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Introduction to Electrodiagnostics

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BASIC PRINCIPLES OF ELECTRODIAGNOSTICS

- The human body constantly generates electrical energy. Specifically, the muscle and nerve cells constantly use electric discharges to communicate among different parts of the body.
- These electric discharges can be recorded, displayed, measured, and interpreted by using specialized equipment.
- In the presence of disease or injury, the architecture and normal processes of nerves and muscles are altered. Recognizing these changes can be useful for diagnosis, monitoring disease progression, and assessing treatments.
- **Electrodiagnostic (EDX)** medicine is the process of observing and interpreting neuromuscular electrical discharges for clinical purposes. We use "EDX" for the remainder of this book to represent this testing, which includes **nerve conduction studies (NCS)** and **electromyography (EMG)**.

BASIC LOGISTICAL DETAILS FOR YOUR FIRST DAY PERFORMING ELECTRODIAGNOSTICS

- The novice EDX consultant (from here on referred to as "you") is faced with learning many new concepts in parallel and at once.
- These include the associated basic science concepts (Table 1.1), hands-on EDX procedures, and analysis of the EDX results. The second basic concept—the hands-on EDX procedure—is the emphasis of this book.
- At first, you will just perform the procedures of an algorithm accurately and efficiently under the guidance of your instructor.
- Once your hands are moving easily from one procedure to the next, you should be able to spontaneously analyze on the fly and mentally adjust a dynamic algorithm.

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TABLE 1.1 Basic Science Concepts to Learn

Membrane Physiology • How physiologic discharges are generated by the cell membrane
Volume Conduction Theory • How electrical discharges spread and propagate in any conducting medium as governed by the laws of physics
Neuromuscular Physiology • Structures and functions of the motor unit, sensory nerve, and associated connective tissue
Body's Response to Injury • Morphologic and electrical timing and changes associated with different types of injury (e.g., demyelination vs. axonal damage)
Anatomic Innervations • Dermatomes and myotomes at the level of the root, plexus, and peripheral nerve

BASIC CONSTRUCTION OF AN ELECTRODIAGNOSTIC CONSULT

Consult Request

- You will be consulted by a clinician who will send all types of chief complaints to "rule out" things. These usually include complaints of numbness, tingling, or weakness. You should view the referral simply as a guideline or starting point for the EDX visit.
- The EDX encounter is different from a regular consult because the emphasis is placed on you as a technician. Therefore, you may want to be more focused and direct without sacrificing professionalism, compassion, or congeniality. Look for possible contraindications (see Box 3.3 in Chapter 3) prior to performing the procedure. Point out reasonable expectations of the test to your patients and warn them that it is uncomfortable but well tolerated by most people.

History

- This is the time to establish a broad differential diagnosis. Try to figure out which body system is involved. Is the etiology neurological? Musculoskeletal? Psychological? Bilateral? Proximal versus distal?

Physical Examination

- At this time, you will essentially confirm your thoughts using the history. This will inform and direct your EDX testing, which should never be set in stone.

Nerve Conduction Studies

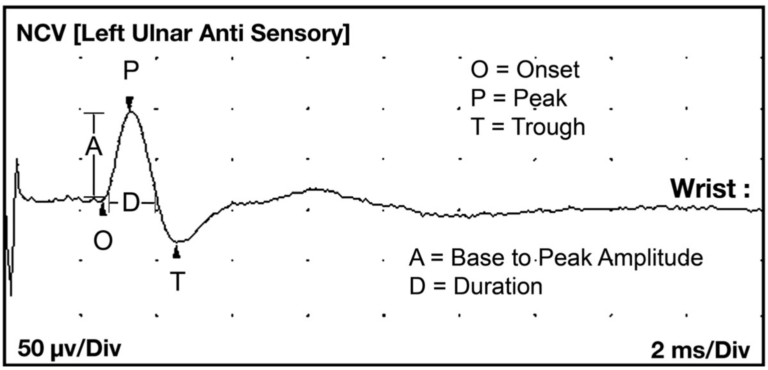
- Typically, this is the first part of the EDX examination. You will stimulate nerves by delivering an electrical current usually via a stimulator wand. The axons of the stimulated nerve generate action potentials that propagate both proximally and distally from the site of stimulation. Electrodes placed over the nerve or a relevant muscle "pick up" the action potential as it propagates under them. The electrical **signal** that is picked up by the electrodes is amplified, filtered, and processed by the equipment.

- The signal is converted to a **waveform** (aka *evoked response*) that is displayed on a screen. The *x*-axis represents time (usually in milliseconds) and the *y*-axis represents voltage (millivolts or microvolts). Considering units of measure is *very* important prior to analysis of the waveform. Properties of the nerves and muscles can be extrapolated and analyzed thereafter. Certain changes in specific attributes of the waveform can reveal the presence or absence of pathology.

Sensory Nerve Conduction Studies

- Pick-up electrodes are placed over sensory nerves. Stimulation of the corresponding nerve (typically proximally) results in a **sensory nerve action potential** (aka *SNAP*) on the screen. The SNAP is the electrical signal summation of discharges by the sensory neuron's depolarizing membranes (i.e., axolemma) beneath the pick-up electrodes (Table 1.2).

TABLE 1.2 Features of the Evoked Response



Latency

- *Latency* is the time between the stimulus and the response. In motor nerve studies, latency includes the nerve conduction time and also the neuromuscular transmission time
- Onset latency: Time from stimulation to initial deflection from baseline
- Peak latency: Time from stimulation to upward peak

Amplitude

- The amplitude is dependent on the number of axons that conduct impulses from the stimulus point to the muscle, the number of functioning motor endplates, and the muscle volume.
- The amplitude is measured from the baseline to the upward peak (base-to-peak) or from the upward to downward peak (peak-to-peak).

(*continued*)

TABLE 1.2 Features of the Evoked Response (*continued*)

Duration • The duration reflects the synchrony of individual muscle fiber discharges. If there is a significant difference in the conduction velocity among nerve fibers, the duration will be prolonged. This is mainly related to the range of the conduction velocities of the large myelinated fibers. • Duration is measured from the onset to the first negative to positive baseline crossing. • Rise time: This is the duration from onset to peak latencies.
Area • *Area* refers to the integrated area between the compound muscle action potential and the baseline. • The area represents a combination of the amplitude and the duration. It therefore reflects the number and synchrony of the muscle fibers activated. • A prolongation of the duration can cause a decrease in the amplitude and may be misinterpreted as a conduction problem. In this situation, there may not be significant difference in the area.

Motor Nerve Conduction Studies

- Pick-up electrodes are placed over a muscle belly. Proximal stimulation of the corresponding nerve produces a **compound muscle action potential** (aka *CMAP*), which is the summation of electrical signals discharged by the muscle fibers' depolarizing membranes (i.e., sarcolemma) under the pick-up electrodes.

Late Responses

- These studies are called "late" because of the prolonged time required for the distal stimulus to travel proximally and return back to the periphery. They are often used to evaluate the "proximal" portions of the peripheral nerves. Some late responses include the H-reflex, F-wave, and A-wave.

Evoked Potentials

- Stimulation occurs at the periphery and pick-up electrodes are placed proximally over the scalp and other areas. Sometimes they are used intraoperatively for monitoring. These include:
  - Auditory-evoked potentials, usually recorded from the scalp but originating at the brainstem level (auditory brainstem response, brainstem auditory-evoked response, brainstem-evoked response, brainstem-evoked potential [BSEP])
  - Visual-evoked potentials
  - Somatosensory-evoked potentials
  - Peripheral sensory nerve stimulation
  - Motor-evoked potentials
  - Peripheral motor nerve stimulation

Electromyography

Typically, this is the last part of the EDX evaluation. A needle electrode is inserted through the skin and fascia to penetrate into the muscle and irritate its membrane (the *sarcolemma*). This irritation elicits transient discharges from the sarcolemma that are picked up by the needle electrode and displayed as waveforms. These waveforms are then analyzed by you (the person performing the test, the EDX consultant). Voluntary and spontaneous electrical discharges by the sarcolemma can be detected by the needle electrode and observed on a screen.

Involuntary Attributes

- Insertional activity: Bursts of electrical discharge directly correlated with irritation by the needle electrode
- Normal and abnormal spontaneous discharges (e.g., endplate spikes, positive sharp waves, fibrillation potentials, fasciculation potentials, complex repetitive discharges, myotonic discharges, myokymic discharges, etc.)

Voluntary Attributes

- Motor unit action potential (MUAP) morphology
- MUAP activation
- MUAP recruitment

EXPLANATION OF FINDINGS

Although the final report will not yet be complete, preliminary findings should be discussed with the patient after the encounter.

ADDITIONAL READINGS

Dumitru D, Amato AA, Zwarts MJ. *Electrodiagnostic Medicine*. 2002.

Wilbourn AJ. Nerve conduction studies. Types, components, abnormalities, and value in localization. *Neurol Clin*. 2002;20(2):305–338, v.