

American Board of Electrodiagnostic Medicine

CNCT Examination Study Outline



Created By:

**Kimberly B. Butler, CNCT, REDT, REPT, CNIM
Teresa Spiegelberg, CNCT, R.NCS.T, R.EEG.T
Andrew H. Dubin, MD, MS**

**Visit the ABEM on the web:
www.abemexam.org**

1. Brachial Plexus

This section is designed to test the candidate's knowledge of brachial plexus anatomy.

- A. Spinal roots
- B. Anterior & posterior rami
- C. Brachial plexus
 - 1. Trunks
 - 2. Divisions
 - 3. Cords
 - 4. Peripheral nerves
 - 5. Myotomes

2. Nerve Physiology

This section is designed to test the candidate's knowledge of nerve physiology. Questions pertaining to anatomy and physiology are included. This category also includes questions concerning propagation of action potentials along myelinated and unmyelinated nerve fibers.

- A. Structure
 - 1. Fascicles
 - 2. Perineurium
 - 3. Epineurium
 - 4. Fiber types
- B. Physiology
 - 1. Propagation of potentials
 - A. Saltatory conduction
 - 1. Myelinated axons
 - 2. Schwann cells
 - 3. Node of ranvier
 - 4. Sodium potassium pump
 - B. Fiber diameter
 - C. All or none response
 - D. Resting potential
 - E. Unmyelinated axons
 - 1. Local circuit conduction
 - 2. Autonomic nervous system

3. Case Histories

This category tests the candidate's clinical decision-making abilities. It combines the candidate's knowledge of peripheral neuroanatomy with knowledge of important basic nerve conduction concepts. For example, a patient history will be presented (symptoms etc.) and the candidate is asked to select which nerve conduction studies will produce the highest diagnostic yield. An example of this format is seen below. There are also questions in this category which are

presented in the form of nerve conduction data. For instance, nerve conduction measurements (latencies, amplitudes, velocities) are given in a chart and the candidate is asked to identify the most likely location and/or cause of the abnormality. In this format the candidate is required to utilize their knowledge of such principles as normal and abnormal temporal dispersion, abnormal amplitude drop, anomalies and side to side comparisons in conjunction with knowledge of clinical syndromes and their presentation during nerve conduction studies.

Sample question of case history presentation

Q. A patient presents with a possible upper trunk brachial plexopathy. Changes in which of the following diagnostic studies would most likely support a diagnosis of a lesion at the upper trunk level?

- A. Median and ulnar sensory studies.*
- B. Radial, median and lateral antebrachial cutaneous sensory studies.*
- C. Median motor and ulnar sensory studies.*
- D. Ulnar and radial sensory studies and ulnar F-wave studies.*

In this particular situation we test the candidate's knowledge of the brachial plexus (which nerves derive their axons from the upper trunk?) and the important concept of sensory studies in a lesion distal to the dorsal root ganglion. The correct answer is "B". The radial, median (esp. from the thumb) and lateral antebrachial cutaneous sensory studies would be most likely to show changes which would support a diagnosis of an upper trunk plexopathy.

4. Cutaneous Distributions

This category tests the candidate's knowledge of dermatomes and the sensory distribution of cutaneous sensory nerves.

- A. Dermatomes*
 - 1. Upper extremity*
 - 2. Lower extremity*
- B. Cutaneous distribution of sensory nerves*
 - 1. Upper extremity*
 - 2. Lower extremity*

5. Terminology

This category tests the candidate's knowledge of terminology in the area of nerve conduction studies and related disorders. Many of the questions in this category are anatomy related. Terminology pertaining to neuromuscular disease and various entrapment syndromes seen in the EMG lab are also included.

- A. Neuroanatomy*

Including innervation of important muscles and common sites of entrapment and clinical syndromes involving individual nerves.

 - 1. Upper extremity*
 - A. Median nerve*
 - 1. Anterior interosseous nerve*

- 2. The carpal tunnel
 - 3. Palmar cutaneous branch
 - B. Ulnar nerve
 - 1. Dorsal ulnar cutaneous
 - 2. Ulnar neuropathies
 - a. Condylar groove
 - b. Cubital tunnel
 - c. Guyons canal
 - d. Tardy ulnar palsy
 - C. Radial nerve
 - 1. Posterior interosseous nerve
 - 2. Superficial radial nerve
 - 3. Saturday night palsy
 - D. Musculocutaneous nerve
 - 1. Lateral antebrachial cutaneous nerve
 - 2. Lower extremity
 - A. Lumbosacral plexus
 - B. Femoral nerve
 - 1. Saphenous nerve
 - C. Obturator nerve
 - D. Lateral femoral cutaneous
 - E. Sciatic nerve
 - 1. Common peroneal
 - a. Deep peroneal (Fibular)
 - b. Superficial peroneal (Fibular)
 - 2. Posterior tibial
 - 3. Sural nerve
 - 3. Cranial nerves
 - A. Cranial nerves I-XII
 - 4. Miscellaneous
 - A. Phrenic nerve
 - B. Suprascapular nerve
 - C. Long thoracic nerve
- B. Clinical syndromes - listed proximal to distal
- 1. Disease of the motor neuron (Anterior horn cell disease)
 - A. Syringomyelia
 - B. Amyotrophic Lateral Sclerosis (ALS)
 - C. Poliomyelitis
 - D. Spinal muscular atrophy
 - 2. Disease affecting the Dorsal Root Ganglion (DRG)
 - A. Neuronopathies
 - 1. Friedreich's Ataxia
 - B. Sjögren's Neuronopathy
 - 3. Disease affecting the root
 - A. Radiculopathy
 - B. Polyradiculopathies
 - C. Root avulsion

4. Plexus
 - A. Brachial plexus lesions
 1. Erb's Palsy
 2. Neurogenic Thoracic Outlet Syndrome
 3. Parsonage Turner
5. Mononeuropathies
 - A. Common sites of entrapment (*See nerves above*)
 - B. Clinical syndromes.
 - C. Mononeuropathy multiplex
6. Polyneuropathies
 - A. Hereditary neuropathies
 1. Hereditary motor and sensory neuropathies (HMSN)
 - a. Diffusely demyelinating (Charcot Marie Tooth)
 - b. Axonal
 - B. Acquired polyneuropathies
 1. Demyelinating polyneuropathies
 - a. AIDP (Guillain Barré Syndrome)
 - b. CIDP (chronic form of GBS)
 2. Axonal polyneuropathies
 - a. Toxic polyneuropathies
 - b. Metabolic polyneuropathies
7. Neuromuscular junction disorders
 - A. Presynaptic neuromuscular junction disorders
 1. Lambert-Eaton (Myasthenic) Syndrome.
 2. Botulism
 - B. Postsynaptic neuromuscular junction disorders
 1. Myasthenia Gravis
8. Disorders of muscle
 - A. Muscular dystrophies
 - B. Myopathies
 - C. Polymyositis

6. Cranial nerves

This category tests the candidate's knowledge of cranial nerve anatomy and relevant testing.

- A. Cranial nerves I-XII
 1. Anatomy
 - A. Innervations
 - B. Cutaneous sensation
 2. Relevant testing
 - A. Blink reflex
 - B. Facial nerve studies
 - C. Other electrophysiological testing of cranial nerves

7. Nerve conduction Concepts

This is the largest category on the written exam. Here the candidate is tested on his/her knowledge of important nerve conduction concepts and the ability to apply those concepts in a variety of situations. Many of the questions are anatomy

related and test the candidate's ability to demonstrate which nerve conduction studies would be most clinically helpful in certain situations.

A. Anatomy concepts

1. Pre and post ganglionic lesions
 1. Localization of pre or post ganglionic lesions
 2. Effect on sensory nerve conduction studies
2. Nerve conduction studies in neurapraxic lesions
 1. Stimulation distal to focal demyelinating lesions
 2. Stimulation proximal to focal demyelinating lesion
3. Nerve conduction studies relevant to specific clinical presentations and syndromes
 1. Nerve conduction studies in focal lesions
 2. Nerve conduction studies in diffuse processes
 3. Nerve conduction studies in multifocal disorders

B. Waveform evaluation & nerve conduction concepts

1. Normal temporal dispersion
2. Abnormal temporal dispersion
3. Abnormal amplitude drop
4. Stimulation concepts
 - A. Stimulus current parameters & their effect
 - B. Volume conduction
 - C. Anodal block
 - D. Stimulus spread
5. Nerve conduction parameters & their interpretation
 - A. Latency & conduction velocity
 - B. Amplitude
 - C. Area
 - D. Duration
 - E. Rise time
6. Clinical value and limitations of late responses
 - A. Clinical utility
 - C. Physiologic origin

C. Pediatric nerve conduction

1. Maturation
2. Technical considerations

8. Wallarian Degeneration

In this category the candidate is tested on his/her knowledge and understanding of the concept of Wallarian degeneration and its effect on nerve conduction studies.

A. Classification of nerve injury and applicable NCV findings

1. Neurapraxia
2. Axonotmesis
3. Neurotmesis

9. Temperature

This very important category tests the candidate's knowledge of temperature effects on nerve conduction studies.

- A. Temperature effects on distal latency and velocity
 - 1. Amplitude
 - 2. Latency & velocity effects
 - 3. Mathematical temperature corrections factors
- B. Temperature effects on Repetitive Stimulation Studies

10. Neuromuscular junction

This category tests the candidate's knowledge of anatomy of the neuromuscular junction, relevant testing and applicable clinical entities.

- A. Neuromuscular junction anatomy & physiology
- B. Clinical entities
 - 1. Pre-synaptic neuromuscular junction disorders
 - 2. Post-synaptic neuromuscular junction disorders
- C. Repetitive stimulation testing
 - 1. Decremental studies
 - 2. Incremental studies
 - 3. Post activation facilitation
 - 4. Post activation exhaustion

11. Muscle physiology

This category tests the candidate's knowledge of muscle anatomy and physiology.

- A. Related anatomy
 - 1. Histological and molecular structure
 - A. Myofibril
 - B. Sarcomere
 - 2. Fiber types
 - A. Three major fiber types (I, IIA & IIB)
 - B. Local circuit conduction
- B. Mechanism of contraction
 - 1. Myosin filaments
 - 2. Actin filaments
 - 3. Role of calcium & the sarcoplasmic reticulum

12. Basic physiology

This category tests the candidate's knowledge of basic physics and of the physiologic principles involved in action potential propagation.

- A. Basic physics
 - 1. Ions
 - 2. Protons
 - 3. Neutrons
- B. Physiologic principles in NCV
 - 1. Propagation of action potentials

- A. Depolarization
 - B. Repolarization
 - C. Silent period
 - D. Sodium potassium pump
2. Resting potential
- A. Polarity
 - B. All or none response

13. Anomalies

This important category tests the candidate's understanding of the very complex subject of anomalous innervation. How anomalies will present during nerve conduction studies as well as confirmation of anomalies and technical complications of nerve conduction waveform evaluation in the presence of anomalies is covered.

- A. Martin Gruber Anastomosis
 - 1. Type I (hypothenar)
 - 2. Type II (first dorsal interosseous)
 - 3. Type III (thenar)
 - A. Technical complications in carpal tunnel syndrome
- B. Riches-Cannieu Anastomosis
- C. Accessory peroneal

14. Late responses

This category evaluates the candidate's knowledge of late responses. Included are questions concerning technical pitfalls & limitations, clinical application as well as physiologic basis of late responses.

- A. F-waves
 - 1. Physiologic origin
 - 2. Clinical applications
 - 3. Technical applications
 - 4. Relationship to M wave
 - 5. A waves
- B. H-reflexes
 - 1. Physiologic origin
 - 2. Clinical applications
 - 3. Technical applications
 - 4. Relationship to M wave and habituation

15. Instrumentation for CNCT technicians

A. Instrumentation

In this category the candidate is tested on his/her knowledge of instrumentation principles.

- 1. Differential amplifiers
 - A. Analog to digital conversion
 - B. Vertical (voltage) resolution
 - C. Horizontal (time) resolution

- D. Data points
- E. Averaging
- F. Filtering effects
- G. Phase cancellation
- 2. Stimulators
 - A. Constant current stimulator (*vs. constant voltage*)
 - B. Stimulator polarity
 - C. Anodal block
 - D. Stimulus parameters
 - 1. Intensity
 - 2. Duration
 - E. Stimulus artifact
- B. Basic electronics

This category tests the candidate's understanding of basic electronics and important principles of electricity.

 - 1. Ohms law
 - 2. Circuit theory
 - A. Simple circuits
 - B. Resistors in series
 - C. Resistors in parallel
- C. Nerve conduction calculation (*of total questions of this part*) category 1

This category tests the candidate's ability to calculate conduction velocities. Factors influencing conduction velocity are also addressed.

 - 1. Nerve conduction velocity calculation
 - 2. Factors affecting conduction velocity
 - A. Fiber diameter
 - B. Degree of myelination
 - C. Temperature
 - D. Internode length
- D. Stimulation concepts

This category evaluates the candidate's knowledge of the principles of electrical stimulation. Stimulation parameters, concepts and technical pitfalls of electrical stimulation are included.

 - 1. Stimulation parameters
 - A. Intensity
 - B. Duration
 - C. Polarity
 - 2. Technical concepts and pitfalls
 - A. Anodal block
 - B. Volume conduction
 - C. Stimulus spread
 - D. Stimulus artifact
- E. Nerve conduction studies technical considerations

This category tests the candidate's knowledge of infection control guidelines and both the physiologic and non-physiologic pitfalls of performing nerve conduction studies.

 - 1. Infection control
 - A. 1994 infection control guidelines
 - 1. Infection transmission

- 2. Modes of transmission
- 3. Disaffection & decontamination practices
- B. Transmissible disease found in the neurodiagnostic setting
 - 1. Universal precautions
 - a. HIV
 - b. Hepatitis
 - c. Jakob Creutzfeldt Disease
- 2. Electrical safety
 - A. Ground loops
 - B. Leakage current
 - C. Electrically sensitive patients
- 3. Physiologic factors affecting nerve conduction studies
 - A. Temperature
 - B. Age
 - C. Body length
 - D. Anomalous innervation
- 4. Non-physiologic factors affecting nerve conduction studies
 - A. Technical factors
 - 1. Electrode size
 - 2. Electrode polarity
 - 3. Distance of reference from active electrode
 - 4. Recording electrode placement
 - 5. Measuring errors
 - 6. Limb position
 - 7. Antidromic vs. orthodromic
 - B. Instrumental factors
 - 1. Equipment parameters
 - a. Filter affects
 - b. Sweep speed
 - c. Gain
 - d. Cursor placement
 - 2. Errors in stimulation
 - a. Excessive stimulation
 - 1. Stimulus spread/volume conduction
 - b. Stimulus artifact

Instrumentation for CNCT technicians

1. Basics of circuit theory

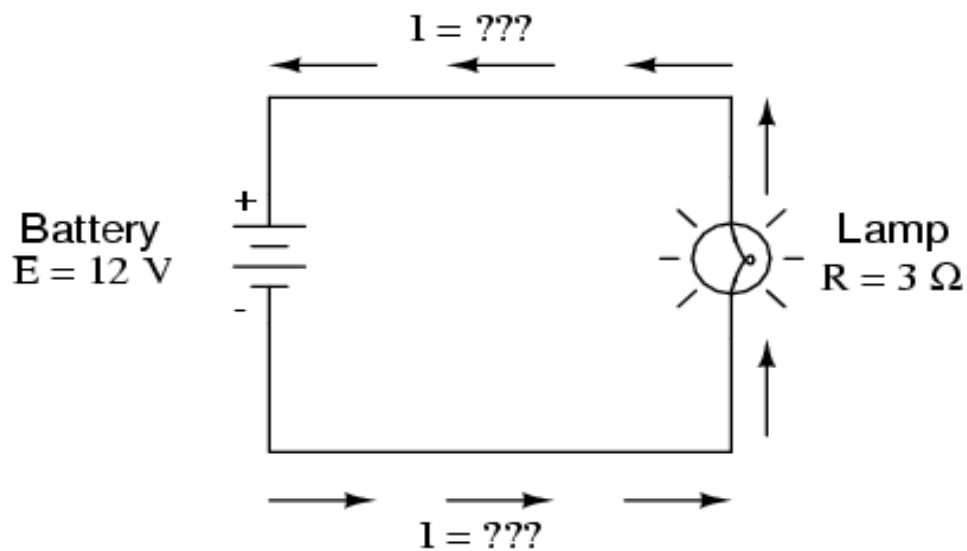
An electric circuit is formed when a conductive path is created to allow for the continuous movement of free electrons. The continuous movement of free electrons through the conductive elements of a circuit is called current. This movement is commonly referred to as “flow” much like the flow of water through a pipe. The motivating force for movement of electrons within a circuit is referred to as voltage. Voltage is a specific measure of potential energy that is always relative between two points. As such, voltage represents a measure of how much potential energy exists to move electrons from one part of a circuit to another. The movement of electrons through conductive elements is not without challenges. The opposition to movement or the “friction” within the system is called

resistance. Resistance, like voltage, is also a quantity measured between two points.

A. Ohm's law

Ohm's law is the mathematical representation of the relationship between voltage, current and resistance. It is represented by V or $E = IR$. Alternatively the equation can be rewritten as $I = E/R$.

Quantity	Symbol	Unit of Measurement	Unit Abbreviation
Current	I	Ampere ("Amp")	A
Voltage	E or V	Volt	V
Resistance	R	Ohm	Ω



In the above example current flow (electron flow) is designated by the arrows, and moves from the negative terminal of the battery to the positive terminal. Knowing the voltage and resistance of the circuit, one can easily calculate the current in the circuit.

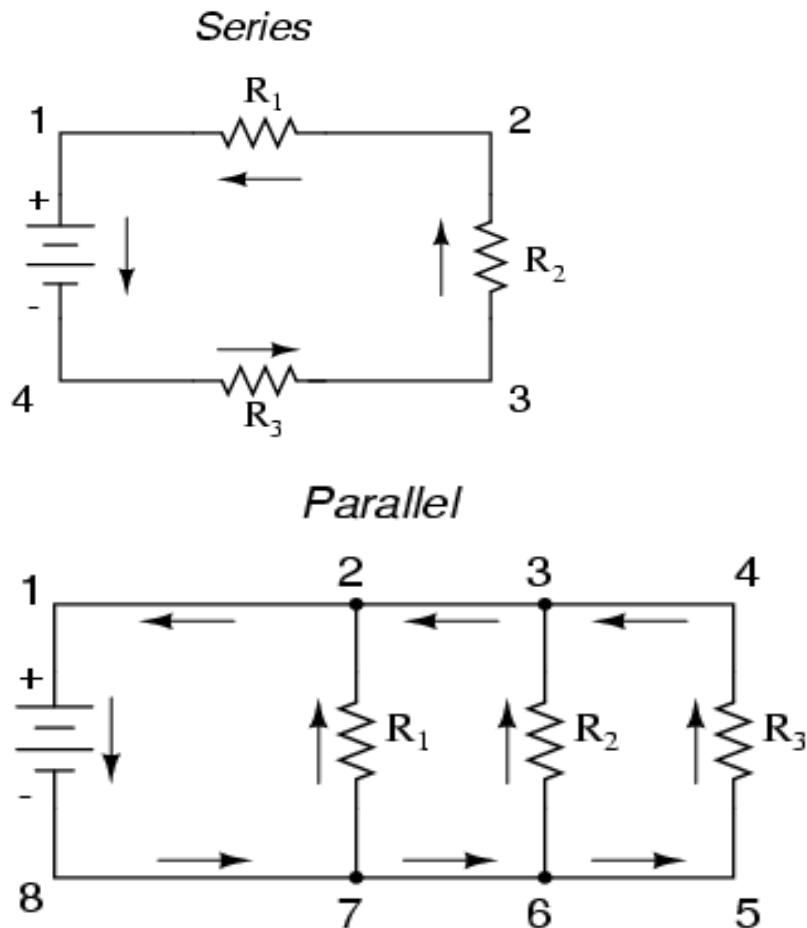
$$I = \frac{E}{R} = \frac{12 \text{ V}}{3 \Omega} = 4 \text{ A}$$

B. Impedance vs. Resistance

Functionally, resistance and impedance are analogous terms. The practical difference between the terms is that resistance represents the opposition to current flow in a DC (direct current) circuit, as opposed to impedance, which represents opposition to current flow in an AC (alternating current) circuit. If the current source is a battery, the term resistance applies. If the current source is a typical electrical socket, the term impedance would now apply.

C. Series vs. Parallel Resistors

For all practical purposes there are only two ways to connect more than two circuit components. They may be connected in series or parallel.



The fundamental difference between series and parallel connections is that a series circuit allows for only one path for current flow, while a parallel circuit allows for multiple points for current flow.

As such the total resistance for a series circuit can be represented by the equation $R_{\text{total}} = R_1 + R_2 + R_3 + R_4 \dots$

In a parallel circuit $R_{\text{total}} = 1/R_1 + 1/R_2 + 1/R_3 + 1/R_4 \dots$. As one can see, in a series circuit the addition of each new connector (resistor) increases the total resistance of the system. However, in a parallel circuit the addition of a new connector merely increases the number of paths for current flow and as such total resistance of the circuit decreases with the addition of each new connector element.

D. Amplifiers

Amplifiers serve to increase the strength of the bioelectric signal. The problem that becomes apparent is that not only will the bioelectric signal be increased, but electrical noise also will be increased. This should render it impossible to discern the bioelectric signal from the background electrical noise as the noise is typically a much larger signal than the bioelectric signal. This seemingly insurmountable problem can be handled rather easily using the principles of differential amplification and common mode rejection. Differential amplification and common mode rejection, as functions of signal processing, refer to two processes that work together. EMG equipment is structured such that signals (noise) that are common to two similar amplifiers (G1 and G2) are amplified. In this situation one amplifier (G1) increases the size of the signal, while the second amplifier (G2) also increases the size of the signal but additionally inverts it. As such, when the two signals that were common to the two different amplifiers are now added (summed), the negative and positive signals that were otherwise exactly the same in characteristic now cancel one another out. The only signal that is left and amplified is the signal (bioelectric) that was unique to G1. In this situation the electrical noise is common to both G1 and G2 and as such can be added (summed) to essentially zero. The bioelectric signal, however, is unique to G1 and as such is only amplified. If the bioelectric signal should also be partially recorded under G2, the resultant bioelectric signal would be smaller. Hence, the critical nature regarding the placement of G1 and G2 when performing sensory and motor studies. The above discussion brings to life the concept of algebraic summation. It takes advantage of the mathematical principle that adding a positive number to its mirror negative number summates to zero (e.g. $(+4) + (-4) = 0$)

2. Signal characteristics and parameters

A. A/D conversion

Whenever you make a measurement of a voltage and that measurement is taken into a computer, an A/D converter is used. A/D converters are electrical circuits that have certain characteristics. The input to the A/D converter is a voltage, with the converter typically designed for voltages from 0 to 10v. The output of the A/D converter is a binary signal. The binary signal encodes the analog input voltage. In essence the output is a digital number. Various points on the analog signal are represented by a digital number. The more points that are “digitized” the finer the fidelity of the converted signal, and the more closely the digital signal represents the analog signal.

A. Resolution

Vertical resolution, horizontal resolution: The resolution of a digital signal in electrodiagnostic testing refers to the size of the signal as it is visualized on the oscilloscope. Vertical resolution—or gain—may be measured in microvolts or millivolts per vertical division. Microvolt gain settings are typically used in recording of small signals typically seen in sensory studies. Larger millivolt gain settings are used for recording motor study responses. Horizontal resolution or sweep refers to a time base and typically ranges from 1-2

milliseconds/horizontal division for sensory responses, to 5 milliseconds/horizontal division for motor responses. In patients with suspected neuropathy, one may need to expand the sweep speed beyond the typical settings to capture a markedly delayed response. Similarly in patients with severe axonal neuropathies, the evoked response for a motor study may be so small that the vertical resolution or gain may need to be adjusted to microvolt ranges to resolve the small response.

B. Signal averaging

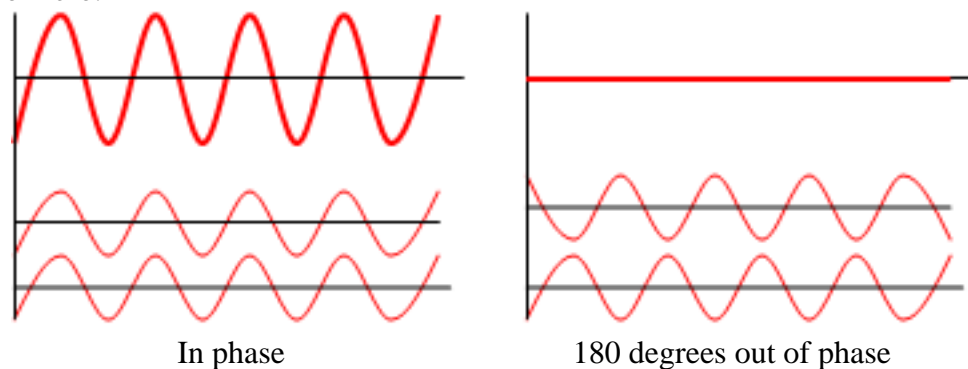
The purpose of signal averaging is to improve the signal-to-noise ratio to ease the detection of low amplitude bioelectric potentials. Signals may be averaged using temporal or spatial techniques. Commercial EMG equipment typically uses temporal averaging. This technique reduces random noise by the square root of the number of wave forms averaged. For this to work several criteria must be met. First the signal in question must be repetitive and invariable. Second the signal must be time locked to a focal point such as the peak of the SNAP response. Lastly, the signal to be averaged and the noise must be independent and remain independent of one another during averaging.

C. Filters

High frequency vs. Low frequency: The function of a filter is to allow for easy passage of a particular frequency signal. A high frequency filter can also be referred to as a low pass filter, as it preferentially filters out signals above a certain frequency and allows signals below a certain frequency to pass through unimpeded. In contradistinction a low frequency filter can also be referred to as a high pass filter. Band pass filters are combinations of low pass and high pass filters that restrict the passage of a signal to a specific frequency range, between the two filters.

D. Phase cancellation

At any given instance in time, a periodic waveform is at a specific point in its harmonic cycle. This construct describes the concept of the phases of a wave. The relationship in time between two or more waveforms with the same or similar harmonically related periods gives a measurement of phase differences. Phase cancellation occurs when two signals of the same frequency are out of phase with one another, resulting in a net reduction in the overall level of the combined signal. Two signals of the same frequency that are 180 degrees out of phase relative to one another will result in a net signal of zero.



3. Stimulator characteristics

A. Constant current vs. constant voltage nerve stimulators

Constant voltage nerve stimulators are relatively simple devices. Unfortunately, with simplicity come problems. If the voltage remains constant when resistance (skin impedance) increases, then the current must decrease. As a result the nerve may not be completely stimulated. The resultant CMAP will then be sub maximal.

Constant current nerve stimulators are safer than constant voltage stimulators. As the resistance or skin impedance increases, constant current stimulators compensate by increasing their voltage. As a result the current stays constant. The stimulation of the nerve remains constant. This insures that the nerve will be fully stimulated and that a supramaximal stimulation and resultant maximal SNAP or CMAP will be obtained. Theoretically constant current stimulators are less likely to be associated with stimulus artifact. There is a limit to how high the nerve stimulator can raise the voltage, and these thresholds are predetermined and help insure electrical safety.

B. Stimulus artifact and spread

The stimulator's cathode (negative pole and anode positive pole) are the two stimulating electrodes. Nerve tissue is typically activated under the cathode. Once an action potential is generated it travels along the nerve in both directions away from the cathode site. Stimulus artifact occurs as a consequence of the above. The depolarization activity generated by the cathode creates a very large electrical disturbance within the tissues surrounding a nerve. The electrical activity is immediately recorded by the EMG equipment as a very large waveform coincident with the instrument's cathode ray tube trace. Stimulus artifact precedes the waveform of the intended biologic signal as it represents an instantaneous volume-conducted disturbance independent of nerve or muscle tissue. Factors that can exacerbate stimulus artifact include excessive sweating and electrode paste, as both allow current flow to follow the path of least resistance, in this case traversing the skin's surface. Placing the ground electrode between the active recording electrode and the stimulating cathode, with the bias towards being closer to the active recording electrode, can reduce stimulus artifact. Cleaning the skin will decrease skin impedance, reducing the amount of current needed to penetrate the skin, thereby reducing stimulus artifact.

C. Stimulus spread

Stimulus spread is an outgrowth of excessive stimulation. As such the depolarizing current spreads beyond its intended target and now depolarizes neighboring electrically active tissues. This effect may result in depolarization of an unintended nerve with subsequent recording of responses that are summated responses secondary to inadvertent stimulus spread, which may result in errors of onset latency and amplitude response determinations.

4. **Recording electrode characteristics**

Surface electrodes are devices that must have the capacity to record responses in the microvolt to millivolt range. The skin presents a major obstacle for surface electrodes, secondary to issues of impedance. Surface electrodes are commonly used because of their ease of use. Most surface electrodes are made of highly conductive metals (silver, gold, tin, stainless steel, etc.). Surface electrodes may range in size from 0.5 cm up to 2.5 cm in diameter.

A. Size of electrodes

Surface electrodes may range in size from 0.5 cm up to 2.5 cm in diameter. The relationship between the size of the electrode and the size of the recorded response must be appreciated; otherwise significant intertrial variation may be noted. The most manifest effect is noted on CMAP recordings. The rule to remember is that, as the recording electrode size increases the CMAP amplitude and area will decrease and slower conduction velocities will be calculated. No clinically significant changes will be noted in onset latency or negative spike duration. The larger recording electrode will record from a larger region of the muscle (volume conductor), thus averaging out the different contributions from the different motor units. Additionally the summated electrical activity is averaged over the larger surface area of the recording electrode, decreasing the overall CMAP amplitude relative to a smaller electrode.

B. Placement

Surface electrodes are usually placed in specific locations to optimize the recording of the waveform. Evaluation of CMAP's requires that the active (G1) electrode be placed over the motor point of the muscle in question, and that the reference (G2) electrode be placed over an electrically silent area. If both electrodes are placed over the same muscle, the resultant CMAP amplitude will be markedly reduced. Additionally minimal peak latency will be shortened. However, onset latency will be unaffected.

C. Stability of electrodes (baseline wander)

Baseline wander and instability may be secondary to patient movement, poor electrode to skin contact, or breaks and bends in the electrical wiring connecting the electrode to the instrument. The recording electrodes resistance is measured in ohms, and an intact electrode and wire circuit should have a resistance less than several thousand ohms. This can be tested with an ohmmeter. If the resistance is noted to be greater than this the electrode and its associated wires should be discarded.

D. Impedance mismatch

Impedance mismatch occurs when the resistance to current flow is markedly different between the active and reference electrode. This can occur when one electrode is in poor contact with the skin or when excessive electrode paste or sweating may create an undesired path of least resistance. The net effect of impedance mismatch is to reduce common mode rejection and increase 60 cycle interference. Clearly this will negatively impact the ability to discern the desired signal.

5. Electrical safety

A. Current leak

All electrical devices leak some degree of current to the equipment's chassis and electrodes. The manufacturer has a responsibility to ensure that current leakage is minimal. A faulty ground plug can allow for potentially dangerous current flow from the amplifiers' ground lead to the patient, if he or she should contact a metal bed frame or other electrical equipment. The maximal acceptable leakage current from the chassis to ground is 100uA and from the patients input leads to ground is 50uA. Current frequencies between 0 and 1000 Hz are particularly concerning, as they are capable of exciting nerve and muscle tissue. Electrically sensitive patients are patients who may have IV's or catheters leading to the heart (arterial lines, central lines, swan ganz catheters). This group of patients should not be exposed to more than 10uA of leakage current. Prior to stimulation, the skin should be dried to remove perspiration and reduce the risk of conducting current to electrically sensitive areas.

B. Safety rules

1. All electrical equipment should be routinely inspected for current leak by trained personnel.
2. The electrical outlet powering the equipment should be checked for electrical safety.
3. To minimize the risk of power surge, the electrical device should be turned on prior to attaching electrodes and off after removing electrodes.
4. Extension cords should be avoided.
5. All electrical devices that are attached to the patient should be plugged into the same outlet to share a common ground.
6. Only one ground should be attached to the patient, not multiple.

Overall references:

- Dumitru D. *Electrodiagnostic Medicine* 2nd edition. Hanley and Belfus, Inc. Philadelphia 2002.
- Kimura J. *Electrodiagnosis in Diseases of Nerve and Muscle: Principles and Practice* 2001.
- Oh, S. *Clinical Electromyography: Nerve Conduction Studies, Second Edition*. Williams and Wilkins, Baltimore 1993.
- Preston D., Shapiro B. *Electromyography and Neuromuscular Disorders: Clinical-Electrophysiological Correlations*. Butterworth-Heinemann, Newton, MA 1998.

These are just some of the fine reference books available to use. Find a book that you like and use that as a reference. The topics in the outline can guide you for what you need to know. Also make sure that you know the terminology.



**ABEM Executive Office
2621 Superior Dr NW
Rochester, MN 55901**

P: 507.288.0100

F: 507.288.1225

www.abemexam.org