensity (1, 3). So far, many authors have reported some pathognomonic findings or results for the specific vestibular disorders. However, much more research remains to be done on the comparison of amplitude-related parameter.

Among aforementioned parameters, amplitude-related parameters change according to the degree of tonic contraction of ipsilateral SCM. There is a direct correlation - the more tonic muscle tension, the larger the VEMP amplitude response (1, 3, 4). Therefore, even normal subjects, whose saccular functions would be equal between right and left side, reveal right/left amplitude difference as well as wide ipsilateral test-retest variations. In order to quantify the right/left amplitude difference and normalize person-to-person variations, IADR can be presented as the degree of asymmetry in amplitude. However, there is a limitation to apply the value directly on clinical decisions because IADR shows a great deal of variations among even normal subjects. Therefore, when collecting a VEMP, we must have some way of controlling the

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amount of muscle tension between the right and left muscle. If not, the difference in the VEMP amplitudes between both sides could simply be because one muscle is more tense or contracted than the other during the test. Accordingly, it is difficult to interpret the VEMP results and make normal range because the difference may come from lack of tonic muscle activity, not from real vestibular abnormality.

Vanspauwen et al. (5, 6) proposed a feedback method making use of a readily available blood pressure manometer with inflatable cuff to control SCM contraction. When analyzing the relationship between the applied cuff pressures and VEMP amplitude, they showed a linear relationship between them. They also used mean rectified voltage (MRV) which directly reflects the SCM electromyograph (EMG), suggesting that the blood pressure manometer allow for a control of the SCM contraction by means of the MRV measures and will result in a much better determination of left/right VEMP amplitude asymmetries.

Since the degree of muscle contraction effects on the VEMP result and its interpretation, the tonic EMG activity that occurs immediately before each sound stimulation can be used for normalization for VEMP results. This method, or with the combination of conventional feedback method, could make the result more reliable and objective.

In this study, we used rectification for EMG normalization based on pre-stimulus EMG activity. EMG rectification available Bio-logic Navigation Pro was utilized for the VEMP wave, amplitude and IADR. Two different methods were employed for SCM contraction in a normal subject -1) 'Supine method', 2) 'Blood pressure cuff method'.

The aim of this study is to evaluate and compare the effect of rectification in two conventional ways of SCM contraction. The change of IADR value was observed after rectification and its usefulness was discussed.

MATERIALS AND METHODS

Subjects

Twenty-two healthy subjects were included (11 men, 11 women) ranging in age 24 to 36 (average 27 yr). All subjects had normal hearing sensitivity (pure tone air conduction hearing level measured at 0.5, 1, 2, and 4 kHz was <20 dB) and no history of vestibular, neurologic disorders. Their tympanic membranes were free of pathology.

VEMP test

The experiments were performed with an auditory evoked potential system, Navigation Pro, Version 6.1.0 (Bio-logic® System Corp, Mundelein, IL, USA). The active electrodes were placed on the skin overlying the medial portion of the contracted SCM muscle belly, the reference electrode on the upper part of the sternum and the ground electrode on the forehead. The respons-

es were obtained from each side separately using tone bursts of 500 Hz (95 dB nHL, rise/fall time=1 msec, plateau time=2 msec, stimulation rate=5.1 Hz), which were delivered unilaterally with insert earphones. The acoustically evoked VEMP responses were amplified (×1,000), band-pass filtered (10 Hz-1.5 kHz), and averaged. Two runs of 128 tone bursts were delivered to each ear. The results of both runs were averaged, providing the final response from which the peak-to-peak amplitude (p13-n23) was calculated. The VEMP response was only considered as being reliable if the p13 and n23 peaks are reproducible in both runs.

System obtained averaged waveform and user marks points (p1 and n1) on it. For rectification, user chose prestimulus rectification (PSR) function on selected waveform and averaged the absolute value of the prestimulus data during 20 msec. That value is divided into each of the 256 points along the collected VEMP waveform. Finally, new rectified waveforms are calculated and displayed below (Fig. 1).

For relative asymmetry ratio of righ/left peak-to-peak amplitudes (Amp), IADR was calculated in both unrectified and rectified VEMP waves.

$$IADR=100(\%) \times (Amp[left]-Amp[right]) / (Amp[left]+Amp [right]).$$

SCM contraction

To contract the SCM during the VEMP test, two different methods were applied: 1) The subjects lie flat on their back, lifting the head off the table and turning to the opposite side ('Supine method'). 2) The subjects have to flex the head approximately 30 degrees forward and rotate it approximately 30 degrees to the

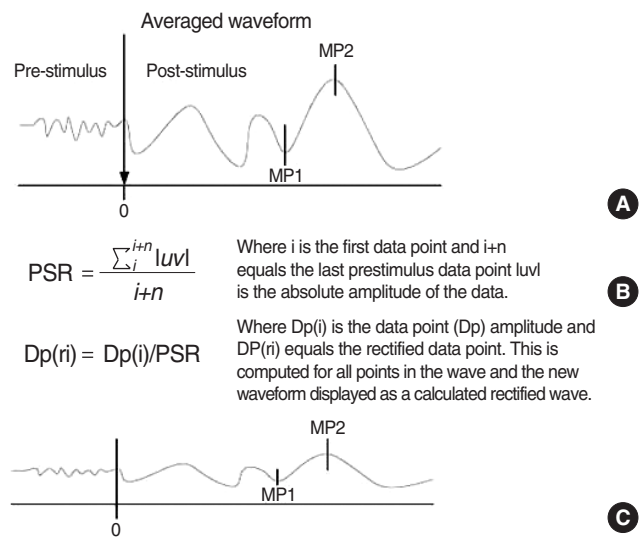


Fig. 1. Schematic rectification flowchart (modified from Bio-logic®) (A) System obtains averaged waveform and user marks points (MP) on it. (B) User chooses prestimulus rectification (PSR) function on selected waveform and average the absolute value of the prestimulus data. (C) New rectified waveforms are calculated and displayed.

opposite side. While holding the cuff between right hand and jaw, the subject push with his or her head against the hand-held cuff to generate a cuff pressure of 40 mmHg ('BP cuff method') (6).

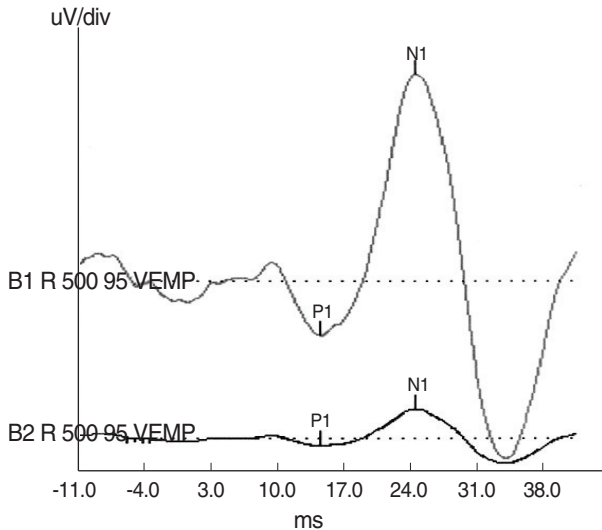


Fig. 2. A real VEMP graph taken from a normal subject. After recording the VEMP, a corrected waveform of small amplitude is calculated and drawn below unrectified wave.

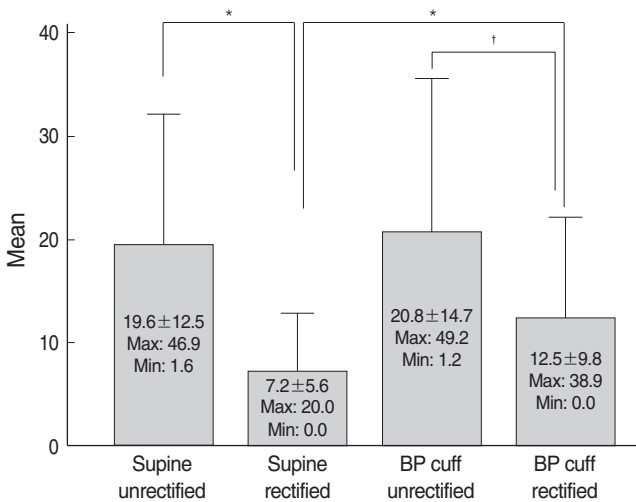


Fig. 3. The summary of mean IADR in each SCM muscle contraction method before and after rectification (N=22). The mean IADRs from each method decreased in a rectified response, showing significant reduction in asymmetry ratio (* $P < 0.05$). The unrectified IADR is not different between supine and BP cuff method ($P = 0.935$). However, noticeable difference was observed between them after rectification even if it was not statistically significant ($P = 0.053$). The lowest mean IADR could be obtained with the combination of the supine method and rectification. Error bars mean ± 1 standard deviation. Supine: SCM contraction method wherein subjects lie flat on their back, lifting the head off the table and turning to the opposite side. BP cuff: method wherein subjects push with their jaw against the hand-held inflated cuff to generate cuff pressure of 40 mmHg.

Data analysis

Data were expressed as the mean ± 1 standard deviation. Statistical analysis was performed using SPSS 12.0 (SPSS software, SPSS, Chicago, IL, USA). Wicoxon signed ranks test was used for mean analysis and a significant level of 5% was adopted.

RESULTS

Normal VEMP responses with p13 and n23 waves were obtained in each healthy subject bilaterally in both 'Supine method' and 'BP cuff method'. The collected VEMP waves were also rectified and new corrected waves were obtained (Fig. 2).

The mean IADRs of unrectified and rectified VEMP in 'Supine method' were 19.6 ± 12.5 and 7.2 ± 5.6 respectively, showing that the IADR of rectified VEMP was significantly reduced ($P < 0.001$). The mean IADRs of 'BP cuff method' were 20.8 ± 14.7 and 12.5 ± 9.8 respectively and the IADR of rectified VEMP was also significantly reduced ($P = 0.013$). This data show IADRs of rectified VEMP decrease in both methods (Fig. 3). There was no statistical difference in unrectified IADR in both 'Supine method' and 'BP cuff method' (19.6 vs. 20.8 , $P = 0.935$).

The coincidence of amplitude-dominant side happened in 17 subjects (77%, right 9, left 8) out of 22 between two different SCM contraction methods. However, only five subjects (23%) had the same direction after the rectification ($P = 0.031$, Fisher exact test) (Fig. 4).

The rectified mean IADR of 'Supine method' (7.2 ± 5.6) was less than the one of 'BP cuff method' (12.5 ± 9.8), which, how-

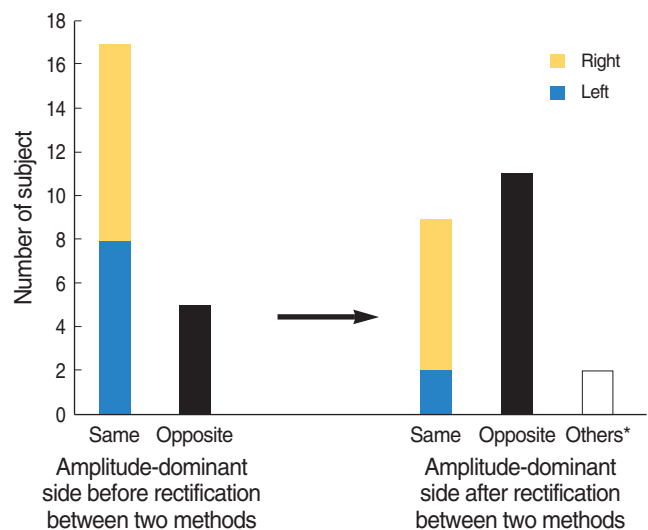


Fig. 4. The coincidence of dominant side in amplitude (right vs. left) (N=22). The coincidence rate between two methods decreased from 77% (17/22) to 40% (9/22) by rectification ($P = 0.031$, Fisher's exact test). This result indicates that people tend to have unilateral dominant SCM contraction even in two different methods, which can be normalized by rectification.

*Subjects whose right-left difference became zero after rectification.

ever, was not statistically significant ($P=0.053$) (Fig. 3).

There was no significant difference in all methods according to the gender.

DISCUSSION

Since the VEMP amplitude is positively proportional to ipsilateral SCM tonic contraction, it is important to make the contraction of the both sides equal and uniform. On this assumption, we can ensure that a difference in amplitude between the right and left VEMPs on a patient is because of vestibular abnormality, not because of the difference of tonic muscle activity due to patient fatigue or improper patient position.

There are several methods to make the contraction equal, of which supine method and feedback method with BP cuff are conventionally used in many clinical setting. However, there still remains some asymmetry in both muscle activities because these methods are designed to make equal contractions only in an indirect way.

This study showed significant decrease in asymmetry in normal subject with the direct use of pre-stimulus EMG. The decrease of IADR was observed in both 'Supine method' and 'BP cuff method'. The right/left difference in rectified VEMP reflects a more amount of vestibular function difference than muscle contraction difference which usually originate from individual variation of muscle, patient fatigue or improper position. Especially, individual variation of SCM can not be ignored because the coincidence of dominant side in amplitude (right vs. left) happened in 17 subjects out of 22 (77%) between two totally different SCM contraction methods. This high coincidence rate indicates that people tend to have unilateral dominance in SCM contraction, which can be normalized by rectification. This explains that the result is not simply accidental, suggesting usefulness of rectification.

In rectified VEMP, asymmetry ratio obtained in supine method is lower than one in BP cuff method, even though it is not statistically significant (7.2 vs. 12.5, $P=0.053$). While the VEMP without rectification, in other words, VEMP not considering PSR as a denominator, showed little difference in amplitude, however, VEMP with rectification made the difference big. In addition to technical error in performing VEMP test, following explanations can be suggested with care. This difference may result from right/left asymmetry of PSR, which is used as a denominator in rectification function, meaning that asymmetry of PSR is larger in 'BP cuff method' than in 'Supine method'. The asymmetry of PSR may be emphasized in 'BP cuff method' because inadequate or uneven muscle recruitment due to low-power contraction can induce difference in pre-stimulus EMG baselines. A small surface electrode on SCM is another factor when uneven muscle recruitment happens. In addition, because the 'BP cuff method' is carried out in sitting position and there is less compensatory sur-

rounding muscle contraction, it enables only the SCM to contract specifically. The VEMP results from only the SCM, which has more individual variation than any other muscles, might induce big right/left difference in PSR.

However, despite of the usefulness, rectification can only reduce the bias from the degree of muscle contraction. Theoretically, in all kinds of SCM contraction methods, IADR should be nearly zero in normal subject after rectification but it was not. It means that rectification can not eliminate muscle contraction bias and it also account for the inadequateness or limitation of rectification. More technical researches and development of standardized methods remain to be performed in the future.

So far, there have been many studies dealing with otologic diseases in terms of latency of p13, n23 or wave threshold. However, there have been few studies referring to amplitude difference or IADR for some specific otologic diseases. Because those amplitude-related data have much variation according to individual, laboratory and SCM contraction method, it is difficult to directly apply those amplitude-related values on clinical decisions.

We compared the IADR using two conventional SCM contraction methods, which are commonly used in many audiological clinics. Because the mean IADRs are not statistically different between two SCM contraction methods, clinicians can choose a preferable method according to their clinics' condition. In addition, if the rectification is employed on the top of those methods, further reduction of IADR would be observed. The lowest mean IADR could be obtained with the combination of both the supine method and rectification, which accounts for the clinical usefulness.

Of course, the ideal situation would be to actually measure the EMG in real time and ask the patient to control the tonic muscle tension using bio-feedback. Unfortunately, the tools to do this are not readily available in most audiology clinics. Rectification is not real-time procedure since only the EMG activity during each pre-stimulus time is averaged and divided into the collected VEMP waveform. However, rectification method may be a good substitute for the real-time EMG monitoring with ease on the following assumption - 1) the pre-stimulus baseline EMG activity would not change after the sound stimulation and 2) the VEMP amplitude has linear correlation with the baseline EMG activity.

Even though it is difficult to decide whether this rectification is valid enough to determine vestibular disorders in terms of amplitude difference, this study would help clinicians make the normal range of IADR in each condition and decide some disease-specific findings using the rectification.

CONCLUSION

In the study of normal subjects, rectified data showed more reduced and reliable IADR. It may help clinicians find some

vestibular disorders according to amplitude-associated parameters without complicated diagnostic methods. In addition, the usage of rectification can be maximized with the proper SCM contraction method.

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