NERVE CONDUCTION STUDIES

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to my father
A.J. Hammer, Jr.

FOREWORD

A FEW YEARS AGO, most fledgling electromyographers discovered fairly early in their training that there were noticeable deficits in the EMG literature. One of the most frustrating was the fact that written information regarding the technical aspects of performing an EMG study was available only in meager amounts, and rather difficult to obtain, scattered as it was, in small fragments, among many different journals/books. Consequently, one searched almost in vain for detailed descriptions of the mechanics of performing both the nerve conduction studies and the needle examination (exactly where to apply the recording electrodes, where to stimulate the nerves, pitfalls in nerve conduction technique to avoid, etc.; exactly where to insert the needle while avoiding major neurovascular structures, how to activate the muscle, etc.). This dearth of material focused on "the basics" is not limited to the discipline of electromyography, of course. It is a paradox of "formal education that many of the most important skills and principles needed in a field never really are taught."[1] Appreciation of the universality of the problem, however, is of little solace to the inexperienced electromyographer, who is fearful of causing grievous harm to some unsuspecting nerve or vessel with each needle plunge, or who finds that, by his calculations, he has just obtained the slowest conduction velocity ever recorded in a human being, and that was along the nerve in an asymptomatic limb of a normal volunteer! Many of the larger EMG Laboratories, by necessity, produced their own "How To" manuals for "in-house" use. These procedural handbooks tended to be eagerly sought after and highly prized by EMG trainees; the widespread distribution (and unauthorized reproduction) of the mimeographed nerve conduction study manual prepared by Jasper Daube several years ago, at the Mayo Clinic, attests to this fact.

During the past few years, the situation has improved considerably in regard to needle myography; two instructional manuals have been published rather recently. Both were designed specifically to help guide the

[1]Editors Notes, *Behavioral Medicine*, Volume 8, June, 1981, page 6.

examiner's needle to the desired muscles, and both achieved their goals. The remaining gap—until now—has been the lack of availability of a publication offering detailed instructions in the performance of the nerve conduction studies. This volume fills that need very ably. Its author has had considerable experience in the field; she has performed thousands of nerve conduction studies herself during the past seven years. In this book, she describes the many possible sources of error one can encounter while performing something as deceptively simple as a nerve conduction study. She emphasizes the necessity for standardization of technique, meticulous attention to detail, and acquisition of normal values for each population studied, if nerve conduction study results of high quality are to be consistently obtained. She illustrates at least one of the methods for performing nerve conduction studies on almost all of the accessible peripheral nerves.

At all times, the information provided is of practical value. For example, one of the most common nerve anomalies is the median-to-ulnar nerve crossover in the forearm (Martin-Gruber anastamosis), which is detectible to some degree in 15 to 30 percent of upper extremities (depending on whether or not the first dorsal interosseous is used as an ulnar nerve recording point). This anomaly is not mentioned at all in some books dealing with electromyography. Others describe the alterations that it produces in the ulnar (or sometimes median) nerve conduction studies when it is almost the sole source of innervation of one of the hand muscles, and when an associated severe ulnar or median nerve lesion is present in the proximal forearm. Unfortunately, it is not in such very rarely seen instances that median-to-ulnar crossovers cause confusion, but, rather, when they are detected on normal patients, or those with carpal tunnel syndrome or a suspected ulnar mononeuropathy. Also, few books describe more than one presentation of this anomaly on the nerve conduction studies; yet, this one forearm nerve anomaly can have at least three presentations (and more, if various combinations are considered), depending on whether an appreciable number of the crossing fibers terminate near the thenar, hypothenar, or first dorsal interosseous area. Ms. Hammer describes all three of the ways in which the median-to-ulnar crossover may present on nerve conduction studies in normal mononeuropathies and how they sometimes produce spuriously fast median motor conduction velocities.

Some will dismiss this manual as being merely a cookbook. If by the term *cookbook* one means a guide offering detailed instructions to the neophyte for performing standardized, reproducible work of high quality—in this case, nerve conduction studies—then it most certainly stands guilty as charged. However, a pertinent point about cookbooks in general should be appreciated: they are only disparaged by persons who already know how to cook (or at least claim they can); they are rarely belittled by the novice, seeking a source from which to learn important procedural information.

In any case, those hungering for knowledge regarding how to perform reliable nerve conduction studies will find this volume to their taste.

Asa J. Wilbourn, M.D.

PREFACE

THIS BOOK IS NOT intended to be a sole source but rather a supplement to a complete training program. Its contents have been restricted so as to include just the information and procedures that are pertinent to the performance and interpretation of nerve conduction studies. Areas such as anatomy and physiology of nerves and muscles, and clinical correlation, have purposely been dealt with in a very broad manner. When reading this book one must remember that the examples given are based on the majority of typical cases and, as with most things in life, exceptions are a constant occurrence.

I would like to acknowledge and thank all of the people who have assisted, inspired, and directed me through this endeavor.

To all of the physicians and technicians who have endorsed and supported the need for such a text.

To all of the physicians at The University of Massachusetts Medical Center, Louisiana State University, and The Cleveland Clinic Foundation with whom I have had the privilege to work. Their clinical and electrical expertise has been a constant source of knowledge.

To Dr. William C. Hulley who from this book's conception to its birth has encouraged and directed me in its format, content, and approach.

To Dr. Asa J. Wilbourn whose contributions reach far beyond the technical training and knowledge he has imparted to me. Dr. Wilbourn inspires an attitude of excellence and an acute attention to detail that is so important in this field.

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Chapter 1

INTRODUCTION

MOST EMG EXAMINATIONS consist of two necessary but distinct parts—the nerve conduction studies and the needle examination. Both the nerve conduction studies and the needle examination are complementary testing procedures that evaluate different aspects of the peripheral neuromuscular system. Because the nerve conduction studies and the needle examination evaluate the peripheral neuromuscular system in different ways, it is unreasonable to think that one part may be performed in lieu of the other. Currently in the literature there can be found a wealth of knowledge concerning the performance and interpretation of the needle examination, but in spite of the importance of nerve conduction studies, there is little detailed information in the literature regarding its technique or interpretation.

Nerve conduction studies should be performed with the following questions in mind. First, is the problem a generalized process, or is it a local problem? That is, does the pathology affect all of the peripheral nerves, or does it affect a single nerve or localized area of the nervous system? Second, is it possible to determine the pathologic process involved, such as axonal loss (the death of a nerve fiber) or segmental demyelination (an abnormality of the myelin sheath surrounding the nerve)?

In order to answer these questions, it is first necessary to determine if each study is normal or abnormal. To do this, every laboratory must have a reliable set of normal values with which to compare these results. The most frequently used normal values are based on results obtained from a "normal" population consisting of a large number of healthy people in various age groups. These values are then compiled to give the upper and lower limits and/or the mean and standard deviation for each study. A reliable set of normal values should be compiled using the same techniques that are used when performing these studies on patients. Another way to determine the normality of a result is to compare one side with the corresponding study on the contralateral uninvolved limb. Care must be taken when judging these results to be sure the comparison is justified. For instance, the amplitudes of some responses may have a greater side-to-side variation than others. This is especially true when the recording sites are not easily accessible or do not have definite landmarks. It is difficult and sometimes erroneous to judge normal values based on a side-to-side comparison without having previously tried the same comparison on a normal population.

Three parameters are determined for most motor nerve conduction studies: (1) the amplitude and configuration, (2) the distal latency, and (3) the conduction velocity. Generally, for sensory conduction studies, only the amplitudes and peak latencies are reported, although conduction velocities may also be determined. Even though an individual parameter may give a clue to the underlying problem or indicate what additional studies need to be done, it is only by studying multiple nerves that valid conclusions are drawn. These conclusions can give considerable evidence as to the pathology and, therefore, the prognosis of the peripheral nerve problem.

Since normal values for nerve conduction studies are based on stringent standards and procedures, utilizing these normals and maintaining their accuracy depends on procedures that are rigorously followed for each study. Machine settings, methods of measurement, placement of electrodes, stimulation sites, recording sites, and types of electrodes are all factors that can change the results. There are different published methods and procedures than those found in this manual. Each method must be judged on the type of equipment and patient population found in the individual laboratory. The only absolute rule that must be followed when performing nerve conduction studies is consistancy of procedures and methods based on the same procedures and methods used to obtain normal values from a normal population. If other methods are found to be better adaptive to the equipment and patient population in a specific laboratory, then these procedures should be used. If they are different than the procedures described in this manual (or elsewhere), then the normal values must be modified by collecting new normal values using those different procedures.

All EMG equipment should have certain basic features: a differential amplifier, a stimulator, and displaying apparatus (oscilloscope and hard copy recorder). The procedures and, therefore, the normal values described here are based on the use of a TECA TE-4® EMG machine.

A differential amplifier amplifies the difference between the electrical activity picked up by the two recording electrodes. The amplifier should have the capacity to change the magnification of the response (gain) and to record certain frequencies while blocking others out (filters). Because the same filter settings may vary slightly between different machine models, each laboratory should collect some normal values and compare them to those in this manual or to other published normal values. If an amplifier is used that has filters set in the machine, they should also be checked against the filter settings used in this manual; if they are different, the normal values (especially for amplitude) must be modified to compensate for this difference. To minimize measurement variation, the gain and the sweep speed should, on each study, remain constant at all stimulation sites. Not only will this allow better comparisons between the different stimulation sites of each study, it will also decrease the amount of measurement variation.

The stimulator used for nerve conduction studies should consist of a stimulating component with an attached surface stimulator. The stimulating component must trigger the amplifier's sweep as well as stimulate the patient. There should be some mechanism to deliver the stimulation manually (not at specific intervals) and automatically at predetermined intervals. The ability to change the intensity of the stimulus is essential. This function may be either part of the component or part of the surface stimulator. The surface stimulator is a hand-held apparatus that is easily maneuvered to different stimulation sites along the nerve. The stimulating prongs or electrodes should be a specific distance apart (usually 2 to 3 cm).

A display screen, or oscilloscope, is used to display the response derived from the amplifier. With this, there must be some method of measuring time (milliseconds) and amplitude (microvolts and millivolts). The ability to store each response on the oscilloscope is very helpful and sometimes imperative when the normal values are based on the comparison of response configuration and/or the superimposition of a series of responses. A hard copy feature should also be present on all EMG equipment. This feature not only provides a permanent record but it also produces more accurate results because the time, size, and configuration of each response can be measured directly from this record.

Other components such as signal averagers, counters, and delay lines might serve specific needs in individual laboratories but are not necessary for procedures in this manual.