MedEdPORTAL®
The Journal of Teaching and Learning Resources

Original Publication

A Self-Study Curriculum in Electromyography and Nerve Conduction Studies for Residents and Fellows

Zachary N. London, MD*, Gary W. Gallagher, MD, Matthew J. Ebright, MD
*Corresponding author: zlondon@med.umich.edu

Citation: London ZN, Gallagher GW, Ebright MJ. A self-study curriculum in electromyography and nerve conduction studies for residents and fellows. *MedEdPORTAL*. 2017;13:10581. https://doi.org/10.15766/mep_2374-8265.10581

Abstract

Introduction: To our knowledge, there are no freely available curricula for a focused resident or fellow rotation in electromyography and nerve conduction studies that address the Accreditation Council for Graduate Medical Education (ACGME) milestones for neurology, physical medicine and rehabilitation, clinical neurophysiology, or neuromuscular medicine. Thus, we created this curriculum to help trainees develop a basic understanding of clinical electrodiagnostic studies. The program objectives map to many of the relevant ACGME milestones, primarily those pertaining to medical knowledge, patient care, and practice-based learning and improvement. **Methods:** The curricular materials include an interactive, hyperlink-driven slide show with 19 educational modules, subdivided further into basic and advanced topics. We also created a 50-question multiple-choice test, paired each question with key concepts, and provided instructions on using the test results to develop a trainee-specific learning plan. **Results:** Residents and fellows have been using this curriculum at the University of Michigan since 2007. The mean and median scores of 80 trainees who took the 50-item test between 2007 and 2016 were 80% and 82%, respectively, with a standard deviation of 10%. In annual surveys of neurology residents, this electromyography rotation has consistently had the highest mean approval rating of all clinical rotations in the training program. **Discussion:** This curriculum is a complete, self-contained learning resource that may be used alone or to supplement a supervised apprenticeship for trainees who want to learn to perform electrodiagnostic studies independently. The content ensures that trainees demonstrate mastery of many of the ACGME milestones for their field.

Keywords

Electrophysiology, Neurophysiology, Neurology, Electromyography, Nerve Conduction Studies, Neuromuscular, Physical Medicine and Rehabilitation

Educational Objectives

By the end of this session, learners should be able to:

1. Summarize the measurable features of the sensory nerve action potential, compound muscle action potential, F-response, H-reflex, and repetitive stimulation.
2. Identify and interpret normal and abnormal electromyographic patterns of resting muscle and voluntary motor activity.
3. Describe the nerve, nerve root, and plexus innervations of the commonly tested upper and lower extremity muscles.
4. Compare the clinical and electrodiagnostic features of common polyneuropathies, mononeuropathies, radiculopathies, plexopathies, and myopathies.
5. Develop an appropriate learning plan based on identified knowledge gaps.
6. Achieve the appropriate Accreditation Council for Graduate Medical Education milestones for neurology residency, physical medicine and rehabilitation residency, neuromuscular medicine fellowship, and clinical neurophysiology fellowship.

Appendices

A. ACGME Milestones Addressed.docx
B. Introduction to EMG and NCS.pptx
C. EMG Multiple-Choice Test .docx
D. EMG Multiple-Choice Test - Answers.docx
E. Learning Plan - Teacher Instructions.docx
F. Learning Plan - Student Version.docx

All appendices are peer reviewed as integral parts of the Original Publication.

Introduction

Electromyography (EMG) and nerve conduction studies (NCS) are diagnostic tests that are almost always performed in conjunction. Together, they constitute electrodiagnostic testing that, by convention, is often simply referred to as EMG. These studies are performed by physicians, usually those with specialty training in neurology or physical medicine and rehabilitation. Physicians may learn this discipline during residency or as part of a subspecialty fellowship in neuromuscular medicine or clinical neurophysiology after residency.

The Accreditation Council for Graduate Medical Education (ACGME) rolled out the Milestones Initiative between 2014 and 2015. The goal of this initiative is to ensure that trainees demonstrate completion of the knowledge and skills specific to their specialties, rather than just completion of rotations.[1] The ACGME has published relevant milestones for neurology residents, physical medicine and rehabilitation residents, neuromuscular medicine fellows, and clinical neurophysiology fellows. All of these include milestone domains related to electrodiagnostic studies and peripheral nervous system anatomy.[2-7]

To our knowledge, there is no freely available curriculum for a focused EMG rotation that addresses these milestones. The American Association of Neuromuscular & Electrodiagnostic Medicine provides educational guidelines for electrodiagnostic training programs on its website.[8] That document contains global educational objectives and recommends that trainee assessment include "any combination of written or oral examinations, either formal or informal." The American Association of Neuromuscular & Electrodiagnostic Medicine and other professional organizations offer fee-based training modules and self-assessment examinations in electrodiagnostic medicine. One training center in Japan has published survey data and test scores based on its 2-day primer course in electrodiagnostic medicine, but the course materials are not included.[9] With the current resource, we have endeavored to develop a complete, self-contained EMG curriculum to address the milestones listed in Appendix A.

This program is a mixed-media, interactive curriculum designed to give trainees a fundamental understanding of the clinical application of electrodiagnostic studies. No specific knowledge or skills are required for a trainee to use this curriculum. The program objectives map to many of the relevant ACGME milestones, primarily those pertaining to medical knowledge, patient care, and practice-based learning and improvement. This curriculum can be used independently or in the context of a supervised apprenticeship. Direct patient experience is necessary for a trainee to master physical skills, which are not addressed in this curriculum.

Methods

Many EMG training programs host only one learner at a time, so we needed to design educational resources that focused on individual, rather than group, teaching activities.

The principal educational resource is a PowerPoint file consisting of electronic modules interconnected by hyperlinks (Appendix B). A summary of these 19 modules is provided in the Table. Implementation of this resource is straightforward. Each module consists of a series of questions that the trainee attempts to answer before advancing the presentation to see the correct responses. After reviewing all of the basic topics in each module, the trainee has the option to explore the module at a deeper level by reviewing questions pertaining to advanced topics. The hyperlinks embedded in the master slide layout allow trainees to shift freely between modules and different levels of complexity. This interactive, nonlinear approach encourages learners to proceed at their own pace and focus on relative areas of interest and relative areas of weakness.

After studying the basic topics in all 19 modules, the trainee completes the 50-question multiple-choice test, which addresses only the basic topics covered in the self-study modules (Appendices C & D). To allow for different learning styles and paces, our trainees are given some autonomy about when to take the test. Most commonly, this is 3 to 5 weeks into a 12-week rotation.

Table. Summary of Modules in Appendix B

Module	Topics Covered
Basic Concepts	Basic concepts of electricity and electronics in clinical electrodiagnostic testing
Nerve Conduction	Measurable features of the sensory nerve action potential, compound muscle action potential, F-response, and H-reflex
Normal Values	Normative values for commonly performed nerve conduction studies
Repetitive Stim	Setup and interpretation of repetitive stimulation studies
EMG–Resting	Normal and abnormal patterns on EMG of resting muscle, including insertional activity, endplate noise, fibrillation potentials, positive sharp waves, complex repetitive discharges, fasciculations, myokymia, cramp potentials, and neuromyotonia
EMG Motor Units	EMG features of voluntary motor activity, including duration, polyphasia, amplitude, and recruitment
Common Scenarios	Electrodiagnostic findings in axonal neuropathy, demyelinating neuropathy, and myopathy
Pathophysiology	Neurapraxia, neurotmesis, axonotmesis, and Wallerian degeneration
Normal Anatomy	Nerve, nerve root, and plexus innervations of upper and lower extremity muscles
Median Nerve	Clinical and electrodiagnostic features of median mononeuropathies at different sites
Ulnar Nerve	Clinical and electrodiagnostic features of ulnar mononeuropathies at different sites
Peroneal Nerve	Clinical and electrodiagnostic features of peroneal mononeuropathies at different sites
Radial Nerve	Clinical and electrodiagnostic features of radial mononeuropathies at different sites
Other Compressions	Clinical and electrodiagnostic features of uncommon mononeuropathies
Anomalous Innervation	Electrodiagnostic features of median-to-ulnar anastomoses and accessory peroneal nerves
Axonal vs. Demyel	Differentiating among demyelinating neuropathies
Root and Plexus	Electrodiagnostic features of radiculopathy and plexopathy
Cranial Nerves	Electrodiagnostic features of facial and trigeminal mononeuropathies
Motor Neuron Dz	Electrodiagnostic features of amyotrophic lateral sclerosis and other motor neuron diseases

Abbreviation: EMG, electromyography

The test is intended to be used as a formative assessment so trainees can identify and address knowledge gaps before the next step of clinical training. We require a score of 65% or higher as a criterion for trainees to proceed to performing needle EMG under direct supervision.

The curriculum includes a resource to help the instructor develop a trainee-specific learning plan to address knowledge gaps (Appendices E & F). This resource maps each item on the multiple-choice test to the self-study questions in the learning modules. After grading the test, the instructor creates an individualized review exercise for the trainee by copying the questions that correspond to the test items the trainee answered incorrectly. Over the next 1 or 2 days, the trainee reviews these questions, types up the answers, and meets with the instructor to discuss them. This allows the trainee to demonstrate mastery of the concepts.

Computer-based learning modules such as these have been shown to be effective for medical education.[10,11] In a meta-analysis, mean achievement effect sizes for asynchronous applications favored distance education modalities over classroom instruction.[12] Giving users control over the pace and order of their learning plan enables them to be more active participants. This can motivate trainees to be more engaged with the lesson and have better achievement of knowledge and skills.[13] Trainee satisfaction rates have been shown to increase with computer-based compared to traditional learning. This correlates with the perceived ease of use and interactivity of the program's design.[14]

Results

Our EMG rotation is a supervised 2- to 3-month experience, with about one new resident or fellow starting per month. We provide each trainee with this material at the beginning of the rotation. Between 2007 and 2016, 80 residents and fellows participated in the rotation and completed the multiple-choice test. All items on the multiple-choice test pertain directly to the curriculum objectives. The mean and median scores on the 50-item test were 80% and 82%, respectively, with a standard deviation of 10%. The posttest learning plan allows instructors to ensure that trainees understand all concepts, including those that were missed on the multiple-choice test.

Since our neurology program started tracking ACGME milestones in 2014, every resident who completed this curriculum achieved a level 5 on the EMG and NCS milestone in the subsequent review period.

Surveys of around 16 to 18 neurology residents per year, from 2011 to 2015 (100% response rate), found that the EMG rotation consistently had the highest mean approval rating of all clinical rotations in our neurology program, with a mean score of 4.10 on a 5-point Likert scale. The mean score of all other rotations combined was 3.58. This suggests a high level of resident satisfaction with this course. There were no suggestions for improvement from limited survey responses.

Neurology residents who participated in this curriculum on average scored in the 90th percentile on the EMG component of the American Academy of Neurology's Residency In-service Training Examination (RITE) from 2007-2016. This was over 10 percentile points higher than the same cohort's mean overall score. The RITE did not provide subscores for EMG before 2007, so no comparative data are available. While the content outline of the RITE does not have the level of granularity necessary to know how it maps to these curriculum objectives, it has been shown that overall RITE scores are associated with performance on neurology certification examinations.[15,16]

Discussion

Teaching electrodiagnosis in a uniform and high-quality manner is challenging. Our instructors present this material in a didactic format a few times per year, but the didactic schedule does not always coincide with trainee start times. This milestone-directed self-study curriculum is flexible enough for trainees to do it any time. Creating interactive tools for individual learners is also challenging, but the hyperlink-based study materials provide the perfect marriage of educator-provided structure and active, self-regulated learning.

When we first developed this curriculum in 2007, the primary educational resource included questions only, and trainees had to look up the answers in a textbook. Based on trainee feedback and in order to make this curriculum freely available, we revised the format of the presentation to include the written answers to the questions, making this a complete, self-contained learning resource.

In response to trainee feedback, we also added 11 videos of common normal and abnormal EMG waveforms. The multiple-choice test still includes only questions about written descriptions of these waveforms. One opportunity to expand this curriculum would be to include a video test to assess a trainee's ability to recognize nerve conduction and EMG waveforms.

After each trainee took the multiple-choice test, we reviewed his or her incorrect answers. Between 53% and 91% of test takers correctly answered each question (Appendix E). Having spent more than 10 years going over test answers with trainees, we have refined the test items and revised those that were felt to be unfair, unclear, or based on outdated information.

Limitations

This resource does not address physical skills that are critical to the study of EMG, such as surface electrode placement, needle insertion, muscle localization, and data entry. One opportunity to bolster the value of this curriculum would be to create a companion educational tool to teach and assess those physical skills. The challenge with translating them into a free educational module, of course, is that they require learners to have access to an EMG machine. Another limitation of this resource is that it does not give trainees much-needed experience in applying the concepts herein to real-life cases. Nor does it address the crucial skill of communicating electrodiagnostic findings to a referring physician in well-organized written reports. The best way to address all these limitations is to use this resource in the context of a longitudinal-supervised EMG apprenticeship.

Zachary N. London, MD: Associate Professor, Department of Neurology, University of Michigan Medical School

Gary W. Gallagher, MD: Assistant Professor, Department of Neurology, University of Michigan Medical School

Matthew J. Ebright, MD: Resident Physician, Department of Neurology, University of Michigan Medical School

Disclosures
None to report.

Funding/Support
None to report.

Ethical Approval
Reported as not applicable.

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Received: December 27, 2016 | **Accepted:** April 17, 2017 | **Published:** May 10, 2017