OPTIMAL STIMULUS ELECTRODE DIPOLE ORIENTATION

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ABSTRACT

The elicited M-Wave that results from the surface stimulation of the median nerve is highly dependent upon the geometric orientation of the stimulus electrode dipole. This phenomenon could make standardization of M-Wave measurements between tests performed on a single subject problematic. We present an experimental paradigm that illustrates this variability in terms of an estimate of the slope of the M-Wave peak potential versus stimulus current amplitude and the minimum stimulus current required to consistently elicit a minimal response. The design of an automated instrument for selecting the optimal stimulus electrode dipole orientation based on the electrode orientation experiment is proposed.

INTRODUCTION

In EMG studies designed to measure elicited M-Wave from an electrical current stimulus, the stimulus electrode dipole is routinely placed roughly parallel to the direction of the nerve trunk [1]. This convention is particularly evident when measuring the M-Wave response of the thenar muscle with the stimulus electrodes placed over the median nerve at the wrist. There is a significant variability in the peak amplitude of the elicited M-Wave response that results from the same stimulus current amplitude used when the geometric orientation of the stimulus electrode dipole is varied. Standardization of the M-Wave response between tests performed on the same subject is therefore not only dependent on consistent positioning of the stimulus electrode dipole but also on consistent orientation of the dipole. Even in the case where the maximum M-Wave is required, electrode orientation could result in a reduced M-Wave for deep lying nerves because of clinical stimulus current limitations.

The factors contributing to the difference in the elicited response with varying stimulus dipole are many and varied. These factors include, among others, the anisotropic and inhomogeneous electrical properties of the tissue medium surrounding the nerve trunk as well as that of the nerve trunk itself [2]. Orientation of the stimulus field relative to the direction of the nerve fibers is also a factor [3].

In practice it is difficult to isolate, with confidence, the dominant effect associated with the observed variability in the M-Wave response amplitude for different electrode orientations. It is possible to measure fairly consistent trends associated with the M-Wave peak amplitude and the electrode orientation for different subjects. The electrode orientation experiment paradigm can then be used to propose a design of an instrument for automated selection of optimal stimulus electrode dipole orientation.

STIMULUS ELECTRODE ORIENTATION EXPERIMENT

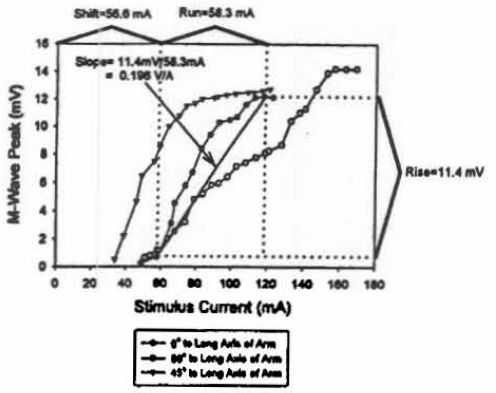

Figure 1. Graph of M-Wave peak amplitude versus stimulus current pulse amplitude for three different electrode orientations illustrating calculation of the parameters associated with the electrode orientation experiment. A 50 µs stimulus pulse width was used. The quoted values were estimated from the graph.

We measured the M-Wave peak amplitudes resulting from median nerve stimulation in five adult male subjects for three different stimulus electrode orientations relative to the long axis of the upper arm. A stimulus electrode dipole was placed proximal to the elbow joint on the medial side of the upper arm associated with the test subject's non dominant hand. Recording electrodes were positioned on the thenar muscle of the associated hand. M-Wave peak amplitudes were measured over a range of stimulus current intensities for three different electrode orientations of zero degrees relative to the long axis of the upper arm, forty-five degrees and ninety degrees. The variability in the responses were characterized by the slope of the M-Wave peak amplitude versus stimulus amplitude curve as well as the minimum stimulus current required to elicit a minimal M-Wave response as illustrated in Figure 1.

For the majority of the five subjects studied, the slope of the M-Wave peak amplitude versus stimulus current intensity curve was highest for the forty-five degree electrode dipole orientation. This result indicates that recruitment of motor nerve fibers at the location specified was most easily achieved at the forty-five degree orientation for most people. The trends associated with the shift parameter were not consistent for different subjects.

PROPOSED INSTRUMENT DESIGN

The stimulus electrode orientation experiment discussed above can be used as the design basis for an instrument that would automate the detection of the optimal stimulus electrode orientation. A block diagram of the prototype instrument that was implemented is illustrated in Figure 2.

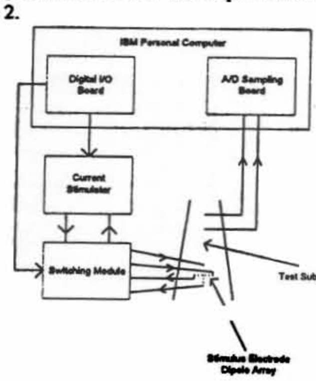

Figure 2. Block diagram of optimal electrode orientation selection instrument. A current stimulator (Dogwood CMS1-200) output is routed between different stimulus electrode dipoles by way of a switching module under computer control. An A/D sampling board records the resultant M-Wave. The instrument prototype consisted of three independent stimulus current dipole paths.

In the instrument, the stimulus current is alternately routed, under computer control, through an array of stimulus electrode dipoles each oriented at a different angle. This task is accomplished by way of a custom designed switching module. A custom designed amplifier module and eight bit A/D sampling board is used to detect and record the resultant M-Wave from which the peak value can be determined.

In the electrode orientation experiments, gross changes in the dipole orientation were investigated. In routine clinical situations, it is unlikely that such extreme variations in electrode orientation would be encountered however variations from five to fifteen degrees could reasonably be expected. The electrode dipole array used in the automated instrument could be designed to test for orientation differences within a range of plus or minus twenty degrees relative to the estimated orientation of the nerve trunk. An instrument design could also be implemented with more than three independent current dipole paths thus allowing for a finer differentiation of the optimal stimulus electrode dipole orientation.

DISCUSSION

We have presented an experiment that demonstrates the differences in the M-Wave response associated with different stimulus electrode dipole orientations for a range of stimulus current amplitudes. Although the reason for these variations is difficult to isolate, it is possible to use the experiment as a basis for the design of an instrument for selecting the optimal stimulus electrode dipole orientation. A proposed design for this type of instrument has been presented and could conceivably assist in the quantitative standardization of M-Wave responses between tests performed on the same subject.

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