# Experiment HN-7: Median Nerve Conduction Velocity

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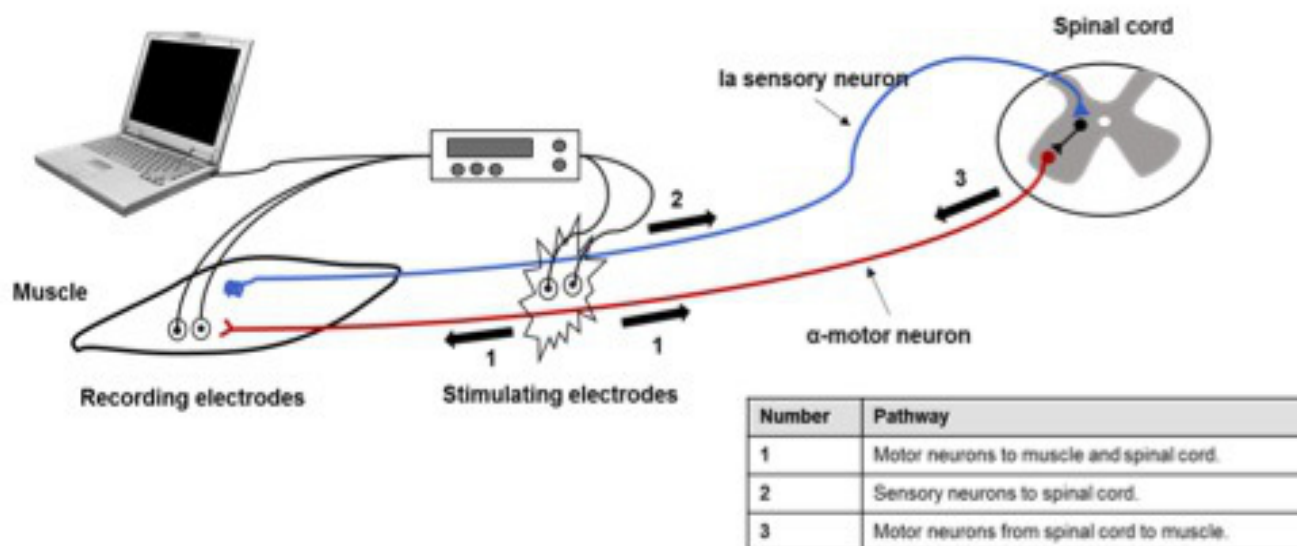
Background

In 1771 Luigi Galvani used electrical stimulation of nerves to induce contractions of frog muscles. Velocity of nerve conduction was first measured in the mid-nineteenth century and in the 1940's new technology permitted routine use of nerve conduction tests to diagnose certain neuromuscular disorders. Today, neurologists frequently assess conduction velocities of both sensory and motor nerves. A nerve conduction velocity (NCV) test is used to examine the strength (i.e. intensity) of the neural impulse as well as the speed at which an impulse travels along nerve fibers. When performing this test, electrical current is applied to the nerve via external stimulating electrodes. An additional set of surface electrodes is placed at the site of the effector to record changes in voltage resulting from activation of muscle fibers. The stimulating electrodes induce action potentials in nerve fibers and these impulses are propagated along the nerve fibers to stimulate numerous muscle fibers. The combined action potentials of the activated muscle cells is called a compound action potential (CAP). A CAP is a biphasic change in voltage (Figure HN-7-B1). The height (amplitude) of the CAP is determined by the number of muscle fibers activated. The width (duration) of the response is a measure of how long it takes for all of the muscle fibers to respond. The CAP is typically characterized by measuring the latency to the peak; that is, the time between the application of the stimulus and the peak voltage.
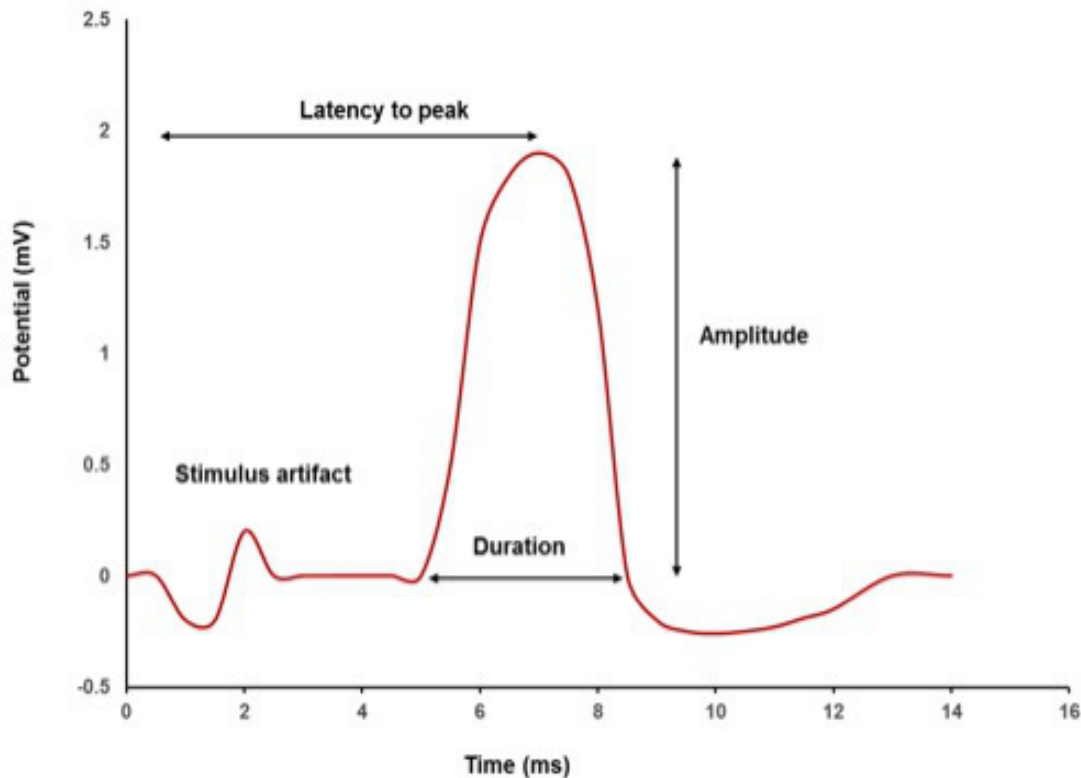
Figure HN-7-B1: Compound action potential of a muscle.

The conduction velocity of a nerve is determined in the following manner. First, the nerve is stimulated at two sites; that is, a short and long distance from the effector. The time between the stimulus and response is measured at each location. The conduction velocity ($m \cdot s^{-1}$) is the difference in distances (m) divided by the difference in response times between the two stimulation sites (s). Conduction velocities of nerves are affected by a number of biologic variables including: axon diameter, degree of axon myelination, gender, age, height, weight. Certain pathologies and environmental variables (e.g., ambient temperature) also affect the speed at which action potentials are propagated along axons.

The standard protocol for evaluating conduction in motor nerves is based on the Hoffmann Reflex (Figure HN-7-B2). Most peripheral nerves are "mixed nerves;" that is, they contain axons from both sensory and motor neurons. Stimulation of such nerves therefore induces impulses in both afferent and efferent directions. Stimulation of Ia sensory neurons causes impulses to travel to the spinal cord and activate α-motor neurons via interneurons within the spinal gray matter. The motor neurons are also directly stimulated resulting in induction of impulses that travel to the effector as well as antidromically toward the spinal cord. The antidromic impulse meets and cancels out the efferent impulse generated in the spinal cord; leaving only the impulse traveling toward the effector from the point of stimulation. The CAP induced by this stimulus is called the M wave.

Number	Pathway
1	Motor neurons to muscle and spinal cord.
2	Sensory neurons to spinal cord.
3	Motor neurons from spinal cord to muscle.

Figure HN-7-B2: Induction of the Hoffmann reflex.

The objective of this laboratory exercise is to measure the nerve conduction velocity of the median nerve. The median nerve is a major nerve of the upper limb. As illustrated in Figure HN-7-B3, it originates from the medial and lateral cords of the brachial plexus of the spinal cord, specifically C5-T1. The nerve runs parallel to the humerus in the brachial region and through the elbow joint where it enters the forearm between the pronator teres muscle and the biceps tendon. It courses along the longitudinal plane on the anterior surface of the arm before passing through the carpal tunnel to innervate the first 3 ½ digits in the palmar and dorsal regions of the hand. The motor fibers of the

median nerve control muscles that regulate movement of these digits. A motor nerve conduction study of this nerve is commonly used to diagnose carpal tunnel syndrome, a condition characterized by numbness, tingling and weakness of the hand. These symptoms are the result of disrupted nerve conduction caused by compression of the median nerve at the wrist.
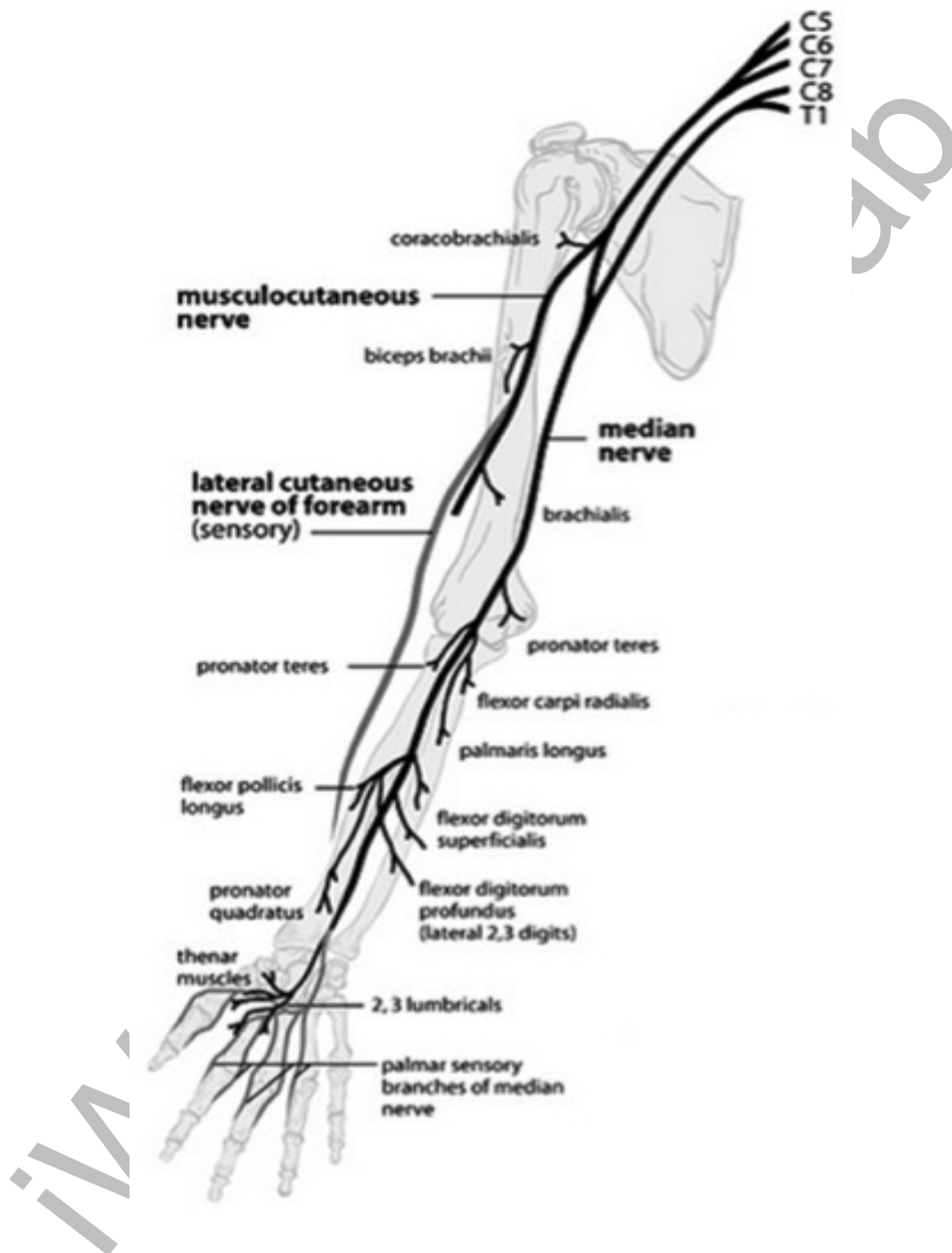
Figure HN-7-B3: Median nerve neuronal root origins from the brachial plexus and its innervations of the upper extremity (Taken from: Peripheral Nerves of the Upper Extremity. OrthopaedicsOne Clerkship. In: OrthopaedicsOne - The Orthopaedic Knowledge Network, 25 Nov. 2010. ver.2.)

Equipment Required

PC or Mac Computer

IXTA data acquisition unit

USB cable

Power supply for IXTA

iWire-B3G cable and three EMG lead wires

Disposable snap electrodes (7)

HV stimulator lead wires

IXTA Setup

1. Place the IXTA on the bench, close to the computer.

2. Check Figure T-1-1 in the Tutorial Chapter for the location of the USB port and the power socket on the IXTA.

3. Check Figure T-1-2 in the Tutorial Chapter for a picture of the IXTA power supply.

4. Use the USB cable to connect the computer to the USB port on the rear panel of the IXTA.

5. Plug the power supply for the IXTA into the electrical outlet. Insert the plug on the end of the power supply cable into the socket on the rear of the IXTA. Use the power switch to turn on the unit. Confirm that the power light is on.


Start the Software

1. Click on the LabScribe shortcut on the computer's desktop to open the program. If a shortcut is not available, click on the Windows Start menu, move the cursor to All Programs and then to the listing for iWorx. Select LabScribe from the iWorx submenu. The LabScribe Main window will appear as the program is opens.

2. On the Main window, pull down the Settings menu and select Load Group.

3. Locate the folder that contains the settings group, IPLMv6Complete.iwxgrp. Select this group and click Open.

4. Pull down the Settings menu, again. Select the MedianNerveVelocity settings file.

5. After a short time, LabScribe will appear on the computer screen as configured by the MedianNerveVelocity settings.

6. For your information, the settings used to configure the LabScribe software and the IXTA unit for this experiment are programmed on the Preferences Dialog window which can be viewed by selecting Preferences from the Edit menu on the LabScribe Main window.

7. Once the settings file has been loaded, click the **Experiment** button on the toolbar to open any of the following documents:

    • Appendix

- Background
- Labs
- Setup (opens automatically)

The Equipment Setup

1. The subject should remove all jewelry from his/her right hand and wrist.

2. Clean the areas where the electrodes will be attached with an alcohol swab (Figure HN-7-S1). Abrade the skin in those areas.
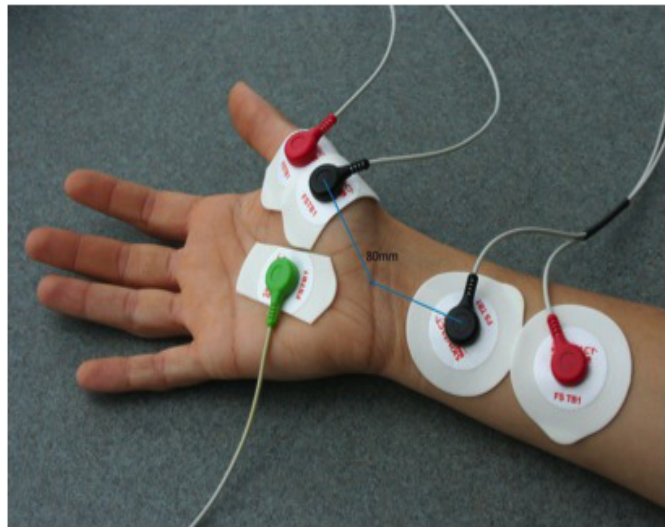
Figure HN-7-S1: Electrode and lead placement for the 80mm measurement. The red and black recording leads are placed on the thumb, the green ground lead is placed in the center of the palm, and the red and black stimulating leads are placed just above the wrist crease.

3. Obtain seven disposable electrodes.

4. Locate and mark the sites listed in Table HN-7-S1; place electrodes over these locations and attach the colored recording leads (Figures HN-7-S1 and S2). *Note: It may be necessary to trim the adhesive of the electrode to prevent overlapping.*

   - Center of the palm: Ground (Green).
   - Slightly distal to the first metacarpophalangeal joint: Recording '+' (Red).
   - Midway between the first metacarpophalangeal joint and the wrist crease: Recording '-' (Black).

5. Locate and mark the following sites, place electrodes over these locations and attach the colored stimulating leads which must be connected directly to the iWorx TA at the red and black stimulator channels.

   - Short distance (80 mm):
     - At the center of the wrist crease 50 mm from the Recording '-' (Black) lead and then 30 mm superior to the center of the wrist crease along the midline of the forearm: Stimulating '-' (Black) lead.

- On the midline of forearm, proximal to the Stimulating '-' (Black) lead: Stimulating '+' (Red) lead.
  - Long distance:
    - In the cubital region where the brachial pulse can be detected (i.e., in the groove between the biceps brachii and brachialis muscles): Stimulating '-' (Black) lead *Note: This location will vary among subjects, so measure the distance between this site and the black recording electrode.*
   - On the medial side of the brachial region proximal to the Stimulating '-' (Black) lead: Stimulating '+' (Red) lead.

Table HN-7-S1. Summary of Electrode and Lead Placement

Electrode	Lead	Placement
Ground - From iWire-B3G	Green	Placed in the center of the palm.
Recording '+' From iWire-B3G	Red	Placed just distal to the first metacarpophalangeal (MCP) joint.
Recording '–' From iWire-B3G	Black	Placed along the pollicis brevis muscle, the midpoint between the first MCP joint and the wrist crease.
Short Stimulating '–' From iWorx TA box	Black	80mm from recording '–' electrode. Measure 50mm from the recording- electrode toward the center of the wrist crease. Then measure 30mm superior to this point along the midline of the arm.
Short Stimulating '+' From iWorx TA box	Red	Placed just superior to the short stimulating '–' electrode, along the same axis.
Long Stimulating '–' From iWorx TA box	Black	Placed at a point just medial to the biceps brachii tendon region, along the median cubital vein. (Confirmation: find the brachial pulse and place the electrode mark just medial to it.) Record the distance between this point and the recording '–' electrode (in mm).
Long Stimulating '+' From iWorx TA box	Red	Placed just superior to the long stimulating '–' electrode, along the median cubital vein.

6. Attach the connector on the end of the iWire-B3G cable to the iWire 1 input of the front of the IXTA (Figure HN-7-S2).

Note – Connect the iWire-B3G cable to the IXTA prior to turning it on.
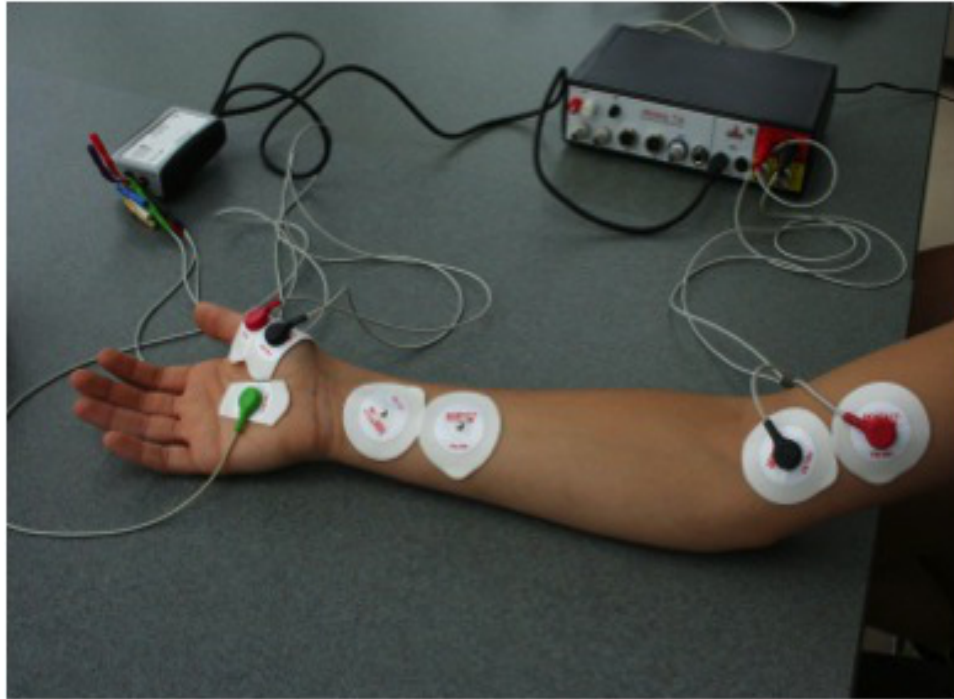
Figure HN-7-S2: Electrode and lead placement for the more distant site (cubital region). The red and black recording leads are placed on the thumb, the green ground lead is placed in the center of the palm, and the red and black stimulating leads are placed in the cubital region as the median nerve runs towards the arms midline.

IXTA Isolated Stimulator

The IXTA has a high voltage stimulus isolator designed to deliver constant current to the nerve or muscle being studied. In situations where the resistance (R) along the path of the current increases, the voltage (V) increases to maintain the current (I in V = IR, Ohm's Law). The ability of the IXTA to adjust the voltage to deliver the required current is known as voltage compliance. The upper limit of this compliance by the IXTA is set at 100 Volts.

Constant current devices differ from constant voltage devices when presented with an increase in resistance, like the dehydration of the conductive gel under the electrodes. As pointed out earlier, a constant current stimulator is voltage compliant. In constant voltage stimulators, the current delivered to the tissue decreases as the resistance increases because the power supply of the constant voltage device is not designed to deliver additional current.

Although the IXTA can generate up to 100 Volts, the current delivered by the unit is limited to a maximum of 20 milliamperes, for a maximum duration of 10 milliseconds per pulse, and a maximum frequency of 50 pulses per second (Hz). At these levels, the maximum amount of power delivered by the IXTA will not cause injury or tissue damage.

The current is selected using the Stimulator Control Panel. The HV Stimulator can deliver a maximum output of twenty milliamperes

The duration, frequency, and number of stimulus pulses generated by the stimulator are also controlled by making changes to the values in the Stimulator Control Panel. The initial values of the pulses generated by the IXTA are programmed by the same settings file that configured the recording

software. For example, if a pulse from the IXTA is programmed for a duration of 1 millisecond and a frequency of 1 Hz, the stimulator will generate a stimulus pulse with the same duration and frequency.

IXTA Stimulator Setup

1. Place the IXTA (Figure HN-3-S3) on the bench near the subject.

Warning: Before connecting the IXTA stimulting electrodes to the subject, check the Stimulator Control Panel to make sure the amplitude value is set to zero (0).

Note: Disconnect the subject from the IXTA prior to powering off the device.

2. Instruct the subject to remove all jewelry before beginning the experiment.
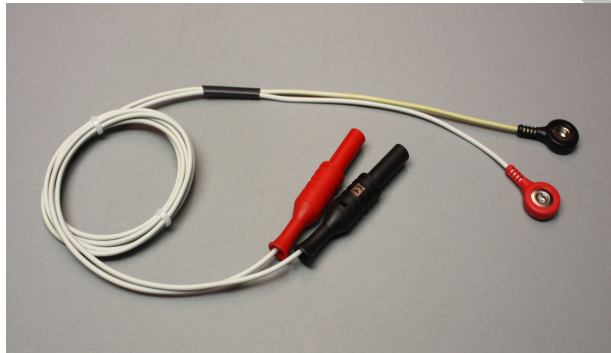

Figure HN-3-S3: The IXTA stimulating electrodes.

Figure HN-7-S4: The front panel of the IXTA with the stimulating electrodes connected correctly.

Warning: Make sure the Amplitude is set to zero.

3. For any of the HVS labs, the stimulator preferences panel will initially come up showing S1, even if S1 is off - use the menu to select the HVS settings.

4. Connect the color-coded stimulator lead wires to the High Voltage Current Stimulator. Make sure you push the safety connector of each lead wire into the appropriate socket as far as possible (Figure HN-7-S4).

5. Connect the 2 stimulating electrodes as stated above.

6. Start with the stimulator programmed in this manner ([Table HN-7-S2](#)):
   - In the Stimulator window - "Time Off" will need to be changed to "Frequency"
   - On the Stimulator Control Panel that appears 2 lines above the upper recording panel.
     - Amps will be the only variable changed (between 5-20 amps). Begin with 5 amps and increase until a consistent response is achieved (7 amps has yielded consistent results).
     - Make sure to hit *APPLY* after choosing the settings.

Table HN-7-S2: Settings on the Stimulator Window Used to Configure the Stimulator of the IXTA for Experiment HN-7.

Parameter	Setting	Parameter	Setting
Stimulator	HVS	Delay (sec)	0.05
Stimulus Mode	Pulse	Amplitude (mA)	5
Start Stimulator with Recording	S	Pulses (#)	1
Time Resolution (msec)	0.01	Pulse Width (msec)	2
Toolbar Step Frequency	1	Frequency (Hz)	1
Toolbar Step Amplitude (V)	0.1	Time-Off Amplitude (V)	0
Toolbar Step Time (sec)	0.1	Holding Potential (V)	0

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WARNING - The Stimulator should only be used for the method of application for which the Stimulator is intended as shown in the directions below.

Note: Disconnect the subject from the IXTA prior to powering off the device.

NOTE: If using the IXTA and built in HV stimulator – all changes in Amplitude are entered directly into the Stimulator Control Panel. Click "APPLY" to make any changes.

Exercise 1: Stimulus Strength and Muscle Response.

Aim: To determine the effect of stimulus strength on the response of the innervated muscle.

Procedure

1. Ask the subject to place his or her right hand on the bench with the palm up. Tell the subject to relax.

Note: The subject should make sure to relax his/her forearm and hand completely. Any tensing of the muscles would interfere with the recording.

2. Set the Amplitude knob on the front panel of the SI-200 unit to zero or in the Stimulator Control Panel for the IXTA.

3. Click Record button on the LabScribe Main window. LabScribe will record a single sweep with a display time of 50 milliseconds. Since the output amplitude is set to zero, there should be no response from the abductor muscle.

4. Increase the output amplitude of the SI-200 by rotating the Amplitude knob one half turn to the 0.5 position which is equivalent to 1 mA or change the amplitude in the software for the IXTA. Click the Record button again and record another single sweep. Click the AutoScale button for the Muscle channel to improve the display of the muscle's response (Figure HN-7-L1).

5. Continue to increase the output amplitude of the SI-200 by rotating the amplitude knob one half turn at a time or by changing the amplitude in the Stimulator Control Panel for the IXTA.

   Note: Each turn is an increment of 0.5. A maximum of twenty is possible.

   • Click the Record button to record a single sweep after each increase in the stimulus amplitude.

   • Continue to increase the output amplitude and record the response until the muscle impulse reaches a maximum level.

6. Perform the following steps for both the short and long stimulation sites:

   • To administer the stimulus, press 'Record' in the upper right hand corner of the computer screen.
   • Repeat this procedure three times for each distance and measure the amount of time between the start of the stimulus and the peak voltage of the CAP (Figure HN-7-L1).
   Note: You many need to continue to increase the amplitude until a response is generated.

6. Select Save As in the File menu, type a name for the file. Choose a destination on the computer in which to save the file (e.g. the iWorx or class folder). Click the Save button to save the file (as an *.iwd file).
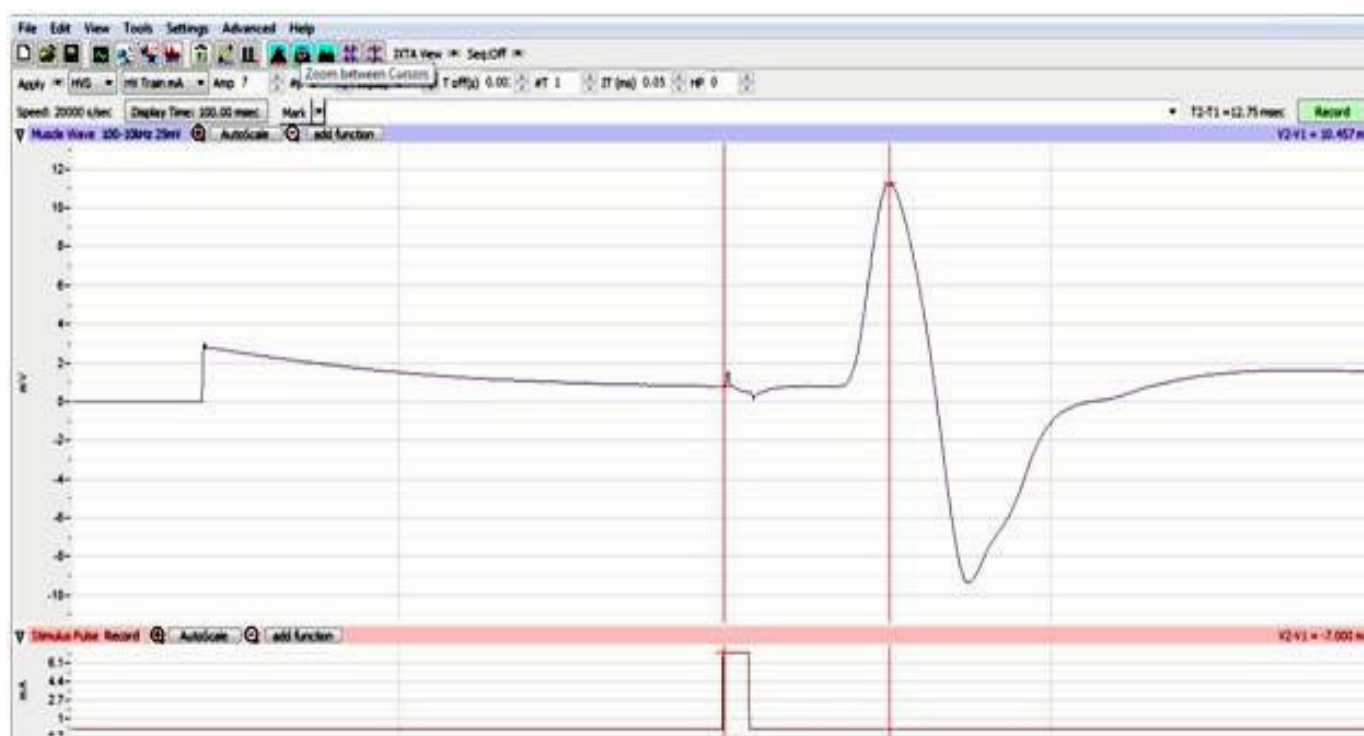
Figure HN-7-L1: A CAP from the median nerve; measuring the amount of time between the initial stimulus and the peak voltage.

Data Analysis

1. Click the Analysis icon in the LabScribe toolbar (Figure HN-7-L2) to view all the recorded sweeps.
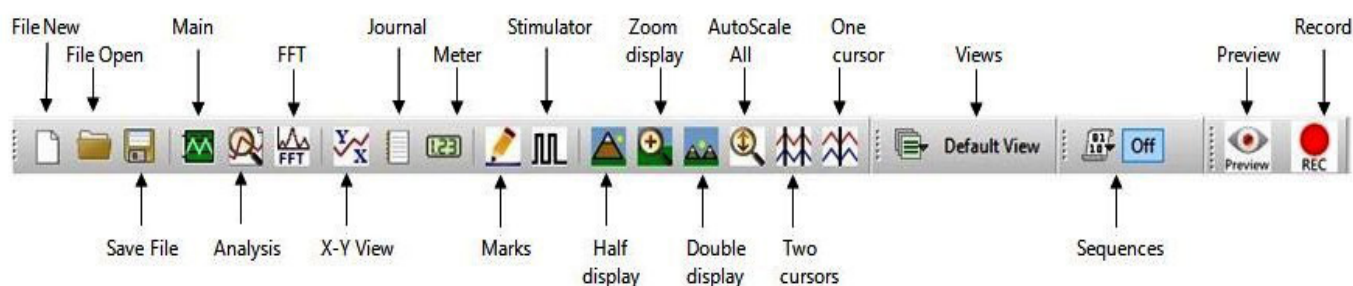

Figure HN-7-L2: The LabScribe toolbar.

2. Use the Windows control-click function to select the sweeps of interest from the Sweeps list on the bottom of the Analysis window. For comparison, superimpose the selected sweeps on each other by clicking the sweeps of interest. See Figure HN-7-L3.

3. Select Title, V2-V1, and T2-T1 from the Add Functions list if they are not already listed. Data analysis can also be performed on the main window.

4. Go to the Sweep List at the top of the Analysis Window and select the sweep that has the lowest muscle response. Selecting a sweep from this menu will display the measured values of that

sweep in the table at the top of the Analysis window.

5. Click the 2-Cursor icon in the LabScribe toolbar. Drag one cursor to the left of the stimulus artifact and the second cursor to the peak of the muscle response. The value for V2-V1 in the table at the top of the Analysis window is the amplitude of the muscle response.
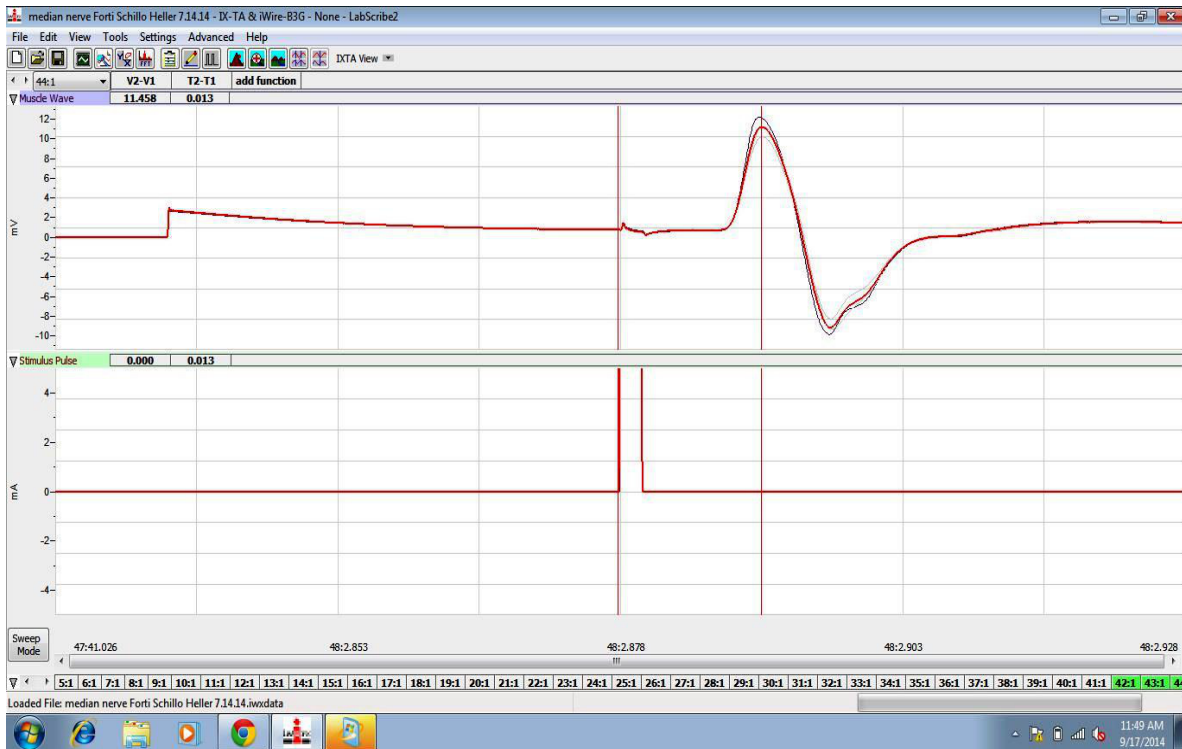

Figure HN-7-L3: Comparison of muscle responses to different stimulus amplitudes. Sweeps are superimposed in the Analysis window. Values for sweep #44 are shown.

6. The functions in the channel pull-down menus of the Analysis window can also be used to enter the names and values of the parameters from the recording to the Journal. To use these functions:

   • Place the cursors at the locations used to measure the muscle response.

   • Transfer the names of the mathematical functions used to determine the muscle response to the Journal using the Add Title to Journal function in the Muscle Channel pull-down menu.

   • Transfer the values for the change in muscle response to the Journal using the Add Ch. Data to Journal function in the muscle channel pull-down menu.

7. Record the stimulus amplitude used to generate the nerve response along with the other data for the sweep in the Journal.

8. Find the amplitudes (V2-V1) for the other selected sweeps in the same manner. Record these values and the values of the stimulus amplitudes used to generate these responses in the Journal.

9. Graph the amplitude of the muscle response as a function of the stimulus amplitude.

10. Place one cursor on the start on the stimulus and one cursor on the peak of the response and perform these calculations:

- Calculate the average amplitude of the three responses for each distance.

- Calculate the difference between the long (B) and short (A) distances (mm) =
$$D_B\text{-}D_A=\Delta D$$

- Calculate the difference in the average conduction times between the two distances (ms)
$$T_B\text{-}T_A= \Delta T$$

- Calculate the Nerve Conduction Velocity (mm/ms or m/s)
$$\Delta D/\Delta T$$

11. Repeat the procedure three times and calculate the nerve conduction velocity for each of these replicates. Calculate the average of these three measurements.

12. Table HN-7-L1 shows nerve conduction velocities in the median nerves of eight subjects who underwent the procedure outlined in this laboratory protocol.

13. According to values reported in the scientific literature conduction velocity of the median nerve ranges between 40 and 78 m·s^{-1}. All but two of the test subjects had velocities that fell within this range.

- It is noteworthy that the three lowest conduction velocities were from the three oldest subjects, one of whom was previously diagnosed with a mild case of Carpal Tunnel Syndrome. According to previous studies the mean conduction velocity of the median nerve is 57 m·s^{-1}. The mean conduction velocity measured with this protocol is 51.4225 m·s^{-1}.

Questions

1. Does the amplitude of the action potential in each fiber in the median nerve increase or do the numbers of nerve fibers in the nerve that respond increase with increased stimulus strength?

2. Does the amplitude of the muscle response increase because the response of each muscle fiber increases or the number of muscle fibers responding increases?

3. Which stimulus amplitudes are subthreshold? Which ones are suprathreshold or submaximal? Which ones are supramaximal?

4. How do conduction velocities differ by:

- age?

- gender?

- Handedness?

Table HN-7-L1. Median Nerve Conduction Velocity in Eight Subjects.

Subject	Gender	Age	Conduction Velocity (m·s^{-1})
1	F	20	67.72
2	M	44	37.59
3	F	21	62.34
4	F	19	51.19
5	F	19	52.8
6	F	63	44.9
7	M	21	58.76
8	M	61	36.08
Mean			51.42
Standard deviation			11.40

Experimental Design

Refer students to the following References and ask them to design their own hypothesis relating to nerve and muscle responses.

This can include:

- Increasing stimulus amplitude

- Reversing polarity of the stimulus

- Looking at other muscle/nerve combinations

Have them perform their experiment and compare results with other groups.

References

Buschbacher RM and Prahlow ND. 2006. Manual of Nerve Conduction Studies. 2nd ed. New York: Demos Medical Publishing; 2006. p. 10-17.

Palmieri, R. M., Ingersoll, C. D., & Hoffman, M. A. 2004. The Hoffmann Reflex: Methodologic Considerations and Applications for use in Sports MEdicine and Athletic Training Research. Journal of Athletic Training, 39(3), 268-277.