Nerve Conduction Studies: Basic Concepts and Patterns of Abnormalities

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KEYWORDS

- Nerve conduction studies • Sensory conduction studies
- Motor conduction studies • F waves • H reflexes
- Clinical neurophysiology • Neuromuscular disease

As a fundamental component of the electrodiagnostic evaluation, nerve conduction studies (NCSs) provide valuable quantitative and qualitative insight into neuromuscular function.[1] Typically paired with needle electrode examination, NCS may direct the clinician to definitive diagnostic testing or provide the sole substantiation of a neuromuscular diagnosis. The clinical value of NCS is tempered by a variety of potential sources of technical error that can be mitigated with careful attention to technique.[2] Like all elements of the electrodiagnostic evaluation, NCS must be interpreted with the clinical scenario in mind, and, in this manner, they serve as a useful extension of the neurologic examination.

The goals of this article are to review the neurophysiologic underpinnings of NCS, to outline the technical factors associated with the performance of NCS, and to demonstrate characteristic NCS changes in the setting of various neuromuscular conditions.

BASIC CONCEPTS

Anatomic Considerations

The responsiveness of the peripheral nervous system to electrical stimulation has been recognized since at least the eighteenth century.[3] In the simplest terms, modern clinical NCSs consist of stimulating a peripheral nerve and recording the response elsewhere on contiguous nerve or from a skeletal muscle innervated by that nerve. Although a variety of methods may be used for stimulus or recording,[4] most NCSs currently are performed with cutaneous, or surface, stimulating and recording electrodes. As a result, it is

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important for the electrodiagnostician to understand that all surface points of stimulation, points of recording, and measurements thereof are approximations of the locations of their subcutaneous targets. This principle is important in terms of understanding that surface measurements may not precisely reflect underlying anatomy and that uncertainty of sites of stimulation or recording limits the value of the study.[5] A useful rule of thumb is that an NCS is useful insomuch as the examiner is certain what is being stimulated and what is being recorded.

For example, surface electrical stimulation of deeper nerves (such as the lower trunk of the brachial plexus) often requires large amounts of current. As a result, nearby neural structures (in this case, other elements of the brachial plexus) are likely to be incidentally stimulated. This may introduce doubt as to the generator of recorded responses elsewhere on the limb. Conversely, recording from proximal muscles that are adjacent to large similarly innervated muscles leads to a degree of uncertainty as to the source of a surface-recorded response.

For these reasons, NCS of proximal structures is technically challenging and performed much less commonly than NCS of more distal, and therefore easier to isolate, limb structures.[6] With careful attention to technique, the examiner can approach a reasonable degree of certainty of selective stimulation and recording of distal nerves and muscles.

Stimulation

Stimulation methods can be tailored to the desired target (eg, needle electrodes may be used to stimulate proximal spinal nerves), but, in general, nerve stimulators consist of a handheld bipolar probe comprising an anode and a cathode. The cathode is typically oriented distally or in the direction of the intended action potential recording. Skin at anticipated sites of stimulation should be cleaned to minimize impedance. The stimulus may be delivered at either a constant current (in milliamperes) or a constant voltage (in volts), generally the former. It is important to ensure that at each site of nerve stimulation all elements of the nerve are depolarized as completely as possible; this is achieved with successive stimuli using increasing levels of current until a point at which the current is increased but the size of the recorded potential does not change. This is referred to as supramaximal stimulation. In practice, this stimulation is performed with small incremental increases in current (around 10 mA with each increase) until an intermediate response is detected. Then the stimulating electrodes are adjusted positionally in a technique called sliding to ensure that the optimal point of nerve stimulation has been isolated.[7] Current is subsequently increased until supramaximal stimulation is obtained. The duration of the stimulus is generally 0.1 milliseconds (ms) but may be increased to up to 1.0 ms if a supramaximal response cannot be obtained with up to 100 mA of current. Motor and larger sensory axons have lower depolarization thresholds (in other words, they are stimulated with smaller amounts of current) than small-diameter sensory fibers,[7] a physiologic feature that has clinical relevance discussed later.

Recording

Recording electrodes consist of an active (or G1) electrode and an inactive (reference or G2) electrode placed at some distance from G1. The spatial relationship between the recording electrodes is important because the distance between them allows for the difference in charge (or voltage) that generates the recorded potential.[8] A compromise must be reached when determining the distance between G1 and G2 recording sites. Electrodes that are too close to one another may lack sufficient electrical distinction, resulting in spuriously small responses, and electrodes placed too far