

# **AMERICAN ACADEMY OF NEUROLOGY CLINICAL NEUROPHYSIOLOGY FELLOWSHIP CORE CURRICULUM**

## **DEFINITION OF SUBSPECIALTY**

The subspecialty of Clinical Neurophysiology involves the measurement and assessment of function of the central nervous system, peripheral nervous system and skeletal muscle for the purpose of diagnosing and treating neurological disorders. Clinical neurophysiological procedures commonly used in diagnosing and treating neurological disorders include EEG, MEG, EMG, evoked potentials, polysomnography, epilepsy monitoring, intraoperative monitoring, movement monitoring (including electronystagmography), and autonomic nervous system testing. EEG, MEG, EMG, and evoked potentials directly measure spontaneous or evoked electrical or magnetic fields generated by the nervous system or muscle. In contrast, respiratory effort, airflow, oxygen saturation, blood pressure, body motion, secretion, and behavioral monitoring are measured using chemical and mechanical techniques. Electrical, magnetic, mechanical and chemical based tests are used in varying combinations in clinical neurophysiology for epilepsy monitoring, polysomnography, movement analysis, neonatal EEG recording, and autonomic nervous system testing.

The proper selection and application of clinical neurophysiology procedures requires a thorough understanding of clinical neurology, normal neurophysiology, and the abnormal findings that occur in the various neurological disorders being tested. Although the field of clinical neurophysiology encompasses many neurological disorders, those that are most commonly evaluated and treated include: polyneuropathies, motor neuron disease, radiculopathies and plexopathies, mononeuropathies, myopathies, neuromuscular transmission disorders, epilepsy, sleep disorders, cerebrovascular disease, dementia, metabolic/toxic encephalopathies, demyelinating disorders (including multiple sclerosis), developmental and inherited disorders of infancy and childhood, spinal cord disorders, parkinson's disease (and other movement disorders), brain tumors and other mass lesions, encephalitis, meningitis, traumatic disorders, orthostatic hypotension and other autonomic disorders. In addition, clinical neurophysiological procedures are typically used to guide the surgeon during vascular, orthopedic and neurosurgical procedures.

## **RECOMMENDATIONS FOR TRAINING AND CERTIFICATION IN CLINICAL NEUROPHYSIOLOGY**

The one year training period currently allotted by the ACGME for clinical neurophysiology residency programs is too limited to provide practical expertise in all areas of clinical neurophysiology. Residents in a one-year clinical neurophysiology training program are therefore encouraged to gain practical experience in one or two main areas of clinical neurophysiology and didactic experience in the remaining. Further fellowship training is necessary for those interested in achieving expertise in other areas of clinical neurophysiology or who plan to enter an academic career in clinical neurology and neurophysiology.

For those completing training programs in clinical neurophysiology there are several examining boards that provide certification. Each of the following requires the candidate to have completed PGY4 training and to parts 1 and 2 of the American Board of Psychiatry and Neurology examination in Neurology or Child Neurology:

- 1) *American Board of Clinical Neurophysiology (ABCN)* provides certification in EEG, epilepsy monitoring, evoked potentials and intraoperative monitoring
- 2) *American Board of Electrodiagnostic Medicine (ABEM)* provides certification in electromyography and nerve conduction physiology
- 3) *American Board of Sleep Medicine (ABSM)* provides certification in polysomnography and sleep medicine, and
- 4) *American Board of Psychiatry and Neurology, Neurology with Added Qualifications in Clinical Neurophysiology* provides certification in all areas of clinical neurophysiology.

Those in training are also encouraged to participate in the American Association of Electrodiagnostic Medicine in-service examination in EMG and neuromuscular disease and American Clinical Neurophysiology Society in-service examination in EEG, epilepsy monitoring, evoked potentials, polysomnography and intraoperative monitoring to test their knowledge of clinical neurophysiology, enhance their understanding of the field, and prepare for certifying examinations.

## **CORE CONTENT**

The following provides a listing of topics considered essential for residents in clinical neurophysiology training programs. The clinical neurophysiology resident should have an understanding of each of these topics by the time training is completed. But it is expected that the resident will gain special expertise in those areas that are the focus of his or her practical training experience in clinical neurophysiology. Knowledge of basic neuroscience, neuropharmacology, neuroanatomy, and clinical neurology is considered a prerequisite for training in clinical neurophysiology.

### **Principles of Clinical Neurophysiology**

Electricity and Electronics: Voltage, current, resistance, direct and alternating current, impedance, capacitance, induction, Ohm's law, circuit analysis, grounding, transistors, piezoelectric effect, and transducers, amplification, input impedance, and differential amplification.

Analog Filtering: Low pass, high pass and notch filters - construction and properties

Electrodes: Electrical properties of electrodes according to materials, shape and size, bias potentials, electrical properties and uses of surface/scalp electrodes, monopolar, concentric, and single fiber needle electrodes, sphenoidal electrodes, depth electrodes, and subdural electrodes, electrical interference and grounding.

Electrical Safety: Electrical power systems, leakage current, macro and micro shock, and electrical safety procedures in the hospital and laboratory

Signal Analysis: Sine and cosine wave analysis, frequency, phase and amplitude, analog to digital conversion, sampling, Nyquist theorem, aliasing, vertical and horizontal resolution, digital filter construction and effects, signal averaging, stimulus artifact, signal to noise ratio, and back averaging, time vs frequency domain analysis, interval analysis, autocorrelation analysis, Fourier analysis, and Fourier analysis and filtering, spectral analysis applied to EEG and EMG, automated signal recognition and seizure detection

Biomechanical and chemical biomonitoring: Oxygen saturation monitoring, respiratory effort monitoring, airflow monitoring, ECG monitoring, transducers, blood pressure monitoring, esophageal pressure monitoring, esophageal pH monitoring, quantitative sudomotor axon reflex testing, thermoregulatory sweat testing, actigraphic analysis, otoacoustic emission analysis, computerized dynamic posturography, motor control testing

Properties of bioelectrical generators: Membranes, channels, transport, membrane potentials, post-synaptic potentials, action potentials, action potential propagation, active and passive currents, current flow in myelinated and unmyelinated nerve, neuromuscular transmission, miniature endplate potentials, volume conduction principles, physiological and structural generators, cellular substrates of cortical rhythms and epileptiform discharges, polarity and field determinations, near and far field recordings, muscle resting membrane and action potentials, muscle excitation contraction coupling, single fiber potentials, compound muscle action potentials, sensory nerve action potentials, fibrillation and positive sharp wave potentials, the effects of temperature on neural transmission

Biostatistics: Establishing normative data for laboratory testing and distinguishing statistically significant findings from clinically relevant abnormalities

## **Neuromuscular Disorders**

Procedures: Nerve action potentials, compound muscle action potentials, electromyography, quantitative electromyography, single fiber electromyography, quantitative EMG, repetitive stimulation, F wave recording, H reflex recording, blink reflex recording and jaw jerk recording

Specific Topics: Clinical applications, recording nerve action potentials, recording compound muscle action potentials, H reflexes, and F waves, stimulation, measurement of potentials, physiological variations, specific nerve conduction studies, motor unit analysis, neuromuscular junction analysis, repetitive stimulation, quantitative electromyography and single fiber electromyography, cranial reflexes (blink reflex and jaw jerk), long latency reflexes to stretch, mixed nerve stimulation, cutaneous stimulation and flexor reflex, the silent period, specific findings in myopathies, neuromuscular junction disorders, peripheral neuropathies, mononeuropathies, radiculopathies and motor neuron diseases.

## **Cerebral Disorders**

Procedures: Electroencephalography and magnetoencephalography, direct visual and quantitative analysis

Specific topics: Clinical applications, physiological basis of the electroencephalogram (EEG) and magnetoencephalogram (MEG), spatial EEG and MEG analysis, bipolar, reference, average and laplacian EEG montage design, intracranial vs scalp recording, quantitative EEG analysis, methods of topographic display including co-registration of EEG and MEG with neuroimaging, artifact detection and analysis, activation procedures and clinical correlations, normal neonatal, pediatric and adult EEG, international classifications of seizures and epilepsy syndromes and their ictal and interictal electrographic correlates, normal pseudoepileptiform activity, neonatal nonspecific EEG abnormalities and neonatal electrographic seizure patterns, EEG findings in focal intracranial lesions, EEG findings in diffuse encephalopathies, PLEDs and periodic patterns in inflammatory and infectious disease, EEG coma patterns, reactivity and prognosis, the assessment of brain death and the American Clinical Neurophysiological Society recording guidelines.

### **Central Nervous System Sensory or Motor Pathway Disorders**

Procedures: Visual evoked potentials (VEPs, flash and pattern reversal), somatosensory evoked potentials (SEPs), brainstem auditory evoked potentials (BAERs), electroretinography (ERG), movement or event related evoked potentials, motor evoked potentials (MEPs)

Specific topics: Clinical applications of evoked potentials, visual, auditory, and somatosensory pathway physiology, origin of waveforms, methodology and interpretation of visual (VEPs), somatosensory (SEPs) and brainstem auditory evoked potentials (BAERs), evoked potential findings in axonal vs demyelinating disorders, the effects of fixation and refraction on visual evoked potentials, the effects of age, temperature and anesthesia on SEPs and BAERs, the cochlear microphonic, otoacoustic emissions and BAERs in auditory dysfunction and neonatal hearing screening, origin of waveforms, methodology and interpretation of the electroretinogram in retinal and degenerative neurological disorders, clinical applications, methodology and interpretation of movement and event related potentials and electrical and magnetic motor evoked potentials

### **Sleep Disorders**

Procedures: Polysomnography, multiple sleep latency testing, maintenance of wakefulness testing, and actigraphy.

Specific topics: Clinical applications (including the International Classification of Sleep Disorders), polysomnographic scoring and interpretation in obstructive sleep apnea, periodic leg movement disorder, REM behavior disorder, somnambulism, night terrors, confusional arousals, nocturnal seizures and other parasomnias, multiple sleep latency testing, scoring and interpretation for excessive daytime somnolence and the evaluation of narcolepsy, maintenance of wakefulness testing, scoring and interpretation for the evaluation of excessive daytime somnolence, wrist actigraphy, interpreting for the evaluation of insomnia and circadian rhythm disorders, the application of positive airway pressure during polysomnography, esophageal pH monitoring for gastroesophageal reflux during polysomnography, the International

Classification of Sleep Disorders, pharmacological intervention in sleep disorders and the effects of medication on sleep testing, and the Epworth Sleepiness Scale.

## **Epilepsy**

Procedures: EEG monitoring (non-invasive and intracranial), video monitoring, EMG and movement monitoring, ECG monitoring, EEG correlation with neuroimaging (including MRI, PET and ictal SPECT), Wada testing, intracranial electrode stimulation and functional mapping

Specific: Clinical applications of epilepsy monitoring, technical aspects of EEG and video monitoring, basic EEG including activation procedures and clinical correlation, normal neonatal, pediatric and adult EEG, international classifications of seizures and epilepsy syndromes and their ictal and interictal electrographic correlates, normal pseudoepileptiform activity, medical management of anticonvulsant withdrawal during monitoring, complications of seizures including trauma, and status epilepticus, EEG spatial analysis techniques for detecting and localizing seizure onset, ictal behavioral semiology, analysis of psychogenic pseudoseizures, syncope and other non-epileptic events, neurological testing during and after seizures for seizure classification and localization, intracranial monitoring for localization of the ictal onset zone based on semiology and scalp EEG recording, intracranial electrode stimulation methods and interpretation for localizing cortical function, Wada testing, co-registration of ictal SPECT with MRI, MRI hippocampal volumetric analysis.

## **Intraoperative Monitoring**

Procedures: EMG monitoring of cranial nerve function, SEPs, BAERs, EEG

Specific topics: Clinical applications, the effects of blood pressure, temperature and general anesthesia on SEPs, BAERs, nerve conduction studies and EEG, methods and interpretation of SEPs for peripheral nerve/plexus repair, spinal cord, brainstem, and cerebral hemispheric surgical procedures, methods and interpretation of BAER monitoring during auditory pathway or posterior fossa surgery, methods and interpretation of EEG monitoring during carotid endarterectomy, cranial facial nerve stimulation and EMG monitoring during posterior fossa surgery, including acoustic nerve tumor resection, spinal cord motor evoked potential monitoring during intra- or extramedullary spinal cord surgery

## **Movement Disorders**

Procedures: EMG, actigraphy, surface EMG monitoring, polysomnography

Specific topics: Clinical applications, EMG guided treatment of botulinum toxin, actigraphic analysis of involuntary movements over long periods of time, surface EMG analysis of tremor, myoclonus, dystonia, tics, chorea and athetosis, motor reaction time analysis, polysomnographic analysis of Parkinson's disease, restless leg syndrome, periodic leg movement disorder and REM behavior disorder

## **Autonomic Function Disorders**

Procedures: Sudomotor testing, ECG, blood pressure, vasomotor testing, thermoregulatory sweat testing

Specific topics: Clinical applications, autonomic control of heart rate, cardiovascular reflexes, sudomotor axon reflex testing, skin vasomotor reflexes, thermoregulatory sweat testing in autonomic disorders, distinguishing pre and post-ganglionic disorders, tilt table testing