AMERICAN CLINICAL NEUROPHYSIOLOGY SOCIETY
Continuing Medical Education Committee
Professional Practice Gap Analysis
Revised January 2022

Sources of Data

- AAN Member reports 2004, 2009, 2010
- AAN Core Curricula in Clinical Neurophysiology
- American Board of Clinical Neurophysiology Candidate Exam Handout
- American Board of Electrodiagnostic Medicine Candidate Exam Booklet
- American Board of Psychiatry and Neurology Initial Exam Content Outline
- American Board of Psychiatry and Neurology Certification Statistics
- ACNS CME Committee Meetings 2014 - 2019
- ACNS Program Committee Meetings 2014 - 2019
- ACNS Course Committee Meetings 2014 - 2019
- ACNS CME Survey 2012
- ACNS Annual Meeting and Courses evaluation forms 2013 - 2019
- ACNS Fall Course evaluation forms 2013 - 2018
- Review of journal articles in *Journal of Clinical Neurophysiology*, *Clinical Neurophysiology*, and *Neurology*
- Results of ACNS In-Service Exam scores 2013 - 2021

Gap #1 - General Practice of Clinical Neurophysiology

Clinical neurophysiology procedures are performed by a large proportion of practicing US neurologists, many of whom have little or no formal training in clinical neurophysiology. Many clinical neurophysiology procedures (e.g. evoked potentials, invasive EEG, advanced EMG procedures) are performed at low volume at many centers; a forum for review and hands-on training are essential to improve and maintain competence in these areas. Similarly, intraoperative monitoring, intensive care unit EEG monitoring, quantitative EEG and stereo EEG for presurgical evaluation are growing areas of clinical neurophysiology with few practicing neurologists having adequate training in these techniques. There is high demand for adult and pediatric neurologists, as well as neurodiagnostic technologists with competence in these areas. Neurologists required additional specialized training to be competent in these types of monitoring.

Summary of Data

Review of national neurology practice surveys indicate that clinical neurophysiology procedures are performed by a large proportion of practicing US neurologists. Many have little or no formal training (e.g. fellowship) in clinical neurophysiology. At most centers, advanced clinical neurophysiology procedures (e.g. evoked potentials, invasive EEG) are performed at low volume; a forum for review and hands-on training is essential to improve and maintain competence in these areas. Significant gaps between current practice and ideal practice have been identified via multiple methods, including: review of the literature, review of clinical neurophysiology fellowship curricula, surveys of ACNS members and Annual Meeting attendees, and results of the clinical neurophysiology in-service exams.

1. **Surveys of United States neurologists.**
   In 2009, the American Academy of Neurology (AAN) surveyed 21,772 members, including 11,963 practicing US AAN neurologists (Neurologists 2009: AAN Member Demographic and Practice Characteristics). The Practice Profile Form (PPF) was sent to a 20% random sample (2,380). The response rates were 56% for the census and 41% for the PPF. The percent of respondents performing intraoperative monitoring was 8.5, with a median number of procedures per month of two. This area of practice is therefore much smaller than other areas of clinical neurophysiology (see general clinical neurophysiology below). The small number of studies performed monthly suggests that it is difficult for practicing neurologists to gain and maintain sufficient expertise in intraoperative monitoring by clinical practice alone. Continuous EEG monitoring in the intensive care unit

was performed by 16.3% of respondents, with a median number of procedures per week of two. Again, this number is insufficient to gain and maintain appropriate expertise in this complex neurophysiologic technique. In fact, when reviewing demographic data on ACNS meeting attendance roughly 50% of participants in the 30-50 year age range indicate a desire to learn neurophysiology technical knowledge by attending these meetings.

From the same survey, practice focus was EEG 32.6%, EMG 8.2%, Epilepsy 39.4%, and Neuromuscular disorders 25.7%.

Procedure	**Percent of respondents who perform/interpret the procedure during the last 12 months**						
	1991-92 (n=1,371)	**1993-94 (n=1,235)**	**1997 (n=1,064)**	**1998 (n=1,230)**	**2000 (n=832)**	**2004 (n=947)**	**2010 (n=897)**
Electrodiagnostic Services:							
Electroencephalography (EEG)	68.0	68.0	69.8	65.0	59.9	61.4	56.9
Electromyography (EMG/NCS) [a]	54.6	55.1	58.1	55.8	49.4	54.4	54.1
Evoked Potentials (EP)	43.5	44.2	46.1	43.7	34.3	32.5	25.6
Intraoperative Monitoring	12.5	13.7	14.5	14.5	11.1	9.8	8.5
Sleep Studies	12.5	11.2	14.7	12.0	10.2	12.0	14.0
Video EEG Monitoring	NA[b]	NA	NA	NA	NA	NA	17.9
Continuous EEG (cEEG)	NA	NA	NA	NA	NA	NA	16.3

Procedure	**For those who perform the procedure, median number performed per month**					
	1993-94	**1997**	**1998**	**2000**	**2004**	**2010**
Electrodiagnostic Services:						
Electroencephalography (EEG)	20	20	20	20	20	20
Electromyography (EMG/NCS) [a]	20	25	25	25	25	20
Evoked Potentials (EP)	5	5	5	4	4	2
Intraoperative Monitoring	2	3	4	1	3	2
Sleep Studies	5	5	10	5	15	11
Video EEG Monitoring	NA	NA	NA	NA	NA	2
Continuous EEG (cEEG)	NA	NA	NA	NA	NA	2

2. **Availability and scope of training programs in clinical neurophysiology.**
   The amount of training received by neurology residents in clinical neurophysiology is quite variable. EEG and EMG training are provided in 75% of neurology residency programs, ranging from 1-5 months. One quarter of neurology residency programs have no requirement for formal training in clinical neurophysiology. Fellowship training in clinical neurophysiology is available as a 5th year of subspecialization. Fellows have six or more months of didactic and clinical experience in the major areas of clinical neurophysiology (electroencephalography, electromyography and nerve conduction studies, polysomnography and assessment of disorders of sleep, or intraoperative neurophysiologic monitoring), and didactic training in other areas of clinical neurophysiology. Typically, concentration occurs in 1 or 2 of these subspecialized areas leaving significant gaps in other areas of clinical neurophysiology even after fellowship training is completed.

   The introduction of the American Board of Psychiatry and Neurology Certification in Epilepsy in 2013 has expanded training options for post-residency clinical fellowship. While this has strengthened core procedures of EEG, video EEG monitoring, epilepsy surgery, and continuous EEG, it has led to further de-emphasis on other procedures, including intraoperative monitoring and evoked potentials. These are the same procedures that trainees have traditionally performed relatively poorly on in-service exams. Nevertheless, many practitioners will be expected to continue performing these procedures after fellowship training.

3. **Board certification statistics.**
   As of 2014 there were 14,674 U.S neurologists who were members of AAN and 4.8% indicated Clinical Neurophysiology as a subspecialty. According to ABPN data, even as fewer than 20% of neurologists have certification in Clinical Neurophysiology, a far greater number indicate that they perform Clinical Neurophysiology procedures. This suggests a knowledge gap is likely between the current knowledge and the need for appropriate clinical practice of neurophysiologic procedures.

   Similarly, as of 2020, there were an estimated 16,414 active Neurology certificates issued by the ABPN, with 2,102 active for clinical neurophysiology and 1,990 for epilepsy.

4. **Examination scores in the Intraoperative Monitoring and Evoked Potentials sections of the American Board of Clinical Neurophysiology Exam and the American Clinical Neurophysiology In-Service Exam.**
   Scores in these areas have been consistently lower than those in other areas of clinical neurophysiology. From 2013- 2021 data the percent correct responses in the intraoperative monitoring (20-47%) and evoked potentials (31-57%), compared to 57-80% in EEG. This gap in knowledge is present in all examinees: current clinical neurophysiology fellows, graduates of clinical neurophysiology training programs, and neurologists in practice.

5. **The number of downloads of guidelines for intraoperative monitoring from the ACNS web site.**
   Guidelines have been published in the recent past for both intraoperative monitoring and continuous EEG monitoring in the ICU and are consistently downloaded for review and supportive data. Members indicate that the guidelines should continue to be a primary focus of the ACNS.

6. **Recent issues in the Journal of Clinical Neurophysiology and tracking of the number of publications on these topics downloaded from the journal web site.**
   Review issues from the Journal of Clinical Neurophysiology highlight core topics in the field. Topics in 2020-2021 include: autonomic testing, evoked potentials, ambulatory EEG, MEG, status epilepticus, electrodiagnostic testing of neuromuscular disorders, critical illness myoneuropathy, and noninvasive brain stimulation**.**

7. **In survey responses of meeting attendees, consistent areas were self-identified as subject to knowledge or practice gaps**. Feedback is obtained each year from attendees of the annual ACNS courses and program, as well as the annual ACNS mid-year courses. In these attendee surveys, requests for specific topic areas have led to identification of the gaps below.

Analysis of Gap #1

1. EEG analysis
a) Basic EEG including identification of normal variants, artifacts, clinical correlation

<u>Example Gap</u>

- **Best Practice:** EEG studies are often improperly ordered for non-seizure conditions such as headache and syncope. Clinical neurophysiologists properly identify normal EEG patterns, common normal variants, and artifacts to avoid misdiagnosis of epilepsy.
- **Current Practice:** Most routine EEG studies are read by physicians without formal clinical neurophysiology training in residency or fellowship. Patients are commonly misdiagnosed with epilepsy because of an "over-read" EEG, which in turn leads to unnecessary lifestyle restrictions, treatment, and medical expense.
- **Resulting Gap:** Inadequate knowledge of normal EEG patterns of wakefulness and sleep, commonly misinterpreted variants such as wickets and small sharp spikes, and extraphysiological and physiological artifacts may lead to the incorrect diagnosis of epilepsy, seizures, and status epilepticus.
- **Educational Need:** Didactic lectures and workshops on routine EEG and standardized reporting of EEG findings according to ACNS guidelines

b) Neonatal and pediatric EEG and normal age-related variants

<u>Example Gap</u>

- **Best Practice:** Clinical neurophysiologists are comfortable interpreting EEG across the lifespan, including recognition of normal variants in children. Clinical neurophysiologists should be aware of indications for EEG in neonates, as described in the ACNS guidelines. Neurophysiologists should be skilled in interpretation of neonatal EEG and application of ACNS terminology and classification systems for neonatal EEG.
- **Current Practice:** Most neurophysiologists have limited training in pediatric EEG, and particularly neonatal EEG. Despite professional society guidelines indicating the need for neonatal EEG use in common conditions such as hypoxic ischemic encephalopathy or for suspected seizures, neonatal seizures are commonly underdiagnosed or misdiagnosed. Few neurophysiologists are skilled in interpretation of amplitude-integrated EEG, widely used for seizure detection by neonatologists.
- **Resulting Gap:** Neurophysiologists are uncertain when faced with some pediatric EEG variants. There is inadequate knowledge of risk factors for neonatal seizures, indications for neonatal EEG, and limited competence in performing neonatal

EEG and aEEG analysis.

- **Educational Need:** Didactic lectures, online materials, and workshops on pediatric EEG, neonatal EEG and seizures, aEEG techniques, and neonatal EEG guidelines.

c) Digital EEG processing and quantitative EEG

Example Gap

- **Best Practice**: Quantitative EEG are used to rapidly analyze large amounts of EEG data, and has been demonstrated to shorten the amount of time necessary to interpret raw EEG data. Experience can improve the utility and reliability of qEEG interpretation.
- **Current Practice**: Current guidelines suggest that quantitative should be incorporated into continuous EEG practice. **Resulting Gap**: Inadequate understanding of qEEG use and techniques can lead to inappropriate over-reliability on, or underutilization of, quantitative EEG in clinical practice.
- **Educational Need**: Symposia and workshops that provide information about the utility and limitations of quantitative EEG, including detection of seizures and ischemia as well as trends in encephalopathy.

d) Critical Care EEG in the intensive care unit

Example Gap

- **Best Practice:** Clinical neurophysiologists understand the pathophysiology of normal and abnormal patterns in ICU EEG, accurately perform and interpret studies, and apply the results of these studies to timely and accurate diagnosis and treatment of patients at risk for neurologic deterioration in the intensive care unit. Current ACNS guidelines in ICU EEG highlight the technical and clinical aspects of this procedure.
- **Current Practice:** Review of surveys of learners, the medical literature, and recent guidelines indicate ICU EEG is often misinterpreted, likely due in large part to the shortage of clinical neurophysiologists who have been trained in ICU EEG. Most clinical neurophysiology training programs have little didactic or practical training in this area. Clinical neurophysiologists who completed training more than several years ago have little or no exposure to formal training in these techniques and those in practice seek training on advanced techniques.
- **Resulting Gaps:** Practitioners performing clinical neurophysiology procedures have inadequate knowledge of ICU EEG, often do not possess the technical skills to accurately perform and interpret studies (competence) and are uncertain how to apply the results of these studies to the diagnosis and treatment of patients at risk for neurologic deterioration in the intensive care unit (performance).
- **Educational Need:** Courses, symposia, and workshops on modern approaches to the neurophysiology of nonconvulsive seizures, the ictal-interictal continuum, and status epilepticus, including the modified Young and Salzburg Criteria, and the 2021 ACNS Standardized Critical Care EEG Terminology

Example Gap

- **Best Practice:** Seizures and status epilepticus in critically ill adults and pediatric patients are rapidly and reliably identified with the addition of quantitative EEG analysis in conjunction with conventional EEG analysis by neurophysiologists. Additionally, non-neurophysiologists (i.e., EEG techs and ICU nurses) are able to comfortably and reliably utilize QEEG to alert neurophysiologists to periods of concern.
- **Current Practice:** Quantitative EEG is used inconsistently, with a lack of standardization of quantitative EEG practices.
- **Resulting Gap:** Inadequate knowledge of information represented by quantitative EEG trends, interpretation of quantitative EEG trend changes, recognition of seizure activity on quantitative EEG, recognition of artifacts on quantitative EEG trends and utilization/manipulation of quantitative EEG software.
- **Educational Need:** Symposia and workshops on quantitative EEG trend basics and utilization of quantitative EEG for seizure detection.

Example Gap

- **Best Practice:** Impending cerebral ischemia and vasospasm in patients with subarachnoid hemorrhage is detected in a timely fashion and reliably with quantitative EEG trend analysis.
- **Current Practice:** Quantitative EEG is rarely used for ischemia and vasospasm detection and there is a lack of standardization of quantitative EEG practices for this application.
- **Resulting Gap:** Inadequate knowledge of information represented by quantitative EEG trends, recognition of ischemia/vasospasm on quantitative EEG, recognition of artifacts on quantitative EEG trends and utilization/manipulation of quantitative EEG software.
- **Educational Need:** Symposia and workshops on quantitative EEG trend basics and utilization of quantitative EEG for ischemia/vasospasm detection.

e) Source localization, source co-registration with neuroimaging

Example Gap

- **Best Practice:** Patients with intractable epilepsy undergo efficient and accurate pre-surgical evaluation including source localization to better define the ictal onset zone.
- **Current Practice:** Many surgical candidates do not undergo EEG source localization as part of the epilepsy surgery evaluation because of lack of specialized software and/or expertise in source localization technique.
- **Resulting Gap:** There is inadequate knowledge of methods of seizure localization, and inadequate competence in source localization and co-registration techniques.
- **Educational Need:** Symposia and workshops on source location, co-registration, and clinical applications of above. Guidelines and commonly accepted standards for EEG source localization.

f) Presurgical EEG evaluation

Example Gap

- **Best Practice:** Patients with intractable epilepsy are identified as potential surgical candidates early in their disease course and undergo presurgical evaluation, including appropriate use of invasive EEG techniques.
- **Current Practice:** Many potential surgical candidates are not identified at all or are identified only after many years of intractable epilepsy. Neurophysiologists may not have received training in newer techniques for invasive EEG, such as stereo EEG.
- **Resulting Gap:** Inadequate competence in recognizing potential surgical candidates, performing presurgical video-EEG monitoring, and implementing invasive EEG for evaluation. Inadequate incorporation of results of video-EEG monitoring into patient treatment plans.
- **Educational Need:** Workshops on video-EEG and invasive EEG procedures

g) Ambulatory EEG including indication for EEG and Video EEG home recordings and basic quality standards

Example Gap

- **Best Practice:** Practicing neurologists are aware of the indications and limitations of ambulatory EEG and video EEG recordings. They are able to weigh the pros and cons of ambulatory EEG studies and other alternative options (Epilepsy Monitoring Unit evaluations, repeat routine outpatient EEG studies, home video of typical events) in order to choose the appropriate study for their patient(s).
- **Current Practice:** There has been a significant increase in the number of ambulatory EEGs performed. This, in combination with wider availability, has raised concern for overuse, that these studies are frequently recommended without a definite indication, that the duration of the studies is inappropriate, or that an alternative investigative approach may have been more appropriate.
- **Resulting Gap:** Inadequate understanding of the indications and limitations of the ambulatory EEG studies. Limited understanding of patient scenarios when alternative options or referral to epilepsy center may be more appropriate
- **Educational Need:** Educational workshops and webinars, utilizing patient scenarios (case-based learning) to discuss the indications and limitations of ambulatory EEGs and other available alternative options.

Example Gap

- **Best Practice:** Ambulatory EEGs studies provide quality data (EEG recording without significant artifact, and preferably simultaneous good quality video) for review by a physician who is appropriately-trained and qualified in EEG interpretation.
- **Current Practice:** There is wide variation in the quality of EEG data, presence and quality of accompanying video recording, quality and extent of monitoring by monitoring technicians, availability of technical support in case of technical difficulties as well as in training and qualification of physicians interpreting the ambulatory EEG studies.
- **Resulting Gap:** Lack of standardization in data acquisition and unreliable interpretation.
- **Educational Need:** Identify minimum standards for ambulatory EEG studies, encompassing recording, monitoring, technical support and interpretation.

2. Magnetoencephalography
a) Clinical indications
b) New guidelines
c) Role in surgical epilepsy
d) Combined EEG-MEG source localization and imaging

Example Gap

- **Best Practice:** Patients with intractable epilepsy should undergo efficient and accurate pre-surgical evaluation, which may include magnetoencephalography. The American Clinical MEG society has published guidelines describing best practices in recording and interpretation of clinical MEG studies
- **Current Practice:** MEG is available only in few centers across the USA and only a small number of patients receive MEG studies as part of the presurgical evaluation. There are a very small number of clinicians who are adequately trained in the analysis and interpretation of clinical MEG data.
- **Resulting Gap:** Lack of knowledge among clinicians for indications and benefits of MEG, e.g: patients who are more likely to benefit from an MEG study and how to incorporate MEG results into the surgical plan. Lack of standardized training in clinical magnetoencephalography resulting in variability in analyses methods and clinical reports
- **Educational Need:** Education on the basics of MEG recordings, benefits and limitations of MEG. Dissemination of the guidelines published through the American Clinical MEG Society for clinical MEG recording and analysis, personnel training, and standards for report writing.

3. Functional Brain Mapping

a) Neurophysiology of brain function

b) Brain mapping to guide surgical resection

Example Gap

- **Best Practice:** Functional brain mapping using various tools (direct electrical stimulation, neuroimaging procedures) is used to map language, memory, motor, and sensory brain regions for optimal preoperative planning and intraoperative interventions.
- **Current Practice:** Epilepsy programs are most often developed in reactive fashion, around local/institutional resources and using teams without the aid of consensus practice guidelines and protocols.
- **Resulting Gap:** Inadequate knowledge and inadequate competency for functional brain mapping
- **Educational Need:** Commonly accepted standards for functional brain mapping, including protocols for testing varying skills to identify eloquent cortex, parameters for stimulation, ability to evaluate the strength of evidence when data are not congruent

4. Intraoperative Neurophysiologic Monitoring

a) Somatosensory evoked potential monitoring

b) Motor evoked potential monitoring

Example Gap

- **Best Practice:** All IOM for spinal cord monitoring adheres to the most current guidelines from the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology and the American Clinical Neurophysiology Society.
- **Current Practice:** MEPs are monitored (together with SSEPs) in most of the institutions that offer spinal cord monitoring, but MEPs are not commonly used for root monitoring. MEPS interpretation is based on consistency and temporal correlation to surgical manipulations. Few institutions perform D waves or spinal cord mapping
- **Resulting Gap:** Training in troubleshooting/interpretation, understanding how different mechanisms of injury are reflected in MEP changes, insufficient use of MEPs for root monitoring
- **Educational Need**: Workshops/case presentations of MEPs monitoring and associated mechanisms of injury, understanding alarm criteria variability with mechanism of injury, Better understanding of the dipoles, far field/near field potentials

c) Peripheral nerve, brachial plexus, and lumbar plexus monitoring

Example Gap

- **Best practice:** Patients are monitored using a multimodality technique: SEPs for root avulsion; Nerve action potentials (NAP) and triggered EMG for assessment of nerve functional integrity and lesion location; tcMEPs from all myotomes
- **Current Practice:** Patients are most often monitored by a single modality, such as SEPs for root avulsion, or triggered EMG or twitches to assess functional nerve integrity in isolation.
- **Resulting Gap:** NAP monitoring/inching technique is rarely applied, Inaccurate assessment of nerve integrity
- **Educational Needs:** Workshops in NAP recordings/inching technique to increase reliability of our clinical correlates

d) Procedures in dorsal rhizotomy

Example Gap

- **Best practice:** Dorsal rhizotomy cases include continuous and triggered EMG of lumbosacral muscles to confirm dorsal nerve roots, localize root level, grade severity of triggered EMG response to train stimulation and avoid sectioning rootlets/roots with primary external anal sphincter innervation

- **Current Practice:** Selective dorsal rhizotomies are not performed commonly and may have variable surgical technique
- **Resulting Gap:** Dorsal rhizotomies are performed with inadequate or incomplete IOM
- **Educational Needs**: Courses and workshops to guide appropriate planning and implementation of IOM for rhizotomy cases

e) Sensory-motor mapping

Example Gap

- **Best Practice:** Practitioners are comfortable and competent in performing central sulcus (CS) localization, motor mapping awake and under general anesthesia, using both Penfield and multipulse train technique. Neurophysiologists are able to continuously monitor the motor pathways, perform subcortical mapping, and monitor ECoG for after discharges (AD), assess depth of anesthesia, delineate lesion
- **Current Practice:** CS localization is via phase reversal technique, the Penfield method to motor map is used in awake craniotomies only (experts are from EEG/Epilepsy field); many do not perform continuous motor monitoring or subcortical mapping. There is common use of multipulse train technique to motor map under general anesthesia but not to look at the ECoG (experts are from the EMG field)
- **Resulting Gap**: There is a resulting underuse of ECoG, CS localization, continuous motor monitoring and a lack of understanding that mapping at a high current density incurs a higher risk of triggering seizures
- **Educational Need:** Workshops and symposia in ECoG mapping, awake and asleep motor mapping, multipulse train technique as the most efficient technique for mapping pyramidal neurons under general anesthesia, and in the use of continuous motor monitoring in association with subcortical mapping

f) Brainstem and cranial nerve mapping

Example Gap

Best Practice: Brainstem mapping includes consistent monitoring and mapping of all motor nerves/their nuclei (free and triggered EMG), BAEP following ACNS guidelines, SEP and MEP monitoring, and /or Corticobulbar tracts (corticobulbar MEPs)

- **Current Practice:** BAEP monitoring is performed inconsistently, many physicians lack confidence and/or competence in cranial nerve monitoring and mapping.
- **Resulting Gap:** There is infrequent monitoring of a variety of CNs, and very infrequent mapping of CNs or CN nuclei
- **Educational Need:** Workshop training including video simulations of CN monitoring and mapping, training for corticobulbar MEP monitoring

g) Language and parietal mapping

Example Gap

- **Best Practice:** Mapping of language and parietal function may be used pre and intra-operatively, with adequate language/parietal baseline testing, appropriate use of the Penfield method, and employment of EcoG for after discharges (ADs) monitoring
- **Current Practice:** Specialized testing is not consistently performed, ECoG may not always be utilized for AD monitoring
- **Resulting Gap:** Inadequate knowledge and skill in performing both pre- and intraoperative mapping
- **Educational Need:** Review appropriate battery of tasks in relation to clinical need, understand the importance of AD monitoring

h) Endovascular NIOM

5. Advanced EMG and NCS techniques

a) Single fiber EMG

b) Motor unit number estimation techniques

c) Neuromuscular ultrasound

d) Compressive neuropathies

e) Pediatric EMG

f) Critical illness related neurophysiology

Example Gap

- **Best Practice:** Critical illness neuropathy and myopathy are rapidly identified through appropriate EMG/NCS and treated early.
- **Current Practice:** Critical illness neuropathy and myopathy are often not recognized, which can prolong the need for ICU care.
- **Resulting Gap:** Inadequate knowledge of risk factors for critical illness neuropathy and myopathy, and inadequate competence in performing EMG and nerve conduction studies in critically ill patients.

- **Educational Need:** Didactic lectures and hands-on workshops on critical illness neuropathy and myopathy.

g) Muscle ultrasound
h) Electroneurodiagnostics of the pelvic floor

6. Sleep/Polysomnography
a) Neurophysiology of sleep disorders
b) Application and interpretation of polysomnography

Example Gap

- **Best Practice:** Sleep evaluations conform to published guidelines for polysomnography, such as the American Academy of Sleep Medicine Clinical Practice Guideline
- **Current Practice:** Many practitioners are not familiar with the applicable guidelines.
- **Resulting Gap:** Inadequate knowledge of optimal polysomnography techniques, inadequate competence in PSG techniques, and inadequate ability to incorporate guidelines into clinical practice.
- **Educational Need:** Didactic lectures and workshops to review sleep guidelines and tools to incorporate guidelines into sleep lab management.

c) Sleep in neurologic disorders (epilepsy, stroke, etc.)
d) Sleep and coma

7. Autonomic Nervous System

Example Gap

- **Best practice:** Neurologists are able to screen patients for autonomic impairment through history, exam, and, when needed, additional testing to provide high value care that improves patient outcomes. Training on the physiology of the autonomic nervous system and current neurophysiology testing used for autonomic disorders allows neurologists to provide high value care for both diagnosis and management of these conditions.
- **Current practice:** Most neurologists are not familiar with the physiology of the autonomic nervous system or appropriate screening, testing or management of autonomic disorders.
- **Resulting gap:** Patients with autonomic disorders are often undiagnosed or diagnosed late in the course of a disease. This results in increased disability from symptoms. Neurologists are often not aware of appropriate treatments for patients which deleteriously impact patient quality of life.
- **Educational need:** Didactic lectures and workshops to increase understanding the physiology of autonomic nervous system and the testing that is available is integral to understanding autonomic disorders, autonomic testing and clinical management to improve patient QOL.

8. Neurophysiology of Cooling after Cardiac Arrest

Example Gap

- **Best Practice**: Targeted temperature management is the current standard of care for comatose patients with a cardiac arrest. Neurophysiologic data (EEG, EP) is integrated with clinical data and other modalities such as imaging and biochemical results for a comprehensive approach to assess comatose patients after cardiac arrest.
- **Current Practice**: Practitioners currently use EEG and evoked potentials inconsistently in determining the prognosis of patients who have undergone targeted temperature management. In a recent study of 8 centers with 202 cardiac arrest patients, only 50% received EEG.
- **Resulting Gap**: Inadequate knowledge regarding the appropriate utilization of neurophysiologic data to assess the prognosis of comatose patients who undergo targeted temperature management following cardiac arrest
- **Educational need**: Didactic sessions, workshops, and symposia regarding the use of neurophysiologic data for prognostication following cardiac arrest

9. Neurophysiology of sports injury and sports medicine

Example Gap

- **Best Practice**: Concern regarding the long-term health effects of concussion, including chronic traumatic encephalopathy, has led to an increasing use of neurophysiologic techniques to identify and monitor concussions. Use of older techniques, such as EEG and evoked potentials, as well as newer techniques, such as multi-limb reaction time testing and visual performance indices can improve detection and monitoring of concussions.
- **Current Practice**: Despite the development of newer techniques for identifying and monitoring of concussion, most newer techniques are not widespread. Conversely, some poorly validated techniques are inappropriately applied.

- **Resulting Gap**: Neurophysiologists often lack adequate knowledge about newer, advanced screening and monitoring techniques for concussion and mild traumatic brain injury
- **Educational need**: Didactic sessions that review newer techniques for concussion and traumatic brain injury screening

10. Neurophysiology of Brain and Peripheral Nervous System Stimulation
a) Deep brain stimulation
b) Responsive neurostimulation
c) Transcranial magnetic brain stimulation (TMS)

Example Gap

- **Best Practice:** TMS is appropriately applied for proven indications including presurgical motor and language mapping, and treatment of Major Depressive Disorder in adult patients.
- **Current Practice:** Very few centers in the USAhave used TMS in clinical practice; the majority has been for psychiatric applications. Few neurophysiologists have trained in this modality.
- **Resulting Gap:** Neurophysiologists have insufficient familiarity with the indications for and underlying physiology of TMS
- **Educational Need:** Education regarding current and emerging uses of TMS, including patient selection, underlying mechanisms, and appropriate application.

12. Practice Management and Leadership in Clinical Neurophysiology
a) Healthcare models
b) Patient safety and quality improvement
c) Billing and coding
d) Educational techniques

Example Gap

- **Best Practice:** Clinical neurophysiologists effectively and efficiently execute their managerial and leadership roles, including effective systems improvement, finance management, and education of staff and team members and trainees.
- **Current Practice:** Clinical neurophysiologists rarely receive formal training in practice management in the course of their clinical development and are unprepared to take on managerial and leadership roles. Billing and coding standards frequently change, with physicians struggling to keep up on current practices.
- **Resulting Gap:** Neurophysiologists are uncertain of how to effectively manage their practices. Billing and coding may be inaccurate or incomplete.
- **Educational Need:** Didactic lectures, workshops, symposia, and other opportunities to develop managerial and leadership skills required of clinical neurophysiologists, including navigation of healthcare systems, patient safety and QI initiatives, updates on billing and coding, and effective educational techniques.

12. Neurophysiology of Movement Disorders
a) Spasticity
b) Myoclonus
c) Physiology of volitional versus involuntary movements

Example Gap

- **Best Practice:** Clinical neurophysiology techniques are applied to distinguish between various types and components of myoclonus, to guide treatment decisions.
- **Current Practice:** Neurologists struggle to distinguish between epileptic and non-epileptic myoclonus. Clinical neurophysiology tools are underutilized to guide diagnosis.
- **Resulting Gap:** Neurophysiologists lack familiarity and experience in using clinical neurophysiology tools in the evaluation of myoclonus.
- **Educational Need:** Workshops, seminars, and other offerings regarding the underlying physiology, etiology, and diagnosis of myoclonus based on neurophysiologic tools.

Gap #2 - Emerging Areas of Practice

Several emerging areas of clinical neurophysiology have significant practice gaps in which the opportunities for training and mentoring fall short of the need for experienced and trained neurologists. Identification of this practice gap has been made in several ways.

Summary of Data

1. **Availability and scope of training programs in clinical neurophysiology**
   Training in these new areas is not available or limited in most neurology residencies. Clinical neurophysiology fellowship training programs provide 6 or more months of didactic and clinical experience in the major areas of clinical neurophysiology (electroencephalography, electromyography and nerve conduction studies, or polysomnography and assessment of disorders of sleep), but typically less clinical experience in other areas, and particularly may lack sufficient exposure to newer techniques. Practicing neurophysiologists out of training may have lacked exposure to emerging techniques that were not available at the time of training.

2. **Recent articles in the *Journal of Clinical Neurophysiology* and tracking of the number of publications on these topics downloaded from the journal web site. Other major publications from *Clinical Neurophysiology, Epilepsia,* and others.**

3. **In survey responses of meeting attendees, consistent areas were self-identified as subject to knowledge or practice gaps**. Feedback is obtained each year from attendees of the annual ACNS courses and program, as well as the annual ACNS mid-year courses. In these attendee surveys, requests for specific topic areas have led to identification of the gaps below.

Analysis of Gap #2

1. New/next generation seizure detection algorithms

Example Gap

- **Best Practice:** Visual assessment of video EEG is currently the gold standard for the diagnosis of seizures and epilepsy. Rapid advancements in seizure detection algorithms offer the potential for more accurate, efficient interpretation of EEG studies and diagnosis of seizures through other approaches.
- **Current Practice**: Several seizure detection devices are currently under investigation for the detection of seizures in long-term epilepsy monitoring units as well as the outpatient setting. Detection modalities in use or being investigated include accelerometry, electrocardiogram, electrodermal activity, mattress sensors, surface electromyography, video detection systems, gyroscope, peripheral temperature, photoplethysmography, and respiratory sensors, among others. Multimodal seizure detection devices may have advantages over unimodal systems in terms of higher sensitivities with lower false detections. Most CN training programs offer little didactic or practical training in these emerging technologies as they are largely investigational at this time, even as families ask their physicians for information about these devices.
- **Resulting Gap:** Inadequate knowledge and competence in using and interpreting available seizure detection and seizure prediction modalities
- **Educational Need**: Symposia and workshops focusing on the current evidence base, also focusing on device availability/selection and patient and seizure characteristics to assist in selecting appropriate detection modalities.

2. Broad band EEG including ultrafast and ultraslow

Example Gap

- **Best Practice**: There is a standardization in the use of broad band EEG use and interpretation.
- **Current Practice**: Currently the use/assessment of ultrafast and ultraslow activity is limited by the variability in training. Misconceptions that dedicated DC amplifiers are needed to assess it may also contribute to its limited use.
- **Resulting Gap**: Interictal and ictal fast activity (HFOs), infraslow activity and ictal baseline shifts are not widely used in clinical practice. There is an inadequate evidence base for their utility, and gaps in the understanding of the pathophysiologic basis and the inter-relationships among the different types of broadband EEG activity. Prospective data examining the value of broad band EEG findings as a predictor of seizure outcome in larger cohorts is lacking.

- **Educational Need**: Symposia and workshops on stereo-EEG addressing broad band EEG interpretation.

3. Neuroplasticity, brain/machine interface, regenerative and rehabilitative strategies

Example Gap

- **Best Practice**: In recent years, several novel techniques including functional electrical stimulation, robot assisted gait training, electromechanical gait training, and brain computer interface, have been utilized to aid patients in recovery from strokes and other neurologic injuries. These techniques utilize new technologies and an evidence based approach to improve patient outcomes.
- **Current Practice**: Although several promising rehabilitation strategies have been developed, the majority of these strategies are not currently in widespread use.
- **Resulting Gap**: Inadequate knowledge of many of the new techniques that are available to aid in functional recovery from neurological and inadequate knowledge to use these techniques in practice.
- **Educational Need**: Symposia that review the use of newer techniques for recovery from neurological injury in clinical practice

4. Neurophysiology of the spectrum of consciousness and psychiatric disorders
a) Advanced assessment of the healthy brain at rest and in meditation
b) Advanced assessment of coma

Example Gap

- **Best Practice**: Neurophysiologic techniques, including EEG and event related potentials, can be used to help distinguish between minimally conscious and persistently vegetative patients. Distinguishing between these patients based upon physical examination techniques alone is often challenging.
- **Current Practice**: To date, only a small number of research centers have used EEG or event related potentials in the evaluation of this patient population.
- **Resulting Gap**: Inadequate knowledge of the neurophysiology of consciousness, and how it can be used to evaluate patients who are minimally conscious or vegetative
- **Educational Need**: Didactic sessions that review of the practice for utilizing EEG and event related potentials in the evaluation of minimally conscious patients

c). Advancements in the neurophysiological assessment of psychiatric disorders

5. Machine Learning in Neurophysiology

Example Gap

- **Best Practice**: Employment of machine learning in various areas of healthcare delivery and clinical practice can optimize patient care. Utilizing data generated in the neurophysiologic evaluation of neuromuscular disease (EMG) and central nervous system disorders (EEG) to detect and predict clinically relevant events and prognoses can improve patient care.
- **Current Practice**: Only a few research centers have used such algorithms in neurophysiology; the vast majority of centers rely on long-standing, neurophysiologist-dependent methods of disease identification that are prone to human error.
- **Resulting Gap**: Few neurophysiologists understand the role and power of using machine learning to augment clinical practice.
- **Educational Need**: Didactic sessions that introduce the concept of deep learning and how clinical neurophysiologists can become involved in its development and utilization.

6. Application of Magnetospinography (MSG) and Magnetoneurography (MNG)

Example Gap

- **Best Practice**: Localization of lesions within the spinal cord and peripheral nerves can be difficult and may require extensive neurophysiologic evaluation and invasive monitoring. MSG and MNG are non-invasive methods that augment current neurophysiological techniques in localization of lesions within the spine and peripheral nerves.
- **Current Practice**: MSG and MNG techniques are practiced by very few centers.
- **Resulting Gap**: Inadequate knowledge about these techniques and their utility in clinical practice.
- **Educational Need**: Didactic sessions that review the use of MSG and MNG, including their sensitivity, specificity, limitations, and their optimal role in neurophysiologic evaluation of spinal cord and peripheral nerve lesions.

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