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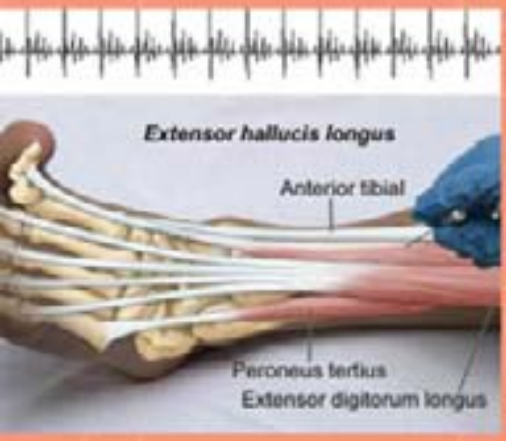

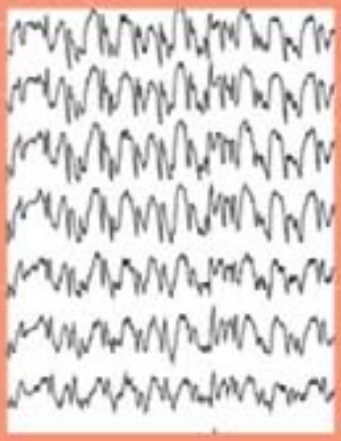

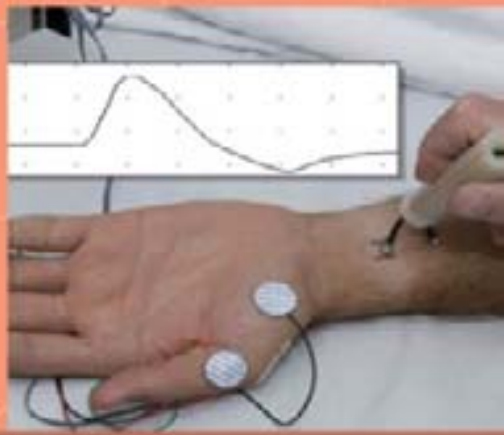

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Third Edition

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CLINICAL NEUROPHYSIOLOGY

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Foreword

Clinical neurophysiology is a mature field. Many of its techniques are standard operating procedures. Clinical neurophysiological approaches are logical extensions of the neurologic examination and can add information that is helpful in making a diagnosis. Because of its usefulness, clinical neurophysiology is practiced by a large percentage of neurologists and physiatrists. Even the neurologists and physiatrists who do not actively practice clinical neurophysiology are expected to understand it. Therefore, it is important for practitioners to understand the fundamental facts and principles of the field and to be current with key advances.

Clinical neurophysiology is also a large field. Like neurology, it encompasses a wide spectrum of issues and illnesses, ranging from the peripheral nervous system to the central nervous system. As in neurology, it is difficult to be an expert in all aspects of clinical neurophysiology, and most practitioners have a focused interest in the field. However, as is true for neurology, clinical neurophysiology has an essential unity. Problems are approached physiologically with methods that measure the electric activity of the nervous system. This is another reason for practitioners to be acquainted with the whole field even if they practice only a part of it.

Currently, there is considerable interest and activity in clinical neurophysiology. Numerous societies in the United States and throughout the world are devoted to this field, and their membership is growing. The two principal societies in the United States are the American Association of Neuromuscular and Electrodiagnostic Medicine, with its journal *Muscle and Nerve*, and the American Clinical Neurophysiology Society, with its journal *Journal of Clinical Neurophysiology*. The umbrella organization for the societies worldwide, the International Federation of Clinical Neurophysiology has members in 58 countries and its journal *Clinical Neurophysiology*. There are several examining bodies for competence in clinical neurophysiology. In the United States, the American Board of Psychiatry and Neurology examines for competence in the broad field, the American Board of Electrodiagnostic Medicine examines in the area commonly known as electromyography, and the American Board of Clinical Neurophysiology examines in the area of electroencephalography.

Where can a physician turn to learn the basics of clinical neurophysiology and be sure the information is up-to-date? When Mayo Clinic neurologists speak about clinical neurophysiology, they speak with special authority. The Mayo Clinic has been a central force in the United States in many areas of the field. In the area of electromyography, Dr. Edward Lambert, a pioneer in the field, made many basic observations that still guide current practice, and, of course, he identified an illness that now bears his name. He has trained many leaders of modern electromyography in the United States. In electroencephalography, Dr. Reginald Bickford was a pioneer and was active in many areas, including evoked potentials and even early attempts at magnetic stimulation of the brain. Many other leaders in electroencephalography have been at the Mayo Clinic, and four of them, in addition to Dr. Bickford, have been presidents of the American Clinical Neurophysiology Society. No one is better suited to orchestrate the writing of a textbook on *Clinical Neurophysiology* than Dr. Jasper Daube, a leader in clinical neurophysiology at Mayo and former head of the Neurology Department there. Dr. Daube is well recognized internationally as an expert in electromyography; he is very knowledgeable about all areas of the subject, basic and applied. He is an outstanding leader with a gift for organization. He has been ably assisted by Dr. Devon I. Rubin, another Mayo clinical neurophysiologist, who has worked with Dr. Daube on several projects in addition to this book.

For all these reasons, it is nice to see this third edition of *Clinical Neurophysiology*. Its many chapters cover the field in a broad way. The first several chapters discuss the basic issues of neuronal generators, biologic electricity, and measurement techniques central to all areas of clinical neurophysiology. A new chapter in this section deals with fundamental membrane and synaptic physiology. Next, the individual areas of the field are discussed: areas including classic electromyography, electroencephalography, and evoked potentials and extending to autonomic nervous system testing, sleep, surgical monitoring, motor control, vestibular testing, and magnetic stimulation. The text is organized for physicians who want to know how to make an assessment of a particular symptom, of a particular system, or for a particular disease. There is valuable information on the use of clinical neurophysiologic testing in a practical setting. Each chapter has periodic summaries of key points, which help understanding and learning. The book is profusely illustrated and has an accompanying CD that includes instructions with pictures of standard nerve conduction studies, anatomical illustrations for performing needle EMG on standard muscles, protocols for the approach to a wide range of clinical problems, and normal value tables.

Clinical neurophysiology, even though mature, like all other fields of medicine, is evolving. Analysis and management of data are becoming more heavily computerized. New methods of quantification are now possible and are being used clinically. New techniques are being developed. Perhaps most important, increasing emphasis is placed on how to improve patient care with better integration of clinical neurophysiologic testing; the third section of the book is devoted to these issues. This authoritative third edition should serve both students and practitioners, keeping them up-to-date about important new advances.

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Preface

Clinical Neurophysiology is the result of more than 60 years of experience at the Mayo Clinic in training clinicians in the neurophysiologic methods for assessing diseases of the central and peripheral nervous systems. The lectures and handouts that were developed initially by Doctors Reginald Bickford and Edward Lambert in electroencephalography and electromyography, respectively, were the seeds of what has grown into the far-reaching field of endeavor of clinical neurophysiology at Mayo Clinic. The clinical neurophysiology teaching programs at Mayo Clinic Rochester, Jacksonville, and Arizona have continued to evolve into a formal, unified, 2-month course in clinical neurophysiology that provides trainees with the knowledge and experience needed to apply the principles of neurophysiology clinically.

The development of clinical neurophysiology at Mayo has paralleled developments in the field of medicine at large. The expansion during the past 25 years of neurophysiology of diseases of the central and peripheral nervous system has been recognized by the American Board of Psychiatry and Neurology, by the American Board of Medical Specialties with a Special Qualifications Examination in Clinical Neurophysiology, and by the Accreditation Council for Graduate Medical Education Residency Review Committee for postresidency fellowships in Clinical Neurophysiology.[1]

The Mayo course in clinical neurophysiology serves as an introduction to clinical neurophysiology for residents, fellows, and other trainees. The course includes lectures, small group seminars, practical workshops, and clinical experience in each of the areas of clinical neurophysiology. The faculty for the course consists entirely of Mayo Clinic staff members. These staff members are the authors of the chapters of this textbook.

Over the years, the material for the clinical neurophysiology course was consolidated from individual lecture handouts into manuals. Persons outside Mayo who had learned about these manuals by word of mouth increasingly requested them. The success of these manuals prompted us to publish the first edition of *Clinical Neurophysiology* in 1996 and a second edition in 2002. The continued evolution and expansion of the field of clinical neurophysiology has resulted in this third edition.

The organization of our textbook is unique: it is built around the concept of testing systems within the nervous system, rather than separated by individual techniques. The book consists of three major sections. The first section is a review of the basics of clinical neurophysiology, knowledge that is common to each of the areas of clinical neurophysiology. The second section considers the assessment of diseases by anatomical system. Thus, methods for assessing the motor system are grouped together, followed by those for assessing the sensory system, higher cortical functions, and the autonomic nervous system. The third section explains how clinical neurophysiologic techniques are used in the clinical assessment of diseases of the nervous system.

This third edition includes new approaches, such as those described in the new chapters on EEG coregistration with MRI imaging in epilepsy and motor unit number estimate studies in peripheral neuromuscular diseases. The underlying physiologic and electronic principles in *Clinical Neurophysiology* have not changed but the approach to teaching them with bullet points and key points has provided simplification and clarification. The clinical problems in which each of the clinical neurophysiologic approaches can add to the diagnosis and management of neurologic disease have been detailed, especially the assessment of clinical symptom complexes with electroencephalography (EEG). The discussion of pediatric EEG disorders, ambulatory EEG, new equipment and digital analyses, magneto-EEG, electromyographic (EMG) techniques, motor unit number estimates, myoclonus on surface EMG, segmental sympathetic reflex, and postural hypotension has

been expanded. Chapters on EMG quantification and single fiber EMG have been reorganized, and major revisions have been made in the discussion of sensory potentials, somatosensory evoked potentials, acoustic reflex testing, cardiovagal function, physiologic testing of sleep, and assessment of sleep disorders. New approaches have been expanded in each of the four chapters on monitoring neural function during surgery, particularly with motor evoked potentials.

For the first time, this edition also includes a CD with material immediately available during clinical electromyography. Pictures are provided, depicting nerve conduction study and somatosensory evoked potential techniques used in the Mayo Clinic EMG Laboratories including accompanying Mayo normal values, images depicting muscle surface anatomy with superimposed illustrated muscles for localization during needle EMG, and algorithms used for assessment of common problems in the clinical EMG laboratory and during intraoperative monitoring. The CD also contains the "EMG Sound Simulator and Synthesizer," a unique, downloadable, interactive program that teaches EMG waveform recognition, and motor unit potential assessment and interpretation. Interactive CNP learning has been shown to be more effective than lectures.[2]

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Acknowledgments

The authors of the third edition of *Clinical Neurophysiology* have made our work as editors both educational and enjoyable. Each of the authors is active in clinical neurophysiology practice, education, and research. They bring their experiences to bear in the chapters they have written. Thus, our task was the remarkably easy one of organizing and coordinating the material. The editors and authors appreciate the skill and professionalism of Roberta Schwartz of the Sections of Scientific Publications; she has had an integral part in the development of this textbook. The work of the medical illustrators, Paul Honerman, David Factor, and David Cheney, and of Raj Alphonse and others in the Media Support Services at the Mayo Clinic, have been invaluable in the development and preparation of the supplemental material including that in the accompanying CD.

Mayo Neurology leadership has continued to encourage and support the Division of Clinical Neurophysiology in its combined efforts to provide trainees with the broad background of knowledge they will need as they enter active practice. This support has provided strong encouragement for this book. The staff in the Division of Neurophysiology—including staff at all three Mayo Clinic sites in Jacksonville, Florida; Rochester, Minnesota; and Scottsdale, Arizona—have contributed in a major way to the clinical neurophysiology course on which this textbook is based. The laboratory directors have been particularly important: Drs. Eric Sorenson, Devon Rubin, and Benn Smith, chairs of the Divisions of Clinical Neurophysiology and directors of the Electromyography Laboratories at the three Mayo Clinics; Dr. Phillip Low, director of the Autonomic Reflex Laboratory and the Nerve Physiology Laboratory; Dr. Elson So, director of the Electroencephalographic Laboratory; Dr. Michael Silber, director of the Sleep Disorders Center; and Dr. Robert Fealey, director of the Thermoregulatory Sweat Laboratory.

The support of the Mayo Foundation has been critical in the development of new directions and unique training programs in clinical neurophysiology. We acknowledge not only this support but also the help given by many others: the trainees who have participated in our clinical neurophysiology program and the students in our courses in continuing medical education who have given us feedback on our teaching material, the technicians who have been a major part of our teaching program and who have provided a helpful critique of our activities, Jean M. Smith and the other secretarial staff who have worked diligently to keep the project on track, and other physicians at our institution who have found our help in clinical neurophysiology useful in the care of their patients.

Jasper R. Daube, MD and Devon I. Rubin, MD