Lecture Three

The Electroneurogram

Introduction

Conduction velocity in a peripheral nerve is measured by stimulating a motor nerve at two points a known distance apart long this course. subtraction of the shorter latency from longer latency (Figure 1) gives the conduction time along the segment of nerve between the stimulating electrodes. Knowing the separation distance, we can determine the conduction velocity of the nerve, which has potential clinical value since, e.g., conduction velocity in a regenerating nerve fiber is slowed following nerve injury.

Skeletal muscle fibers (70 μm diameter) are much larger than myelinated nerve fibers (2 to 20 μm); hence the amplitude of field potentials recorded from active nerve trunks are much smaller than field potentials recorded from groups of active muscle fibers.

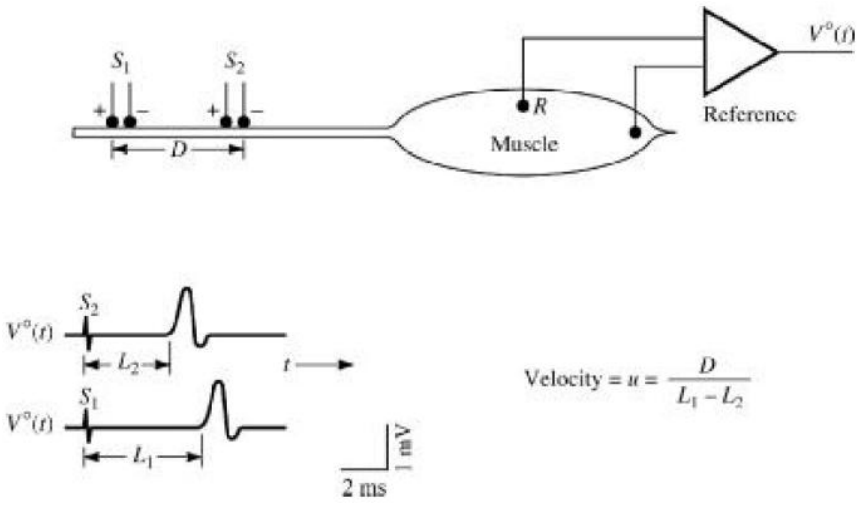


Figure 1: Measurement of neural conduction velocity via measurement of latency of evoked electrical response in muscle. The nerve was stimulated at two different sites a known distance *D* apart.

Email: mahir.rahman@uomus.edu.iq

FIELD POTENTIALS OF SENSORY NERVES

Extracellular field responses from sensory nerves can be easily measured from the median or ulnar nerves of the arm by using ring-stimulating electrodes applied to the fingers (Figure 2). Recording at two sites a known distance apart along the course of the nerve enables one to compute the conduction velocity of the sensory nerve. Long pulses cause muscle contractions, limb movement, and undesired signals (artifacts). These are avoided by positioning the limb in a comfortable, relaxed posture and applying a brief, intense stimulus (square pulse of approximately 100 V amplitude with a duration of 100 to 300 μs). A patient ground is placed at the wrist between the stimulating and recording electrodes to provide a ground point for the passive electric field coupling from the stimulating electrodes. The skin should be abraded under both the stimulating and recording electrodes to reduce skin resistance and ensure good contact.

Clinically, field potentials are recorded using high-gain, high-input-impedance differential preamplifiers with good common-mode rejection capability and low inherent amplifier noise. Figure 2 shows that the measured ENGs are on the order of 10 μV, and power-line interference is sometimes a problem even with good amplifier common-mode properties. The input leads should be properly twisted together and shielded. In addition, if warranted, the subject could be placed in an adequately shielded room or cage.

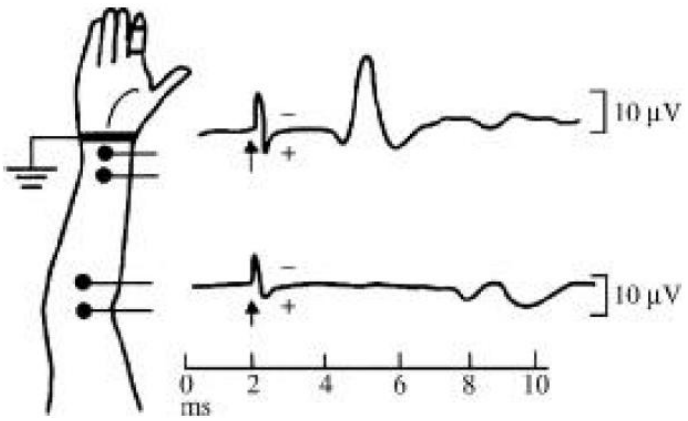


Figure 2 Sensory nerve action potentials evoked from median nerve of a healthy subject at elbow and wrist after stimulation of index finger with ring electrodes. The potential at the wrist is triphasic and of much larger magnitude than the delayed potential recorded at the elbow. The difference in magnitude and waveshape of the potentials is due to the size of the volume conductor at each location and the radial distance of the measurement point from the neural source.

REFLEXLY EVOKED FIELD POTENTIALS

When a peripheral nerve is stimulated and an evoked field potential is recorded in the muscle it supplies, it is sometimes possible to record a second potential that occurs later than the initial response. As the neural stimulus site is brought progressively closer to the muscle, the latency of the first response decreases, whereas the latency of the second response is increased. This behavior of the second response indicates that to activate the muscle, the stimulus must travel along the nerve toward the central nervous system (proximally) for some distance before ultimately traveling in the opposite direction (distally).

The latency of the second response is such that the activity could have traveled proximally along sensory nerves as far as the spinal cord to elicit a spinal reflex. If the posterior tibial nerve in the leg is stimulated, a late potential can be evoked from the triceps surae muscle (Figure 3).

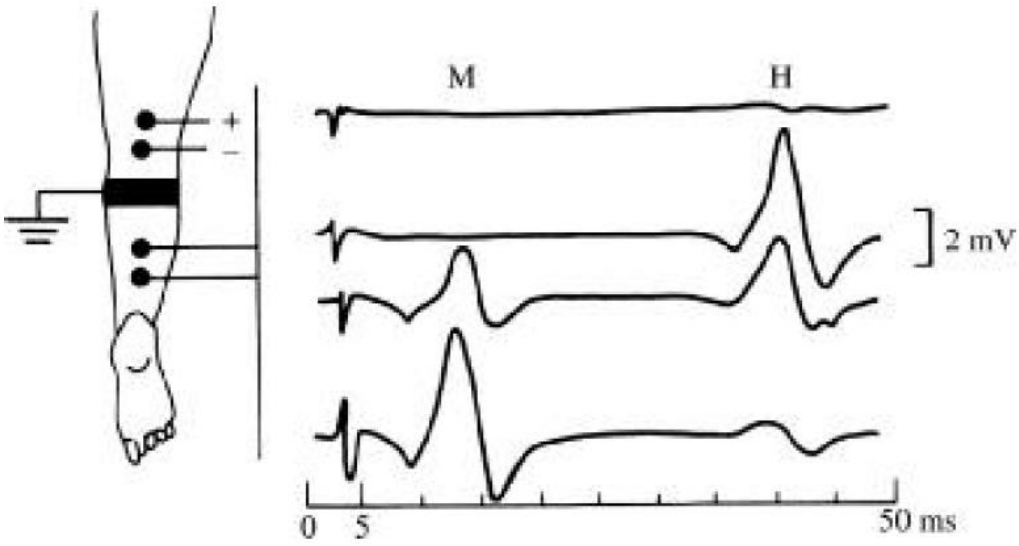


Figure 3 The four traces show potentials evoked by stimulation of the medial popliteal nerve with pulses of increasing magnitude (the stimulus artifact increases with stimulus magnitude). The later potential or H wave is a low-threshold response, maximally evoked by a stimulus too weak to evoke the muscular response (M wave). As the M wave increases in magnitude, the H wave diminishes.

Electromyograph (EMG)

Introduction

The Electromyography (EMG) is a neurophysiological technique for examining the electrical activity of skeletal muscles. The muscular membrane potential is the source of the electrical signal in an EMG. The muscle fibers innervated by the axonal branches of a motor neuron form a motor unit (MU). Each motor unit's muscle fibers are mixed with those of other MUs. The summation of action potentials of MUs is called motor unit action potential (MUAP). The anatomical and physiological characteristics of the motor system are reflected in the biosignal obtained from a muscle or its fibers.

As such, EMG recording and analysis are powerful neurophysiological techniques that can be employed to: a) identify the health status of the motor system; b) localize and typify peripheral and central abnormalities and lesions; c) determine the temporal course and the severity of motor system abnormalities, and d) determine and evaluate the effectiveness of treatment strategies.

Muscle activity can be detected during resting state or during voluntary movement. In addition, induction of compound action potential (CMAP) and motor evoked potential (MEP) can be obtained by means of peripheral nerve stimulation (PNS) and cortical stimulation, respectively. While PNS provides measurement of integrity of the peripheral motor system, cortical stimulation through techniques such as Transcranial Magnetic Stimulation (TMS), permit examining the integrity of the corticospinal tract.

Skeletal muscle is organized functionally on the basis of the motor unit (Figure 4), which consists of a single motor nerve fiber and the bundle of muscle fibers to which it is attached. The fibers of a given motor unit are interspersed with fibers of other motor units. Thus, the active muscle fibers of the single motor unit (SMU) constitute a distributed bioelectric source located in a volume conductor that consists of all other fibers within the muscle (active and inactive), blood vessels and connective tissue. The evoked field potential from the active fibers of an SMU has a triphasic form of brief duration (3 to 15ms) and an amplitude of 20 to 2000μV, depending on the size of the motor unit. The frequency of discharge usually varies from 6 to 30 per second.

One of the disadvantages of recording the EMG by using the convenient surface electrodes is that they can be used only with superficial muscles and are sensitive to electrical activity over too wide an area.

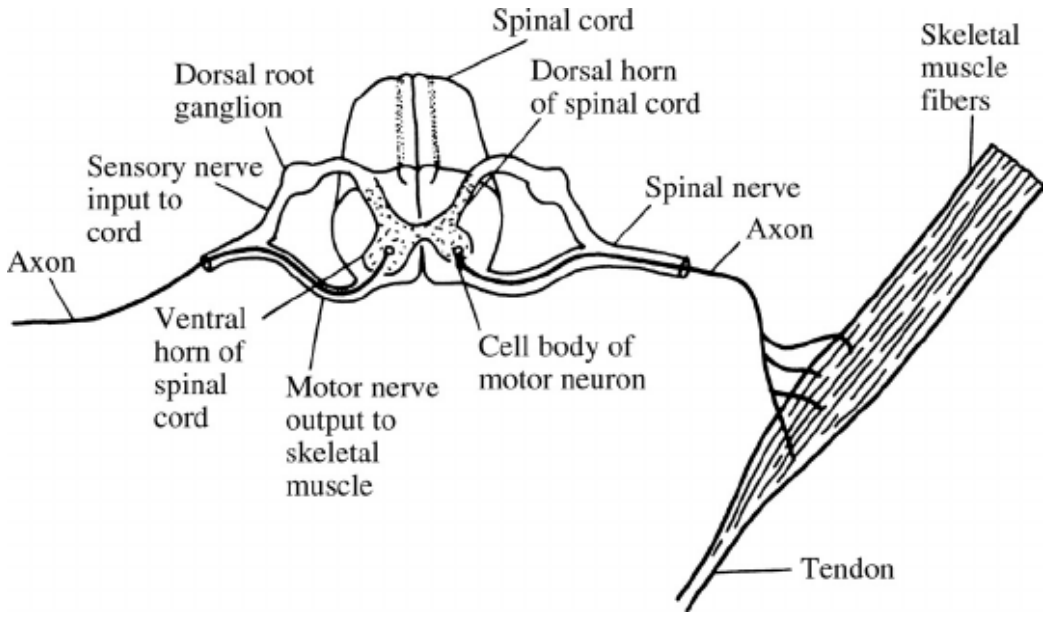


Figure 4 Diagram of a single motor unit (SMU), which consists of a single motoneuron and the group of skeletal muscle fibers that it innervates.

Various types of monopolar, bipolar, and multipolar insertion-type electrodes are commonly used in electromyography for recording from deep muscles and from SMUs. These types of electrodes generally record local activity from small regions within the muscle in which they are inserted. Figure 5 shows motor unit potentials from the normal dorsal interosseus muscle under graded levels of contraction.

At high levels of effort, many superimposed motor unit responses give rise to a complicated response (the interference pattern) in which individual units can no longer be distinguished.

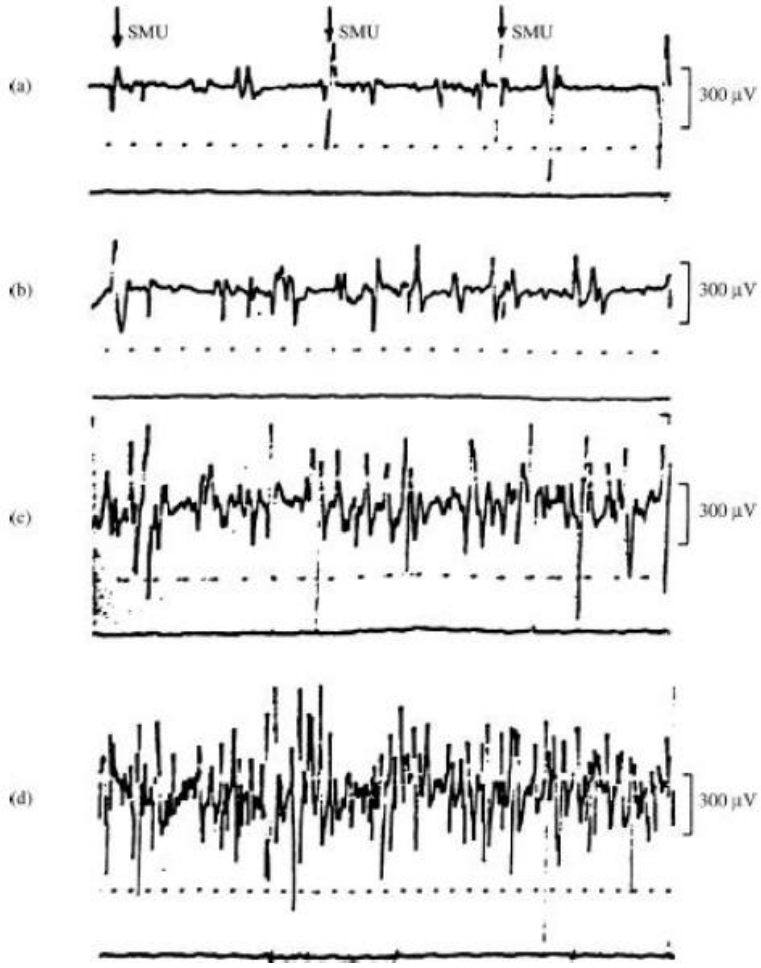


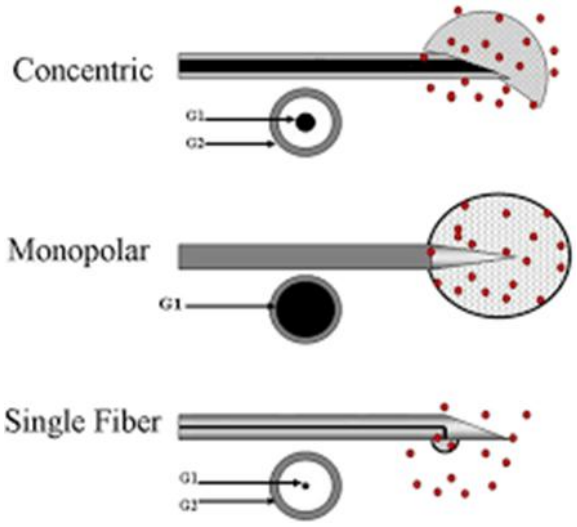
Figure 5 Motor unit action potentials from normal dorsal interosseus muscle during progressively more powerful contractions.
(c) individual units can no longer be clearly distinguished in the interference pattern.
(d) Interference pattern during very strong muscular contraction. Time scale is 10ms per dot.

EMG recording techniques.

1. Needle EMG (nEMG)

nEMG permits local recording from deep muscles by means of insertion of a needle electrode into the muscle tissue. Anatomical landmarks are used to pinpoint the needle insertion location, which may then be verified by a successful contraction of the chosen muscle. Individual MUs may be evaluated using nEMG, which also records high-frequency signals like various kinds of spontaneous activity with improved sensitivity and precision.

However, nEMG has several limitations. First, it reflects the activity of only a small number of active MUs whose fibers are close to the position of the detection site (not representative of all the fibers in the MU, due to its small detection volume). An adequate sample is needed to ensure adequate power (sensitivity and specificity) of the analysis of MUAPs.



Moreover, standard sample size is difficult in exploring small muscles. Second, nEMG is painful especially during muscle activation, and prolonged nEMG recording is not possible. Furthermore, nEMG is time and temperature sensitive. In this regard, the detected signal in nEMG may vary as a function elapsed time from the onset of the nerve

injury. Since the temperature exerts a profound influence on neuromuscular transmission and propagation of the action potential along the muscle fibers, a low temperature at the examination area modifies the parameters and characteristics of the recorded signals.

2. Surface EMG (sEMG)

sEMG is a technique to measure muscle activity noninvasively using surface electrodes placed on the skin overlying the muscle, and has several advantages. First, sEMG recording is painless, especially when used in the absence of peripheral nerve stimulation. Furthermore, sEMG electrodes record from a wide area of muscle territory providing a more global view of MUs. Finally, it allows prolonged simultaneous recordings of muscle activity from multiple sites.

However, sEMG has a relatively low-signal resolution, is highly susceptible to movement artifacts and body temperature. In addition, sEMG signals are dominated by the contributions of superficial MUs, while deeper MUs are not assessed; conditions that increase skin resistance subsequently disturb the sEMG signal (e.g. obesity and edema).

(a) solid metal bar electrode (dry);
(b) pin electrodes (dry);
(c) eyelet on cloth with magnetic connector (wet or dry);
(d) disposable Ag-AgCl electrode (wet);
(e) carbon-filled elastomer electrode (dry);
(f) disposable electrode with a sponge saturated with an electrolyte gel (wet).