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EDITORIAL

Vestibular-evoked myogenic potentials: do we know all the basics?

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Like any other event in human history, a revolutionary discovery such as a new diagnostic test will catch the attention of those within the field. The initial evaluation focuses on the parameters of the test, followed by an evaluation of the clinical application of the test. As time passes, the semantics of the test receive less attention, while clinical applications gain more and more attention. Sometimes, clinical applications and outcomes are reported before the basics of the test have been fully explored. Many of these published studies would not meet the required standards of the test and are thus difficult to apply to the clinical setting.

Since the introduction of vestibular-evoked myogenic potentials (VEMPs) as a test to evaluate the vestibular system, many articles have been published discussing technical points as well as disease outcomes and clinical applications. During the last two decades, those discussions have given us many new insights into VEMPs in the clinical setting. We are now able to test, diagnose, and treat patients with balance problems much more efficiently. However, basic research about some very basic questions, including how we should record, interpret, and validate data is lacking and not standardized between different laboratories and different diseases. VEMP, in comparison to other widely used electophysiological tests such as electronytagmography (ENG), videonystagmography (VNG), and auditory brainstem response (ABR), is less studied and unified across the globe when it comes to basic test recording and interpretation properties.

After the initial burst of research regarding the test recording paradigm and basic properties of the test, the attention has shifted toward the clinical utilities in diagnosis and treatment of various diseases. To make matters more complicated, the advent of various forms of VEMPs, e.g., ocular, cervical, galvanic, air- and bone-conducted VEMPs, without knowing the basic properties of the tests, has brought more confusion and doubt to the table. In this brief communication report, I will attempt to discuss some of the unsolved issues regarding basic parameters of the various forms of VEMPs which have been in use in the clinical setting for the purpose of diagnosis and treatment of patients. I will try to limit the discussion to electromyogenic potential (EMG) and electrode location, montage, and electrode effect on the outcome of the recording as well as their impact on the diagnosis of the disorders and possible source for literature disparity on the laterality, reproducibility, and shape of the waveforms.

An experienced electrodiagnostician can usually identify the motor nerve being studied by inspecting the configuration of the surface-

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recorded compound muscle action potentials. It has been generally accepted that differences in muscle activity around the active or reference electrode might be a factor accounting for the differences in configuration and waveform morphology of the field potentials. The belly-tendon montage is the standard method used by most EMG laboratories to record surface motor nerve responses. This method assumes that the recorded electrical activity arises at the active electrode site, which is located over the motor point on the muscle belly. The reference electrode, placed on the muscle's tendon, has traditionally been considered to be electrically inactive or indifferent. An initially negative biphasic compound muscle action potential (CMAP) is typically recorded from targeted muscle during EMG recordings using the belly-tendon electrode array. This potential's onset is negative because the recording electrode is purposefully positioned over the muscle's endplate zone, making it near-field potentials. The positive phase is in large part due to the summated far-field potentials generated from the combined intracellular action potentials encountering the musculotendinous junction, making this part far-field potentials. The same montage has been widely used to record cervical and ocular vestibular-evoked myogenic potentials.

During the VEMP introductory stages, very few basic and fundamental experiments were conducted to address the basics of electrode montage and the interaction between the two electrodes. The initial studies addressed response incidence, optimal stimulus rates, type of stimulus, stimulus envelope, and effects of the various disorders on the presence and morphology of the recordings. Since the test's introduction, the waveform shape, laterality and morphology of the response have been questioned by many authors, including the tests' pioneers. The first discussions regarding application of conventional electrode montage - active electrode to the belly of the muscle versus reference electrode - unfortunately did not cause any investigators to explore the electrode array's effect on the waveform morphology and laterality of the response. To date, there are very few reports on the subject. The possibility of electrode interaction, cross-talk, and EMG potential contamination has received minimal investigation. The lack of standard electrode montage that addresses cross talk among the electrodes, lack of agreement on the laterality of muscle contraction, and lack of agreement on sound delivery and recording makes it very difficult if not impossible to compare the studies and reach a valid conclusion.

Active electrode position on the upper part of the muscle demonstrates the largest potentials, but due to the difficulty of finding the area, the belly of the muscle is used in routine recording as it reveals a more consistent response waveform morphology. My previous study revealed that the belly of the muscle is not the optimal recording site. It is a well-known fact in the electrodiagnostician community that if the endpoint zone electrode is repositioned to another position, a large triphasic, initially positive, far-field potential will be recorded. This is one reason why some of the VEMP studies have reported such responses.

Bipolar EMG signals with high temporal resolution indicate propagation of activities along the muscle fibers and a rather small effect of non-propagating signal components. When dealing with a large muscle and high levels of electromyogenic activity, the cross talk between the electrodes could be significant, especially in patients with small potentials due to muscle or nerve disorders.

The effect of the reference electrode position on the potentials as well as on the EMG recording in general has not been extensively evaluated in the neurophysiologic literature. It has been shown that the reference electrode registers the electrical activity as a far-field or volume-conducted potential. This is the potential that is recorded at a distance from the signal generator. The amplitude of this potential remains relatively constant, even when the position of the recording electrode is changed slightly. Potentials from muscles further away may also reach the recording site through volume

conduction, thus contributing to the EMG signal contamination. This phenomenon is referred to as ‘crosstalk’. In bipolar recordings, as much as 30% of a signal detected directly over the active muscle can be detected at ‘inactive’ sites. The possibility of muscular electrical activity being recordable at sites other than over the sternocleidomastoid (SCM) and inferior oblique muscle belly has received minimal attention. There are a few studies addressing this issue for cVEMP, but no clear conclusion has been drawn and no standard protocol has been suggested to reduce the possibility of electrode cross-talk. The interaction between the electrodes while recording the oVEMP seems to be a more serious issue. The extra-ocular muscles have rich innervation, with many small motor units that allow them to be activated during rapid eye movements to produce rapid synchronous discharge. It is not surprising that they produce significant electrical activity during the initiation of rapid eye movements, which spreads over a wide area. Recent convergent evidence has demonstrated that under some conditions, extraocular EMGs can be recorded from the face and scalp. Given that electrodes placed around the eyes typically overlie more than one extra-ocular muscle, the recorded surface activity represents the sum total activity from nearby muscles.

It is clear that the VEMP parameters are affected significantly by testing conditions and technical pitfalls. Ambiguities also exist in the interpretation of VEMP tracings. The implication of the cross-talk between electrodes is not yet clear, but certain issues come to mind. The issues related to reproducibility, laterality of the response, absence or presence of a small response in patient muscle weakness or demyelinating diseases can be addressed by basic investigation. There are certain issues that needed to be answered so the test and its results can become universally comparable and reliable. Should the electrode locations for motor nerve recording be modified so that the response better reflects the activity at only one electrode? Does conduction block and abnormal CMAP dispersion predominantly affect nerves that have a major contribution from the reference electrode to the recorded CMAP? If so, are the configuration changes that result from muscular or nerve disease related to abnormalities in the axons innervating a larger group of muscles, or are the changes due to aberrations in the axons supplying the muscle directly under the active electrode? The study of the distribution of conduction velocities and potential distributions across multiple recording points will address this question to some degree. What would that type of analysis show when reformatted for a contributing reference electrode?

Until the basic parameters for VEMP recording have been adequately addressed, interpretation of the recording and waveform morphology analyses will be biased by possible electrode cross-talk and their locations. This issue will make data comparison difficult, and questions regarding the response laterality and morphology will remain un-answered. I urge our research community and audiologists to consider reviewing the VEMP literature and attempting to address some of the unsolved basic questions which will help us to better understand the physiology of electromyogenic potentials and how to optimize their recording and interpretation.