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Application Note 111 Nerve Conduction Velocity

This application note details how to measure nerve conduction velocity along the ulnar nerve of a human subject. This is a standard site for nerve conduction velocity measurement due to the relatively large size of the nerve and easy access of the forearm. Other nerves may be used, however. This note is intended for use with Acq*Knowledge* software versions 4 and higher using MP160 or MP150 data acquisition hardware. Contact BIOPAC for information about earlier hardware or software versions.

NOTE: Nerve Conduction Velocity (NCV) measures should use a wired setup.

- Wireless BioNomadix have a variable timing jitter of ±0.5 ms rms, due to digital data buffering and wireless transmission, and are not recommended for NCV applications or any other physiological measurement where equivalently small timing differences are being measured; instead, BIOPAC recommends our wide range of wired amplifiers, such as EMG100C.

Overview

Nerve conduction velocity is the speed at which an electrical stimulus signal passes through the nervous system. If an electrical stimulus is applied externally to a nerve fiber, a current flows from the positive stimulating electrode into the interior of the neuron and leaves again at the negative electrode. If the charge reaches a certain threshold level, then the cells in the nerve depolarize and an action potential is set off.

The speed of this action potential, or nerve conduction velocity, can be measured by recording the amount of time it takes for the charge to travel from the stimulus electrodes to recording electrodes located somewhere else along the nerve. Given this information you can then divide the physical distance between the two electrode sites by that length of time to find the velocity. This information is useful in determining the status of the nervous system and whether or not there are any deficiencies in the conduction of electrical information throughout the body.

When choosing an appropriate nerve on a subject, several basic factors should be kept in mind: size (diameter) of the nerve itself, ease of electrode placement, and accuracy of nerve length measurement.

Equipment Required

- MP160 data acquisition system (including HLT100C or AMI100D) or MP150 data acquisition system (including UIM100C)
- One (1) STM100C
- One (1) EMG100C
- One (1) STMISOC
- Two (2) EL500 electrode pairs
- One (1) EL503 electrode
- Three (3) LEAD110 electrode leads
- Two (2) LEAD110S shielded electrode leads
- Fabric tape measure or other flexible length measuring instrument

Hardware Setup

1. Set the STM100C to: OUT 0, 0% LEVEL, POS, and DC.
2. Set the EMG100C to: Channel-2 (on top), Gain-2000, LP-5 kHz , 100 Hz HP-OFF, and HP-10 Hz.
3. Attach the STM100C to the left side of the HLT100C/AMI100D or UIM100C.
4. Attach the EMG100C to the right side of the HLT100C/AMI100D or UIM100C.
5. Plug the cabled end of the STMISOC into the EXT STIM outlet on the STM100C.
6. Plug two LEAD110 into the side of the STMISOC.
7. Plug one LEAD110 into the EMG100C "GND" port.
8. Plug two LEAD110S into the EMG100C (black wire into "Shield").

Figure 1: Amplifier setup and lead connections for recording nerve response

Electrode Connections

The electrode connections for setting up a nerve conduction velocity test consist of a pair of stimulating electrodes and a pair of recording electrodes (including a ground). The electrodes to be used for stimulating the nerve should be BIOPAC EL500 dual electrodes (or any suitable replacement). These disposable, pre-gelled electrodes come in connected pairs which are 1 5/8" apart (center to center). Please review the stimulation safety guidelines.

1. Place an EL500 dual electrode lengthwise along the ulnar nerve over the elbow, on the posterior side of the arm.
   - This is the stimulating electrode.
   - The optimal location is shown below. To find the exact placement, hold your left arm out in front of you, palm up (assuming you are the subject). Using your right hand, feel the two bones on the bottom/inside of your elbow. The ulnar nerve travels between these two points. Place the EL500 dual electrode directly on the ulnar nerve as it runs lengthwise between these two bony projections.
2. Place another EL500 dual electrode lengthwise along the ulnar nerve at the inside of the wrist, slightly toward the little finger (see Figure 2 below).
   - These are the recording electrodes and will pick up the responses to the initial stimulus after they are propagated along the ulnar nerve.

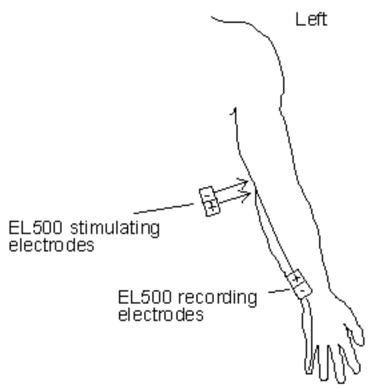

Figure 2: Electrode placement on the left arm (note the polarity)

3. Place an EL503 electrode somewhere on the same arm, preferably either slightly above or below the elbow.
4. Connect the pair of LEAD110 from the STMISOC to the EL500 stimulating electrodes (over the elbow).
5. Connect the pair of LEAD110S from EMG100C VIN+/VIN- to the EL500 recording electrodes (on the wrist).

- Note the polarity shown in the diagram below. This is important so that you get two easily measured positive peaks.

6. Connect the LEAD110 from EMG100C GND to the EL503 electrode to create a ground.

Optional Setup - Multiple recording points

You can use multiple recording electrodes instead of a single set of recording electrodes to determine nerve conduction velocity. Simply place another set of recording electrodes anywhere along the ulnar nerve, making sure they are all in-line with the ulnar nerve. You can then measure the time and physical distance it takes the stimulus to pass by one set and reach the next. This setup can be used to verify the nerve conduction velocities found using the basic setup.

STIMULATION SAFETY GUIDELINES

When using the STMISOC, it is possible to generate voltages as high as 200 v p-p. These voltages are potentially dangerous, especially if the stimulator's high voltage outputs are connected across the subject's heart. Across the heart means that the heart is potentially in the electrical path from lead to lead; this potentially dangerous situation occurs when the stimulation electrodes are placed on opposite sides of the subject's body.

NEVER PLACE STIMULATION ELECTRODES ON OPPOSITE SIDES OF THE SUBJECT'S BODY!
Always use the stimulator with the leads placed in relatively close proximity to each other and relatively far from the heart, and with the leads placed only on the SAME side of the body. The figure in Electrode Connections illustrates correct connection techniques when using the STMISOC.

CAUTIONS FOR USE!

Even the safest stimulation units, if used incorrectly, can cause serious harm. The following points illustrate fundamental rules for using stimulus isolation units to stimulate subjects.

1. NEVER APPLY THE STIMULUS SIGNAL IN SUCH A MANNER AS TO CAUSE CURRENT TO FLOW THROUGH THE HEART.

Primarily considered, this rule implies that stimulation leads should never be split apart so as to be able to touch opposing sides of the body surrounding the heart. For example: NEVER CONNECT THE STIMULUS ISOLATION UNIT SO THAT ONE LEAD TOUCHES THE LEFT ARM AND THE OTHER LEAD TOUCHES THE RIGHT ARM. Both stimulus leads [(+) and (-)], should be applied to the SAME side (left or right) of the subject's body.

Furthermore, always stimulate AWAY from the heart. Stimulation probes (such as BIOPAC's EL350 or the EL351), which constrain the distance from the positive stimulation output to the negative stimulation output, should always be used for skin surface stimulation of nerve or muscle. The EL350 or the EL351 stimulation probes fix the distance between stimulation outputs to 35mm. It is not recommended that this distance be increased for skin surface stimulation of nerve or muscle. An increase in this distance simply allows stimulation currents to circulate over a larger area, which is usually not necessary for nerve or muscle stimulation scenarios.

2. Always start the stimulation process with the stimulator control set the LOWEST possible level.

The control for the STMISO series stimulus isolation units is located on the STM100C stimulation module. Set the control knob to the 0% level, prior to the onset of the stimulation protocol. During the protocol, increase the stimulus intensity by SLOWLY turning the control knob towards the 100% level. Stop increasing the intensity at the first sign of subject discomfort.

IMPORTANT NOTES!

A. It takes as little as 15 micro-amps directed across the heart to instigate ventricular fibrillation.

This situation can be readily achieved by using sub-surface stimulation needle electrodes that insert directly into the heart. It is considerably more difficult to achieve ventricular fibrillation on the same heart using surface electrodes, but it is possible to do so, evidenced by the performance of cardiac defibrillation units used in hospitals or by paramedics.

B. Qualified experienced professionals should supervise any protocols where electrical stimulation is applied to human subjects.

Electrical stimulation protocols are not simple. Please contact BIOPAC Systems for any questions regarding the use of BIOPAC's stimulation units or accessories.

REGULATORY STANDARDS

The harmonized, international regulatory standard relating to the safety of nerve and muscle stimulators is **IEC 601-2-10**. Certain stimulation equipment is excluded from this standard, such as stimulators intended for cardiac defibrillation; however, for the purposes of defining relevant safety metrics for BIOPAC's STMISO series stimulation units, this standard is quite relevant.

BIOPAC' s STMISO series stimulation units are designed in such a manner that the power available to stimulate the subject is limited. This limitation of power is achieved through the use of stimulus isolation transformers which have physical constraints (due to their size and construction) which absolutely in accordance to known physical laws—constrain the maximum transferable power to be no more than a specific level.

Section **51.104** of the **IEC 601-2-10 standard** clearly specifies the limitation of output power for a variety of wave types.

- For stimulus pulse outputs, the maximum energy per pulse shall not exceed 300 mJ, when applied to a load resistance of 500 ohms.
- For stimulus pulse outputs, the maximum output voltage shall not exceed a peak value of 500 V, when measured under open circuit conditions.

All BIOPAC STMISO units employ stimulus isolation transformers that limit the output pulse width to 2 ms maximum, under 500 ohm load conditions. In addition, the highest available output voltage is 200 V pk-pk (STMISOC) under open circuit conditions.

For the pulse energy calculation for STMISOC:
Joules = Watts x Seconds
Watts (instantaneous maximum) = (200 V x 200 V) / 500 ohms = 80
Joules = 80 W x 0.002 seconds = 0.16 Joules = 160 mJ

Accordingly, the highest possible energy output using the STMISOC is 160 mJ. In all cases the maximum available energy, from the STMISO series stimulus isolation units, is limited to be considerably less than the 300 mJ maximum as specified by IEC 601-2-10.

BACK TO ELECTRODE CONNECTIONS

Software Setup

1. Under **Set Up Data Acquisition > Channels**, set Analog Channel 2 to acquire and plot data. Label it "Nerve Response" or any other appropriate name.
2. Under **Set Up Data Acquisition > Length/Rate**, set the sampling rate to 10,000 Hz, acquisition length to 20 msec, Autosave file, and record to MP160/150.
3. Under **Set Up Data Acquisition > Stimulator**, create a 10 volt square wave with a 200 µsec (.2 msec) pulse width to be output once on Analog Output 0 (as shown below in Figure 3).
   - Note that the pulse is 1 msec after the beginning of the acquisition. You must take this into account when measuring the response time.

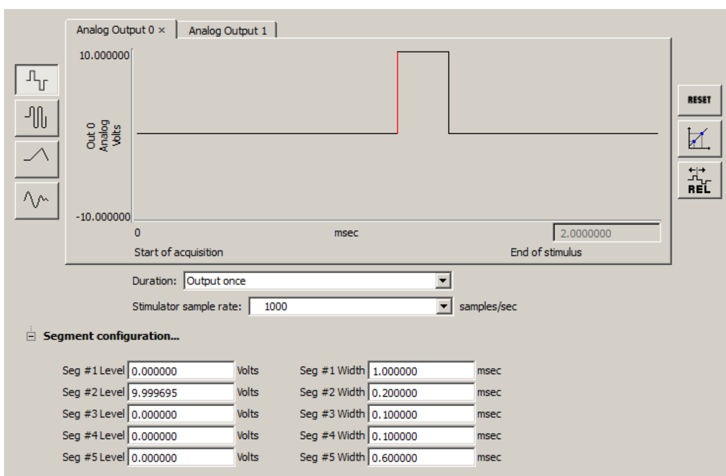

Figure 3: Stimulator setup window for Nerve Conduction Study

Procedure

1. Power up the MP unit.
2. Launch the Acq*Knowledge* software.
3. Before you begin the experiment, check to make sure that the STM100C Level attenuation knob is turned to 0% (for safety purposes, this denies any voltage from leaving the MP unit).
4. Use the Level attenuation knob to control the intensity of the stimulus output through the electrodes. Start with **0** (zero) Volts and increase slowly.

5. Increase the Level for each successive acquisition until the required threshold is reached.
    - For some subjects it may be as low as 40 or 50%; however 90% is not uncommon. If the voltage is too low, your waveform will appear as a rather flat line with only an early spike which represents the stimulus itself, but not the response to it. When the threshold is reached, you will begin to see a positive response approximately 5 msec after the stimulus.

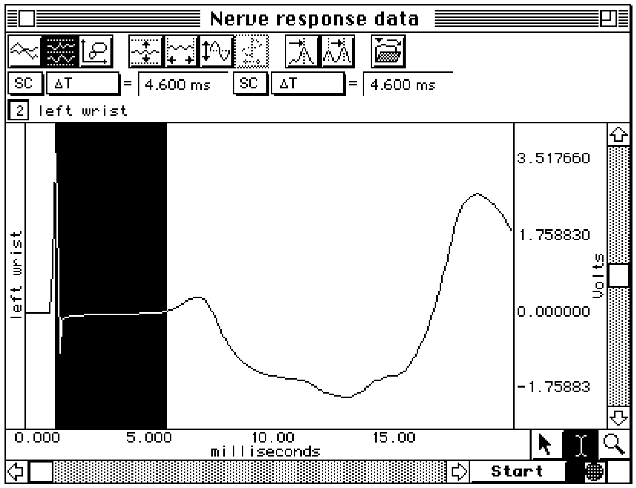

Figure 4: Sample waveform of nerve response near the wrist

Waveform Analysis

Once you have found an appropriate threshold and suitable data has been collected, analysis can take place.

1. Scale the waveforms so that only the stimulus and the response are displayed in the graph window.

   The most easily recognized portion of the waveform is the "twitch" response which is the large dip centering around 7-17 msec in the waveform above. This is the response that the subject's arm gives at the time of stimulation. It is due to the contraction of the electrically stimulated muscles in the vicinity of the stimulating electrodes.
    - An early spike will occur in the waveform which represents the response to the stimulus as it is conducted by the skin. This period of time is virtually instantaneous as it is determined by the speed of electricity. This spike will be our point of measurement for determining the point of stimulus.
    - In addition to the stimulus peak, there will be a peak at approximately 5 msec representing the response to the stimulus along the ulnar nerve.
2. Use the I-beam tool to select the area between the stimulus and the onset of the response; the exact point for measurement will be the first onset of the nerve response.
3. Use the measurement pop-up windows to determine the time between the stimulus and the onset of the response (delta t measurement).
4. Use a tape measure to determine the (external) distance that the stimulus traveled along the nerve.
    - Determine the exact distance (in centimeters) between the midpoint of the stimulating electrodes and the midpoint of the recording electrodes. The measured distance should be about 20-30 centimeters depending on the size of the subject.
5. Divide the distance by the time measurement to determine the speed.
    - Average nerve conduction velocities are in the range of about 45 to 55 meters per second. At this rate it would take a signal about 5 msec to travel 25 centimeters. Variations will occur over a range of subjects.