Laryngeal Electromyography

Third Edition

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Robert Thayer Sataloff, MD, DMA, FACS
Steven Mandel, MD
Yolanda Heman-Ackah, MD
Mona Abaza, MD

Plural Publishing Inc.

PLURAL PUBLISHING
INC.

5521 Ruffin Road
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e-mail: info@pluralpublishing.com
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PREFACE

Since the mid-1970s, extraordinary advances in basic science, laryngology, and technology have resulted in dramatic improvements in our understanding of the human voice and our ability to diagnose and treat voice disorders. Laryngeal electromyography (LEMG) is among the most important of the many new developments.

Although LEMG has been recognized since 1944, and important research regarding its application has been performed from the 1950s through the present day, its practical clinical importance has been appreciated by more than a few researchers only for the past couple of decades. Even now, many laryngologists do not have access to LEMG, even though there are skilled electromyographers in their communities. Most electromygraphers (neurologists, physiatrists, and others) have had no training in the study of laryngeal muscles and are reluctant initially to insert needles into laryngeal musculature. This book is written as an easy guide for laryngologists, neurologists, physiatrists, and other potential electrophysiologists who are anxious to add LEMG to their clinical armamentarium. LEMG can be performed by trained specialists in any of these fields, and expert laryngeal electromyography is essential to accurate laryngologic diagnosis. LEMG should be available to any voice care team.

The first and second editions of this book covered most of the practical aspects of laryngeal electromyography, as well as essential scientific information required to understand the procedure and its interpretation. The third edition has updated and expanded these topics, adding new information including evidence-based research. Extensive new literature on intraoperative monitoring has been summarized. The book includes neurophysiologic information that should be helpful to laryngologists who want to begin performing LEMG, as well as discussions of laryngeal anatomy, needle placement technique, and selected voice

disorders that should help experienced electromyographers who are not laryngologists become comfortable with LEMG.

Chapter 1 provides an overview of laryngeal electromyography and its clinical applications. **Chapter 2** discusses anatomy and physiology of the voice, providing a distillation of essential information for neurologists and physiatrists interested in adding LEMG to their practices. **Chapter 3** discusses vocal fold hypomobility and its various causes, not all of which are neurogenic. In **Chapter 4**, the fundamentals of electrodiagnostic evaluation are summarized. This chapter is intended to provide a clinically practical introduction for laryngologists. **Chapter 5** reviews the evolution of laryngeal electromyography from 1944 through 2016, summarizing the most important and most recent literature on the topic. **Chapter 6** includes case studies to demonstrate the practical application of LEMG in clinical care. **Chapter 7** has been rewritten extensively to provide the latest information of intraoperative vocal fold monitoring. Appendix I is a convenient outline summary of LEMG, and Appendix II is a republication of an evidencebased practice parameter on the topic.

We hope that this book provides practical help for physicians in various specialties and that it facilitates wider utilization of this invaluable procedure.

ABOUT THE AUTHORS

Robert Thayer Sataloff, MD, DMA, FACS

Robert Thayer Sataloff, MD, DMA, FACS, is Professor and Chairman, Department of Otolaryngology-Head and Neck Surgery and Senior Associate Dean for Clinical Academic Specialties, Drexel University College of Medicine. He is also Adjunct Professor in the Departments of Otolaryngology-Head and Neck Surgery at Thomas Jefferson University, as well as Adjunct Clinical Professor at Temple University and the Philadelphia College of Osteopathic Medicine; he is also on the faculty of the Academy of Vocal Arts. He is the conductor of the Jefferson University Choir. Dr Sataloff is also a professional singer and singing teacher. He holds an undergraduate degree from Haverford College in Music Theory and Composition; graduated from Jefferson Medical College, Thomas Jefferson University; received a Doctor of Musical Arts in Voice Performance from Combs College of Music; and completed residency in Otolaryngology-Head and Neck Surgery and a fellowship in Otology, Neurotology, and Skull Base Surgery

at the University of Michigan. Dr Sataloff is Chairman of the Boards of Directors of the Voice Foundation and of the American Institute for Voice and Ear Research. In addition to directing all aspects of these two nonprofit corporations, he has led other nonprofit and for-profit enterprises. He has been Chairman and Chief Executive of a multiphysician medical practice for over 30 years, and he served as Vice President of Hearing Conservation Noise Control, Inc. from 1981 until the time of its sale in 2003. He has also served as Chairman of the Board of Governors of Graduate Hospital; President of the American Laryngological Association, the International Association of Phonosurgery, and the Pennsylvania Academy of Otolaryngology-Head and Neck Surgery; and in numerous other leadership positions. Dr Sataloff is Editor-in-Chief of the *Journal of Voice*; Editor-in-Chief of *Ear, Nose and Throat Journal*; Associate Editor of the *Journal of Singing*; and on the editorial boards of numerous otolaryngology journals. He has written approximately 1000 publications, including 61 books, and has been awarded more than $5 million in research funding. His medical practice is limited to care of the professional voice and to otology/neurotology/skull base surgery. Dr Sataloff has developed numerous novel surgical procedures, including total temporal bone resection for formerly untreatable skull base malignancy, laryngeal microflap and minimicroflap procedures, vocal fold lipoinjection, vocal fold lipoimplantation, and others. He has invented more than 75 laryngeal microsurgical instruments produced by Integra Medical, ossicular replacement prostheses produced by Grace Medical, and novel laryngeal prostheses with Boston Medical. Dr Sataloff is recognized as one of the founders of the field of voice, having written the first modern comprehensive article on care of singers and the first chapter and book on care of the professional voice, as well as having influenced the evolution of the field through his own efforts and through the Voice Foundation for nearly 4 decades. He has been involved extensively throughout his career in education, including development of new curricula for graduate education. Dr Sataloff has been instrumental in training not only residents but also fellows and visiting laryngologists from North America, South America, Europe, Asia, and Australia. His fellows have established voice centers throughout the United States and in Turkey, Singapore, Brazil, and elsewhere. He also is

active in training nurses, speech-language pathologists, singing teachers, and others involved in collaborative arts medicine care, pedagogy, and performance education. Dr Sataloff has been recognized by Best Doctors in America (Woodward White Athens) every year since 1992, *Philadelphia Magazine* since 1997, and Castle Connolly's "America's Top Doctors" since 2002.

Steven Mandel, MD

Dr Mandel is Clinical Professor of Neurology at Hofstra Northwell School of Medicine. He received his medical degree from Albert Einstein College of Medicine in Bronx, New York. He is president of Neurology and Neurophysiology Associates of Pennsylvania and New Jersey. His areas of interest include neuromuscular electrophysiology, minor head injury, peripheral nerve disorders, laryngeal electromyography, and disability medicine. He has coedited three books, *Minor Head Injury*, *The Handbook of Neurology of the Lower Extremities*, and *Laryngeal Electromyography*, and has published more than 100 articles. Dr Mandel is Associate Editor of the *Journal of Disability* and *Disability Medicine*. He is a frequent lecturer and has actively participated in community service organizations for adults and children with disabilities. Dr Mandel is married to Heidi Mandel, doctor of podiatric medicine, and has three children, Jesse, Elisabeth, and David.

Yolanda Heman-Ackah, MD

Yolanda D. Heman-Ackah, MD, is an otolaryngologist, certified by the American Board of Otolaryngology, who subspecializes in professional voice care and laryngology. Her background as a trained musician, dancer, and singer makes her uniquely qualified to understand the vocal demands of the performing artist and to tailor treatment of professional voice disorders based on this understanding. Her primary practice focus is in treating the professional voice user (singers, actors, public speakers, physicians, lawyers, teachers, etc.), but she also treats other voice and airway problems such as laryngopharyngeal reflux disease, spasmodic dysphonia, laryngeal papillomatosis, airway stenosis, vocal fold paralysis, arytenoid dislocation, and laryngeal cancer. Her approach to the care of the professional voice is multidisciplinary and includes the active involvement of speaking voice therapists, acting voice therapists, singing voice therapists, gastroenterologists, neurologists, pulmonologists, general surgeons, and other health care professionals, as indicated by the individual patient's needs.

Dr Heman-Ackah received her Bachelor of Arts degree in Psychology and her Doctor of Medicine degree from Northwestern University as part of the Honors Program in Medical Education. She completed a residency in Otolaryngology-Head and Neck Surgery at the University of Minnesota and then completed a

fellowship in Professional Voice Care and Laryngology under the preceptorship of Robert T. Sataloff, MD, DMA, in Philadelphia, Pennsylvania. Following her fellowship, she founded and directed the Voice Center at the University of Illinois at Chicago, where she brought professional voice care to the Chicago voice community, and was Assistant Professor of Otolaryngology-Head and Neck Surgery. She has also held the positions of Head of the Section of Laryngology and Co-Director of the Voice Center at the Cleveland Clinic, Clinical Professor at Drexel University College of Medicine, and Clinical Adjunct Associate Professor of Otolaryngology-Head and Neck Surgery at Thomas Jefferson University Medical College in Philadelphia.

Dr Heman-Ackah is known nationally and internationally for her pioneering research on the laryngeal chemoreflex, which has furthered our understanding of how laryngeal reflexes can contribute to sudden infant death syndrome, as well as for her research in developing measures for voice analysis and in describing strobovideolaryngoscopic findings in singers. Dr Heman-Ackah has received numerous awards and grants for her research, including awards from the American Academy of Otolaryngology-Head and Neck Surgery, the American Laryngological Association, and the American Laryngological Voice Research and Education Foundation. She has been elected to membership in the International Association of Phonosurgeons, the American Laryngological Association, the Triologic Society, and the American Broncho-Esophagological Society. She is also a member of the National Association of Teachers of Singing (NATS), the Voice and Speech Trainer's Association (VASTA), the National Academy of Recording Arts and Sciences, the Latin Academy of Recording Arts and Sciences, and the Voice Foundation. She is the National Medical Advisor for VASTA, as well. She has written numerous publications, including coauthoring the first textbook on laryngeal electromyography. She is a member of the Editorial Board of the *Journal of Voice* and a reviewer for *Laryngoscope*, *Otolaryngology Head and Neck Surgery Journal*, and *Annals of Otology, Rhinology, and Laryngology*. Most recently, she was named a Top Doctor by America's Top Doctor. She continues to pioneer advancements in voice care through her basic science and clinical research, as well as through educational programs for medical students, residents, singing teachers, speech-language pathologists, otolaryngologists, and other physicians and voice professionals.

Mona Abaza, MD

Dr Abaza received her undergraduate degree in biology from Pennsylvania State University and her medical degree from The Medical College of Pennsylvania in 1991. Her surgical training began at the University of Medicine and Dentistry of New Jersey in Newark, followed by a 2-year Intramural Research Training Award Fellowship at the National Institute on Deafness and Other Communication Disorders (National Institutes of Health [NIH] in Bethesda, Maryland). After leaving the NIH, she began her Otolaryngology-Head and Neck Surgery residency at the University of Texas Health Science Center in San Antonio. She then completed a fellowship in Laryngology/Professional Voice Care with Robert Sataloff, MD, DMA, at the American Institute for Ear and Voice Research in Philadelphia, Pennsylvania. Joining the University of Colorado Health Sciences Center, Department of Otolaryngology-Head and Neck Surgery as an Assistant Professor in 1999, she is currently Professor, Vice Chair for Education, and Residency Program Director. Dr Abaza most recently opened the University of Colorado Hospital Voice Practice at the National Center for Voice and Speech at the Denver Center for Performing Arts, where she serves as medical director.

CONTRIBUTORS

Mary J. Hawkshaw, RN, BSN, CORLN
Research Professor
Department of Otolaryngology-Head and Neck Surgery
Drexel University College of Medicine
Philadelphia, Pennsylvania
Chapter 7

Jeffrey Liaw, BS
Medical Student
Drexel University College of Medicine
Philadelphia, Pennsylvania
Chapter 7

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To Our Families

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Laryngeal Electromyography: Introduction and Overview

Laryngeal electromyography (LEMG) is a procedure that evaluates the integrity of the muscles and nerves of the larynx. The movements of the vocal folds are coordinated by the activities of the muscles of the larynx, the cartilages of the larynx, and the brain and nerves that supply the muscles of the larynx. Anatomy and physiology of the voice are discussed in Chapter 2. Details of the procedure and its clinical applications are introduced in this chapter and expanded upon in subsequent chapters; important points are summarized in Appendix I. Diagnostic LEMG is indicated in patients who have evidence of a movement disorder of the vocal folds. The purpose of diagnostic LEMG is to help elucidate the cause of these movement disorders and serve as a guide to diagnosis. Laryngeal motion abnormalities can be caused by joint dysfunction, muscular abnormalities, or central or peripheral neural disorders involving the larynx. Understanding the etiology of the motion abnormality is important in developing an effective treatment algorithm. LEMG has proven extremely helpful clinically, although evidence-based data confirming the

usefulness of LEMG remain scarce (Appendix II). Movements of the vocal folds are coordinated by the activities of the muscles of the larynx, the cartilages of the larynx, and the brain and laryngeal nerves that supply the muscles of the larynx. Anatomy and physiology of the voice are discussed in Chapter 2.

PRINCIPLES OF AND INDICATIONS FOR DIAGNOSTIC LEMG

Diagnostic LEMG is performed to evaluate the integrity of the laryngeal neuromuscular system. LEMG takes advantage of the fact that nerves have an electrical signal that is transformed into a chemical signal at the neuromuscular junction. Electrodes are placed transcutaneously in the muscles of the larynx. The electrodes sense the electrical impulses within the muscle and convert them to visual and auditory signals that can be interpreted by the physician performing the procedure or an electrophysiologist.

LEMG PROCEDURE

LEMG is performed often as a diagnostic procedure, but it can also be used therapeutically to help guide the identification of the position of the laryngeal muscles for therapeutic injections and to monitor the activity of the laryngeal nerves during operative procedures. The procedure for LEMG for therapeutic and diagnostic indications involves the use of needle or hooked-wire electrodes via a percutaneous insertion technique. Intraoperative monitoring of the laryngeal nerves most commonly involves the use of surface electrodes, although needle and/or hooked-wire electrodes can also be used for this indication. Some otolaryngologists perform LEMG themselves. Neurologists, physiatrists, or electrophysiologists can also perform LEMG. The otolaryngologist's decision to perform LEMG with the help of other professionals depends on his or her level of comfort and expertise in interpreting electromyographic findings. Because neurologists, physiatrists, and electrophysiologists perform electromyography (EMG) on other neuromuscular systems on a daily basis, and because their professional training equips them with expertise in interpretation of complex neuromuscular electrical

signals, many otolaryngologists prefer to have them assist in the interpretation of diagnostic LEMGs. Because the use of LEMG for botulinum toxin injections into laryngeal muscles requires a less sophisticated level of expertise in LEMG interpretation, often this procedure is performed solely by the otolaryngologist.

To perform LEMG, the patient is usually asked to lie down with the neck extended, a position that brings the larynx closer to the skin and aids the palpation of laryngeal landmarks for accurate insertion of the electrodes into the laryngeal muscles. As with all other sites of injections, the neck is cleansed first with alcohol. The insertion of the needles through the skin feels like a pinprick; the insertion into the muscles of the larynx may be almost free of sensation or may produce a mild stabbing sensation, similar to the sensation experienced when receiving an intramuscular injection. Local anesthetic can be given to prevent the pinprick sensation on the skin; however, injection of the anesthetic itself results in a pinprick sensation as well as a burning sensation and thus is not used routinely. Local anesthetic should not generally be given to reduce the sensations experienced during insertion of the electrodes into the muscles, as anesthesia may alter the electrical signals of the nerves and the muscles and confound the results, and it should not be given so a patient's ability to swallow and cough remains intact.

A surface or ground electrode is placed on the forehead, chest, or another part of the body away from the neck to help filter background electrical activity. The electrode used in diagnostic LEMG is usually a needle electrode or a hooked-wire electrode that is inserted with the use of a needle. Because surface electrodes record electrical activity over a large surface area, they are not sensitive enough to provide accurate information about the small individual muscles in the larynx. Needle and hooked-wire electrodes sample electrical activity over a smaller surrounding area and thus are better suited for recording the activity of the small intrinsic laryngeal muscles.

There are four pairs of muscle groups in the larynx: the thyroarytenoid (TA), the lateral cricoarytenoid (LCA), the posterior cricoarytenoid (PCA), and the cricothyroid (CT). There is also an unpaired interarytenoid muscle that is tested only rarely. The TA, PCA, and CT muscles are tested on each side routinely. Usually, testing of these three groups of muscles provides sufficient information about the integrity of the superior and recurrent

laryngeal nerves and the muscles that they innervate for most clinical purposes. When equivocal results are obtained or when additional information is needed, the lateral cricoarytenoid and interarytenoid muscles may be tested as well. The needles are inserted through the skin and into the laryngeal muscles. The positions of the thyroid and cricoid cartilages are identified and the needle is passed through the cricothyroid membrane and in the direction of the muscle of interest. When the needle is positioned correctly, the patient is asked to perform laryngeal maneuvers (phonatory, respiratory, or swallowing) that require contraction of the muscle of interest and relative relaxation of the other muscles of the larynx. Testing of the cricothyroid muscle, for example, involves sliding from a low-pitched sound to a high-pitched sound. Testing the posterior cricoarytenoid muscle involves performing a forceful sniff. For the thyroarytenoid, lateral cricoarytenoid, and interarytenoid muscles, saying */i/* produces the desired muscle activity. The anatomic distinction among these three muscles is that the thyroarytenoid muscle sits higher and more toward the middle of the larynx than does the lateral cricoarytenoid muscle, the lateral cricoarytenoid muscle sits laterally and posteriorly in the larynx, and the interarytenoid muscle lies between the arytenoid cartilages and more posteriorly in the larynx than do the lateral cricoarytenoid and thyroarytenoid muscles. Differences of electrical activity in these muscles and in positioning of the needle for accurate insertion into each laryngeal muscle are discussed in Chapter 5. When the needle is in the correct position, the electrical signal seen on the oscilloscope and the auditory signal heard through the speakers will be increased with the appropriate phonatory, respiratory, or swallowing maneuver. If botulinum toxin is to be injected, it is injected through the EMG needle once the intended muscle is isolated. If LEMG is being performed for diagnostic purposes, the specific facets of the electrical signal are assessed as described briefly here and in detail in Chapters 4 and 5.

INTERPRETING LEMG RESULTS

Diagnostic LEMG involves the assessment of four main characteristics of the EMG signal: insertional activity, spontaneous

activity, recruitment, and waveform morphology. The results of LEMG alone are not sufficient to establish a specific diagnosis. LEMG gives general information about the integrity of the motor units (the nerve fibers and their respective muscle fibers), the muscle, the nerve, and the neuromuscular junction and must be interpreted within the context of the clinical setting. A multitude of disease processes can produce damage to any of these structures. LEMG quantifies neuromuscular function and, sometimes, can give an indication of the chronicity of abnormal function. The etiology of the voice dysfunction is established on the basis of the history of the patient's voice dysfunction, the physical examination, imaging studies, laboratory studies, and results of LEMG and biopsies, as indicated by the suspected disease process.

Each of the factors investigated with LEMG provides an indication of the chronicity, the site of pathology, and the prognosis for recovery. Serial LEMGs can be performed to follow changes in nerve recovery or degeneration over time, allowing a better indication of the prognosis for recovery. In patients with paresis (weakness, hypomobility) or paralysis (complete nerve dysfunction, essentially immobility), the results of the LEMG may also help to guide subsequent voice therapy. If mild paresis is found, the patient should receive voice therapy aimed specifically at increasing the strength of the paretic muscle. In patients with moderate paresis and/or paralysis who may benefit from surgical procedures to enhance voice production, LEMG may aid in determining the nature and timing of the surgical procedure. If there is evidence of an ongoing neural degenerative process, surgery may be delayed until degeneration is complete or tailored to accommodate additional surgery as the disorder progresses. Similarly, if there is evidence of reinnervation, surgery may be delayed until maximal recovery has been achieved.

SUMMARY

LEMG is a procedure that evaluates the integrity of laryngeal nerves and muscles. It is particularly useful in differentiating disorders affecting the superior and recurrent laryngeal nerves from those affecting the laryngeal joints, neuromuscular junctions, or

the muscles of the larynx. LEMG should be considered as an extension of the physical examination, not as an isolated laboratory procedure. LEMG abnormalities are interpreted within the broader clinical context and are used to assist in the diagnosis and treatment of vocal fold motion abnormalities.