UNION EUROPÉENNE DES MÉDECINS SPÉCIALISTES
EUROPEAN UNION OF MEDICAL SPECIALISTS

The UEMS Section of Clinical Neurophysiology

European Training Requirements (ETR)

for Clinical Neurophysiology

Updated version 2017 (FINAL)

INTRODUCTION

Clinical neurophysiology (CN) is a highly specialized medical specialty dedicated to quantitative and objective diagnostic examinations of various diseases and disorders affecting the nervous system, sensory and pain systems, muscles, sleep, vigilance and consciousness. Lately, the discipline has strongly extended also into long-term monitoring in the operating room, intensive care and emergency units as well as invasive and non-invasive neuromodulation-based diagnostics and treatments. The specialty requires both depth in clinical skills and technical expertise.

The Union of European Medical Specialists Clinical Neurophysiology Section (UEMS-CN) has formulated a new curriculum for training in CN. This document replaces the previous UEMS core curriculum for clinical neurophysiology from 2008, which has been used as the basis for this updated proposal. The present update was prepared in close collaboration with the European Federation of Clinical Neurophysiology (EFCN).

The aim of the UEMS-CN is to present recommended standards and guidelines for training in Clinical Neurophysiology within the European Union (EU) in order to acquire specialist competence in CN.

The primary goal is that this curriculum in CN will constitute an approved training program in all countries within the EU where CN is practiced as an independent specialty. It is recognized that currently, CN is not an independent specialty in all EU countries. In addition, there are a number of structural and operational differences in the health care systems, appointment procedures, and training protocols in different countries. Thus, the second goal of this curriculum is to harmonize as much as possible the education and training to achieve equal competency among those medical doctors practicing CN in different EU countries.

The independent specialty of clinical neurophysiology consists of several subfields of neurophysiological services, called ñmodulesòfrom here on in this document.

This European Training Recommendation (ETR) for Clinical Neurophysiology sets the standard of theoretical and practical skills required for full competency for independent specialty of CN and the specific clinical and technical aims of the five years training period.

AIMS

The purpose of this document is to define an ETR for the independent specialty of clinical neurophysiology, which leads to high quality standard for training in CN in the EU countries. The UEMS-CN does hold neither the intent nor the authority to impose a defined curriculum structure, content or aims to individual countries. This document solely aims to provide national authorities and professional bodies involved in the development of curricula for the training of clinical neurophysiologists with a comprehensive reference framework of core competencies to be achieved by the end of CN specialist training in Europe.

This curriculum focuses on describing the training process for those trainees aiming to become specialists in CN with full competence in the entire field of the independent specialty of CN after five year training as defined by the UEMS. A fully competent specialist in CN is expected to have completed all the basic modules, to have theoretical knowledge of all advanced training modules of the CN techniques and services, and to have achieved practical skills to some extent in most of the advanced modules.

The UEMS-CN recommends that the standards set in this curriculum for competence within each module for independent specialists would also be applied in those EU countries where an independent specialty does not exist. In these countries, CN is mainly practised by specialists from other fields of clinical neurosciences who typically specialize in a narrower section of CN. This can be indicated in their title, e.g. neurologist with competence in ENMG, paediatric neurologist with competence in EEG, or specialist in rehabilitation medicine with competence in ENMG, after they have achieved the same level of expertise in each module as the independent specialty consultants.

The aims of this document are to provide guidelines and to describe what is thought to be the necessary minimal level of knowledge for a specialist in clinical neurophysiology from 2017 on.

DESCRIPTION OF GOALS

Specialty Profile

The specialty of CN involves the detection and evaluation of pathophysiological changes of the central nervous system, peripheral nerves, muscles and sensory systems (visual, auditory, somatosensory) as well as sleep and vigilance. A consultation in our field implies that the neurophysiologist designs and performs an investigation for diagnosis, analysis, therapeutic orientation, and prognostic judgement of the disturbances causing the patientsôproblems.

In addition to diagnostics, clinical neurophysiologists perform long-term monitoring of wide range of nervous system functions during surgery and anaesthesia as well as in intensive care and emergency units.

Furthermore, clinical neurophysiologists provide specialist services e.g. for preoperative and intraoperative mapping of cortical speech and motor areas, localisation of the epileptogenic zone with intracranial recordings, as well as therapeutic neuromodulation (repetitive transcranial magnetic stimulation (rTMS), transcranial direct current stimulation (tDCS)). To do so, an extensive knowledge of all medical specialties in addition to neurology and related clinical neurosciences is necessary.

Clinical neurophysiology is essentially a service discipline, providing diagnostic help to nearly all other medical specialties including neurology, neurosurgery, neuroanaesthesiology, and paediatric neurology as well as intensive care medicine, neonatology, hand and paediatric surgery, vascular surgery, internal and general medicine, rheumatology, occupational medicine, oncology, orthopaedics, physiotherapy, rehabilitation and pain medicine, psychiatry, pulmonology, ophthalmology, and otorhinolaryngology.

CN specialist meets patients of all ages, from preterm babies to elderly, from outpatients to critically ill patients in the intensive care unit, from simple entrapment neuropathies to severe diseases, acute emergencies and rare hereditary disorders.

Rapid advancements in technology, especially concerning digital signal analysis, constantly expand the diagnostic armamentarium and widen the indications for performing certain examinations. The consulting physician must also be knowledgeable about telemedicine which is a growing part of the speciality.
The specialist should thus continually assimilate knowledge of new methods and scientific research, and actively participate in method development.

CN specialist should know the indications, restrictions, and proper use of CN methods to be able to prioritize and judiciously select services appropriate for each clinical context. Each CN specialist not only supervises or performs diagnostic tests, but also interprets those tests in relation to the clinical presentation of each individual patient. The specialty is therefore a union of quantitative and objective tests applied to clinical situations, and clinical skills are required.

GENERAL GOALS

Introduction:

Nowadays, the Seven Roles of Physicians, as defined by the Can Meds framework, are broadly adopted by medical educational platforms as the structure for the organization of competencies a medical professional should have.

Although the role of Medical Expert continues to play a central role in medical education, the physician nowadays is expected to play many different roles in medicine. These competencies, being Medical Expert, Collaborator, Communicator, Manager, Health advocate, Scholar and Professional, need to be learned and taught

during medical training and should be accomplished at the end of every medical specialist training.

The different roles will not be described in detail here, but are expected to be part of the specialist training in general. Some of the roles will be mentioned explicitly in the text below (in parenthesis).

Goals:

Medical training

The specialist education and training in CN shall lead to sufficient knowledge of the anatomy and physiology of the nervous system, of neurological diseases and their pathophysiological mechanisms, and of other diseases and injuries that alter the functions of the peripheral (neuromuscular) or central nervous system, sensory systems, cognition, or sleep and vigilance (***Medical expert).***

Diagnostic activity in clinical neurophysiology covers diseases and functional disorders in the central nervous system, peripheral nerves, all sensory organs, the autonomic nervous system, the motor unit and striated skeletal muscle, sphincter muscles, and the urogenital organs, sleep and vigilance. In addition to diagnostic application of neurophysiologic techniques, the residents should acquire good abilities in long-term monitoring of nervous system functions during sleep, surgery, anaesthesia, and intensive care, and in the use of neurophysiologic methods for treatment of patients (e.g. non-invasive brain stimulation). Apart from practical skills in neurophysiologic examination methods and the handling of equipment, thorough knowledge of measurement technology, electronics, electrical safety factors, signal analysis, psychophysics, and telemedicine is required. (***Medical expert)***

Supplementary Education and Training

Meeting the general goals for the specialty requires supplementary education and training in related disciplines (e.g. neurology, neurosurgery, paediatric neurology, neuroradiology, neuropathology, clinical genetics, hand surgery, pulmonology, and psychiatry). Supplementary education shall provide the resident with the knowledge and skills necessary to adequately assess history, symptoms, and clinical findings provided with a referral, thereby enabling to plan and carry out a relevant neurophysiologic examination with optimal combination of neurophysiologic tests. The focus of supplementary education should be on training the residentõs abilities to routinely carry out and evaluate history and clinical examination including neurological status of paediatric and adult patients.

Visiting other laboratories and centres of excellence in various subfields of clinical neurophysiology should be encouraged during the training period.

When the training is finished, the specialist should be encouraged to follow continuous medical education to keep their medical expertise and competencies up-to-date.

Theoretical Education

The specialist training programme shall be paralleled by theoretical studies and other complementary educational activities. This should include national and international courses and conferences annually.

In collaboration with their tutors, residents shall plan literature studies and select courses intended to promote the development of competence, providing knowledge and skills that may otherwise be difficult to acquire within the framework of specialist training.

The training centres should organize for the trainees regular (weekly) and systematic theoretical education comprising all modules of the independent specialty of CN. The training centres or national authorities should provide regularly updated lists of literature required for specialist competence or formal examination in clinical neurophysiology.

Quality Assurance

The specialty training shall be supervised. It is the responsibility of the chief medical officer (head of the department/clinic or equivalent) to plan the specialist training programme with the resident so that specialist competency can be achieved within the stipulated time frame that has been defined by UEMS to be five years for the independent specialty of CN.

Furthermore, it is the responsibility of the chief medical officer to ensure that the resident receives the supplementary education and training specified under the description of goals, and that complementary education/training is provided when the need for knowledge cannot be met within the normal framework of activities.

The progress of residents shall be continuously assessed with personal logbooks (e.g. electronic portfolio), and be checked against the individualôs own goals and national specialist training programme.

Training in administration and management

Management and leadership are important part of the specialist training programme ***(Manager/Medical leader)***, and residents shall therefore:

- train their ability to make independent and well-founded decisions concerning issues involving medical ethics
- acquire knowledge about general healthcare policy goals and priorities
- be given opportunities to participate in departmental activities related to organizational planning, financial management, production control, and quality improvement
- acquire knowledge of and insight into the leadership role of the physician

- be encouraged to participate in research and development, and to refine their capabilities for critically appraising the results from various methods and technologies
- increase their knowledge about the potential for preventing disease and injury, and participate in individual and general prevention activities
- develop their teaching skills by participating in the education and training of various categories of staff and undergraduate students
- acquire proper knowledge in laboratory quality control systems and their application in the field of CN as well as their use in administration and management
- acquire formal theoretical education in health care management

Central laboratories in clinical neurophysiology today tend to expand their consulting activities to satellite laboratories at county and local hospitals. This requires good knowledge of administration and leadership.

Internal and external collaboration

The interaction between clinical neurophysiologists and referring colleagues is important. As clinical neurophysiologists are increasingly working as team members, the educational experience shall include practice in presentation during rounds, preparing interpretative reports and active participation in team work and patient case meetings with referring physicians (**Collaborator).**

SPECIFIC GOALS FOR INDEPENDENT SPECIALTY OF CLINICAL NEUROPHYSIOLOGY

Introduction:

The optimal goal of the CN training is to become a specialist in CN with as detailed and qualified training as possible. It is recognised that in many EU countries clinical neurophysiology is not an official and independent medical specialty. In most of these countries, the CN training is part of the neurology training. However, to become a fully competent CN specialist, most of the 5 year the training period has to be filled with whole-time education in clinical neurophysiology, as specified below.

This curriculum describes the pathway to be followed to become a fulltime competent clinical neurophysiologist after a 5 year training period in those countries where CN is practised as an independent specialty. After the practical training, there may be a formal national exit examination as is the case in some of those European countries currently having CN as an independent specialty.

We recommend that the requirements for competency in each module of the CN would be similar, whether the country has or doesn't have an official specialty of CN. This will guarantee the high European standard for quality of CN education and independent, qualified performance of the large variety of CN services.

Specialist training for clinical neurophysiology:

To become a fully-competent specialist in clinical neurophysiology, five years of training is in principle required. Of these, 3-4 years should be at a central department (laboratory) of Clinical Neurophysiology performing not only ENMG or EEG examinations but full range of CN services including evoked potential recordings, psychophysical measurements, long-term monitoring for epilepsy and sleep disorders as well as pre- and intraoperative CN recordings for both paediatric and adult patients.

Additional to this, at least 6 months of training in neurology or paediatric neurology is required. The remaining 6 months could be in neurology or a related speciality, as listed above under *Supplementary Education and Training*. A PhD or MD thesis within the field, where this implies a minimum 2 yearsôprogram based on original research, could result in a reduction of the time required to become a specialist by a maximum of 6 months.

The training should start with one year of basic training in medical technology and basic theoretical neurophysiology in addition to practical training in basic CN modules; e.g. ENMG, EEG, and night polygraphy. During this first year, the trainee should acquire basic knowledge and skills in adult EEG and ENMG under the supervision of specialist. (The former curriculum proposed 500 EEG and 500 ENMG examinations to be performed during the first year, which can still be used as a guideline.) Basic scientific training, including medical statistics should be provided. After this first year, the mentor and the department head should review the progress and aptitude of the trainee for the subject, and in an interview determine whether the training should proceed.

During the following three years of training, the trainee should perform both basic and, with time, more advanced ENMG, EEG and sleep studies to get good clinical routine in these methods, both in adult and paediatric patients. The second year of CN training should include introduction to and growing competence in evoked potential recordings including TMS methods, psychophysical tests, reflex recordings, and small fibre tests (somatic, autonomic). During the last two years of education, methods of the advanced CN modules should be included in the training program such as Video-EEG for epilepsy diagnostics, examinations for disorders of sleep and vigilance, and intraoperative neurophysiologic monitoring.

It is recommended that the trainee writes at least one scientific report during the course of the training and is given opportunity to lecture, at least locally. He/she should also participate in annual national scientific meetings and, during the course of the training, participate in international conferences in clinical neurophysiology.

The head of the department of clinical neurophysiology where the training takes place is ultimately responsible for declaring the trainee a specialist, preferably after a formal exit examination as is currently the case in some UEMS countries. If the trainee lacks the required knowledge, as described below, an additional year of training could be allowed. If the needs are still not met, the trainee should not be recommended to the health care authorities for a specialist diploma.

A specialist exam is not mandatory in all UEMS countries, but it should be provided for any trainee who demands it. Specialist examination should preferably be regularly organized by the personnel of university departments of clinical neurophysiology (or neurology in countries where CN does not exist as an independent specialty). When these are not available, the national medical society may nominate specialists in CN to act as official examiners.

Content of Learning: Modules of CN services

In the following text, the contents of the specialty training are given in a modular structure since many physicians working within the field in the ñon-specialistò countries will only deal with one or the other types of neurophysiologic services. These clinicians must achieve the same level of specialist competence in one or more modules of the entire field of CN in order to be able to work all over Europe providing services of independent specialty of CN.

As the status and practices of CN services in different EU countries vary, training should preferably be determined by the number of cases seen for competency. This will normally be achieved in a certain time, but this time depends on activity within training centers. The following part defines the recommended number and type of tests to be independently analyzed and performed within each module of CN services during the training period.

Training should cover all the different aspects of competence: theoretical knowledge as well as ability to perform and analyze the CN tests in practice, and interpret the findings in relation to the clinical symptoms and signs.

The recommendation considers clinical neurophysiology as a series of modules of CN techniques, some of which are basic and required to be accomplished before proceeding to more advanced techniques. A fully-competent consultant of independent specialty will have demonstrated theoretical knowledge in all, and practical skills for competence in all basic modules as well as in most if not all of the advanced modules listed below.

1. Electroencephalography (EEG)

Basic module: Interpretation of a total of 1500 EEG recordings is considered the minimum requirement, with a mix of ages (preterm, neonatal, pediatric, adults up to old ages; all independently analyzed). While the use of long term EEG monitoring (CEEG) and videotelemetry EEG (VEEG) is increasing, the number of EEGs required will reduce commensurately. A mix of standard and prolonged EEGs (ambulatory-EEG (AEEG), CEEG, and VEEG) is expected.

Records should be normal and pathological, with mix of common and rare neurological conditions, and include activation techniques; special electrodes (e.g. sphenoidal, subcutaneous wire electrodes); recording settings and use of different montages; recordings in the emergency and intensive care units (ICU) and operating rooms (OR); trouble shooting and electrical safety. Some use of archive material for rare conditions would be acceptable.

Advanced EEG module includes preoperative epilepsy investigations with VEEG and surface and special electrodes (supraorbital, sphenoidal, zygomatic), intracranial and per-operative EEG recordings, CEEG and coma prediction, quantitative EEG with advanced EEG signal analysis techniques and EEG trends (e.g. FFT/power, cross correlation and coherence, time-frequency plots, amplitude integrated EEG, electrical source analysis techniques, back-averaging and functional connectivity analyses), broad-band EEG, spreading depression/depolarization.

2. Electroneuromyography (ENMG)

Basic module: Technology, neurophysiological basis and performance of nerve conduction studies (NCS) and needle EMG should be understood and mastered, together with a sufficient knowledge of the neuroscience underpinning nerve conduction, EMG and the range of pathologies met.

A minimum of 1500 patients for independently performed complete ENMG examinations (finished cases not given nerves or muscles sampled); comprising motor and sensory nerve conduction studies (unusual as well as commonly examined nerves) and needle EMG of common and rare muscles.
This would also include F waves and H reflexes, quantitative motor unit potential and interference pattern analyses and repetitive nerve stimulation for myasthenic disorders. Appropriate case mix of neuropathic, myopathic, and neuromuscular junction diseases, as well as hereditary and acquired diseases should be covered.
Different ages, adults and children, and different settings, outpatients and ICU, should be included.
Some use of archive material for rare conditions would be acceptable.

Advanced ENMG module includes single-fiber EMG techniques, macro-EMG, laryngeal EMG, nerve and muscle excitability testing, sphincter EMG, EMG of the diaphragm, near-nerve needle NCS, ion-channel ENMG, EMG-guided botulinum toxin injections, performing skin and muscle biopsies, reflex recordings (blink reflex, masseter reflex, masseter silent period, corneal reflex, flexor reflex, T-reflex and long-loop reflex (C-response)) and measurement of axonal excitability. These should be studied after competence in the standard ENMG techniques has been achieved.

3. Small fiber tests

Basic module: This requires thorough theoretical knowledge about psychophysics, different algorithms for sensory threshold tracking and magnitude estimation, and signal detection theory as well as anatomy and neurophysiology of large and small fiber pathways and autonomic nervous system. The basic module includes quantitative sensory testing (QST) of tactile, vibratory and thermal sensory modalities as well a sympathetic skin response (SSR) and heart rate variability (HRV).

Advanced module: This consists of contact heat evoked potential (CHEP) and laser evoked potential (LEP) recordings, skin biopsy for epithelial nerve fiber density measurement, and specific tests for autonomic nervous system function (e.g. tilt test, axon reflex flare, quantitative sudomotor reflex).

Theoretical knowledge should also involve microneurography and neuropathology of small fiber disorders.

Competence in these modules will require 50 patients each.

4. Evoked Potentials (EP)

Basic module: It is expected that EP modules will be taken with another module, e.g. EEG or ENMG. The technological and neurophysiological basis of signal generation, stimulation, recording and interpretation; including cephalic and non-cephalic references must be understood.
A minimum of 250 evoked potentials is required including both normal and various abnormalities across a range of modalities including:

Visual evoked potentials (VEP),
Brainstem auditory evoked potentials (BAEP)
Somatosensory evoked potentials (SEP)
Motor evoked potentials with magnetic stimulation (MEP)

Advanced EP module: theoretical knowledge of neurophysiological basis and pathophysiological processes, stimulation and recording techniques, as well as practical skills in analyzing and interpreting the results in the clinical context are required. The techniques include brainstem audiometry with BAEP technique, Vestibular Evoked Myogenic Potentials (VEMP), LEP, CHEP, cognitive Event Related Potentials (ERPs: N100, P300, MMN (Mismatch negativity), N400 etc.), Transcranial magnetic stimulation Evoked Potentials (TEP), paired-pulse TMS techniques, navigated TMS for preoperative cortical mapping, and TMS-EEG.

5. Intraoperative Monitoring (IOM), advanced.

Intraoperative monitoring (IOM) module requires prior competence in basic EEG, EMG and EP modules. IOM is mostly performed in specialized centers such as university hospitals. The recommendation is that training and practice in neurophysiologic IOM techniques should only be performed by or under the responsibility of a clinical neurophysiologist.
For both of the main indications, scoliosis and posterior fossa surgery, IOM competence requires at least 50 monitored patients.
Competency must involve good knowledge and awareness of true/ false positive findings, the effects of anesthesia and blood pressure on the EMG, evoked and EEG signals as well as the surgical risks related to different operation techniques and stages.
The IOM services demand time and good collaborative abilities of the clinical neurophysiologists as IOM is team work between several experts (surgeon, anesthesiologist, laboratory technicians in addition to clinical neurophysiologists). They need to be done regularly to maintain competence, with multidisciplinary team playing an integral part in planning and tailoring IOM services.

6. Neuromodulation, advanced.

This module can be done after completing the basic and advanced EP and basic EEG modules. It includes special techniques of non-invasive and

invasive brain stimulation, both diagnostic and therapeutic, as well as interventional clinical neurophysiology, such as repetitive transcranial magnetic stimulation (rTMS; e.g. for depression, pain, dystonia), transcranial direct current stimulation (tDCS), vagal and hypoglossal nerve stimulation. The module also includes preoperative assessment and prediction of efficacy of invasive motor/auditory/prefrontal cortex stimulators with navigated TMS, and assistance with microelectrode recordings (MER) during implanting of deep brain stimulators (DBS).

In each type of procedure, a minimum number of 30 independently treated patients are required, with thorough theoretical and practical knowledge of the techniques and their therapeutic effects during follow up considered mandatory.

7. Intracranial clinical neurophysiology, advanced.

This advanced module should follow the basic and advanced EEG and EP modules and optionally Neuromodulation module. It leads to competence in highly specialized neurophysiological services for epilepsy surgery and invasive therapeutic neuromodulation.

It will cover all intracranial recordings including subdural, epidural, intra-cortical, depth recordings, and stereo-EEG for pre-surgical evaluation of epilepsy, and per-operative electrocorticography as well as direct cortical stimulation and microelectrode recordings (MER) during neurosurgery and DBS implantation.

These CN services are always performed in a multidisciplinary framework, with full competence developed within such a team. Full competence will require independent care of minimum 100 procedures.

8. Visual Neurophysiology, advanced.

This module includes corneal or conjunctival, whole-field, pattern-evoked, and multifocal electroretinography (ERG) as well as electro-oculography (EOG) for the study of retinopathies and eye-movement disorders. As these investigations are performed in both vision science labs and in clinical neurophysiology departments, common standards should be applied. It is envisaged that departments of CN involved in ERG and EOG should adhere to the international standards and guidelines.

Competency in ERG and EOG recordings, analyzes and interpretation will require a minimum 100 patients with a mixture of normal and abnormal findings, both hereditary and acquired conditions. Some cases may be from archive material.

9. Investigations of sleep and vigilance

Basic module: Includes competence for cardio-respiratory night polygraphy (often done with ambulatory devices at home) in the assessment of day-time

sleepiness due to sleep apnea and periodic leg movements in sleep. A minimum of 100 recordings is required to be independently analyzed and interpreted during training, with normal and abnormal recordings and various types of sleep apnea and sleep related movement disorders. This module also requires ability to interpret clinical questionnaires assessing e.g. quality of life, and mood, anxiety or personality disorders.

Advanced sleep module: This module should only be taken after the basic EEG and Sleep modules have been completed. The diagnostics of sleep related neurological disorders and abnormalities in vigilance requires advanced neurophysiological techniques such as polysomnography (PSG), multiple sleep latency test (MSLT), maintenance of wakefulness test (MWT), actigraphy and pupillography, and occasionally also VEEG for differential diagnostics.
Thorough knowledge about normal and pathological sleep-related disorders and EEG-polygraphy phenomena, at different ages from neonates to elderly is required.
A minimum of 200 analyzed and interpreted patient recordings, with 100 full PSG are required.
Some rare conditions may be studied from archive material

10. Neurophysiology of movement disorders, advanced.

This module should follow basic ENMG and EP modules and includes kinesiology, tremor analysis, and multi-channel surface EMG techniques for these, as well as motor readiness potential (contingent negativity or Bereitschaft potential) and back-averaging EEG techniques. Some of these involve different applications of standard techniques in specific contexts, e.g. surface EMG for orthostatic tremor. A minimum of 50 patient recordings are required for competence in each technique.

11. Ultrasound, advanced.

This technique is complimentary to other peripheral neurophysiologic methods, both EMG and NCS. It should be applied in connection with an ENMG examination, where it may provide additional valuable localizing or etiological information.
Competence for clinical neurophysiologist requires hands-on courses in specialist centers, training under supervision of a competent clinical neurophysiologist or radiologist, and at least 100 patients independently investigated and interpreted in relation to ENMG findings and clinical context.

12. Multidisciplinary techniques, advanced.

Clinical neurophysiology is increasingly used as a part of multimodal functional brain imaging, utilizing advanced EEG analysis techniques and magnetoencephalography (MEG) or TMS-EEG techniques in combination with SPECT, PET, fMRI, DTI and their co-registration. These neurophysiological services require prior competence in basic and advanced EEG, EP, and neuromodulation modules. As multimodal functional imaging is mainly used for

scientific research purposes, exact numbers of patient cases for competence will not be recommended here.

Some of the above modules are considered fundamental (Basic modules), while others depend on adequate previous training (Advanced modules):

Basic	**Advanced**
EEG	Advanced and Intracranial EEG
ENMG	Advanced ENMG
Small fiber tests	Advanced small fiber tests
EP	Advanced EP (Cognitive ERP, pain EPs)
	Intraoperative monitoring (IOM)
	Non-invasive neuromodulation, presurgical mapping of speech and motor areas
Night polygraphy	Sleep and vigilance (PSG, MSLT, MWT)
	Movement disorders
	Ultrasound

The recommendation is that primary competences within relevant basic modules are mandatory before proceeding to secondary advanced modules.

At the end of practical training period in clinical neurophysiology, the specialist in independent specialty of clinical neurophysiology has to have achieved full theoretical and practical knowledge and skills in all basic modules and, to some extent, in most of the advanced secondary modules.

The next chapters describe the specific aims to be achieved during the training period for independent CN specialty, separately for central and peripheral nervous systems. The theoretical knowledge demanded at the beginning of both sections as well as the examinations listed under both Headings A (*Be able to independently perform, analyze and interpret*) are considered as the core competencies to be achieved during the training period.

SPECIFIC AIMS OF TRAINING: Central nervous system

The specialist in clinical neurophysiology shall

Have knowledge of

- Normal neurophysiology of the central nervous system, including visual, auditory, sensory and motor systems, sleep and vigilance as well as normal age-related alterations
- Neuroplasticity

- Encephalopathies and focal brain lesions.
- Different forms of epilepsy and functional seizures

- Dementia, MS, ophthalmological, neurodegenerative and hereditary, infectious, metabolic and autoimmune diseases, sleep disorders, traumatic and vascular and oncological diseases
- Psychiatric disorders

- The international 10-20 and 10-10 systems for EEG recordings.

- Parametric and non-parametric quantitative-EEG signal and connectivity analysis as well as source localization methods
- Electrical safety, technical artefacts and trouble shooting

A. Be able to independently perform, analyse and interpret

Most of the examinations listed below are performed routinely at all neurophysiological central laboratories. Residents shall achieve the knowledge and skills which enable them to independently perform these examinations and assess the results in relation to the patientôs disease. Residents shall also be able to determine when a more experienced specialist should be consulted about unexpected results or results that are difficult to interpret.

EEG*:*

- Resting EEG, children, adults and elderly
- Effects of hyperventilation and photic stimulation.
- EEG with simultaneous video monitoring
- EEG in neonates and preterm babies
- The normal development of EEG at different ages
- Neurophysiologic diagnostics of brain death
- EEG during sleep and sleep deprivation (epilepsy diagnostics)
- Long-term recording with ambulatory equipment and/or telemetry
- Different EEG-patterns in coma and their prognostic implications
- Progression patterns of different forms of dementia.
- Different epileptiform EEG patterns and recognition of epileptic syndromes
- Analysis and classification of seizures (in VEEG with simultaneous video recording)
- Focal abnormalities
- Brain death
- Benign EEG variant rhythms in different age groups

Sleep:

- Classification of the different sleep stages
- Sleep patterns in infants
- Awakenings and arousals
- Parasomnias
- Nocturnal seizures and their differential diagnostics
- Respiratory events and periodic limb movements
- Apnoea, hypopnoea, periodic limb movements and EOG (electro-oculogram) in

polygraphic and polysomnographic recordings
- Polysomnography (PSG)
- Multiple sleep latency test (MSLT)
- Maintenance of wakefulness test (MWT)

Evoked potentials:

- VEP (Visual Evoked Potential), flash stimulation
- VEP, pattern stimulation
- SEP including subcortical response
- BAEP -brain stem auditory evoked potentials and auditory evoked potentials (AEP)
- MEP - motor evoked potential/ transcranial magnetic stimulation (TMS): diagnostic monitoring, preoperative mapping, and treatment applications (repetitive TMS, rTMS)

B. Have good knowledge of and some experience in performing/scoring

All specialists are not expected to have an independent command of the examination methods below since they are used more or less frequently in central laboratories. Residents should, however, have extensive knowledge concerning the theoretical background of the recordings and clinical indications for which these methods are to be used, and during their continued training become increasingly independent in the performance and assessment of these examinations.

- Sphenoidal recording and recording with other special electrodes for EEG
- Automatic frequency analysis of EEG
- Topographic EEG analysis (mapping)
- Continuous monitoring of brain function in intensive care units
- SEP after dermatome stimulation
- Quantitative sensory testing (tactile, vibratory, thermal)
- Brainstem audiometry with BAEP technique (ABR)
- ERG, electroretinography (whole-field stimulation, corneal recording)
- EOG, electro-oculography
- CHEP (thermal evoked potential recording)
- VEMP (Vestibular evoked myogenic potentials)
- nTMS (neuronavigated TMS)
- Skin and muscle biopsy
- Event-related and cognitive evoked potential tests (e.g., P300, MMN, N100, N400 tests), including back-averaging techniques
- Determination of reaction time and use of computerized attention tests
- Tests for autonomic nervous system function:
    - SSR (sympathetic skin response)
    - HRV (heart rate variability)
    - pupillography

C. Have been present during, or have theoretic knowledge of

management and performance

The examinations below are performed less frequently and are not available at every central laboratory. The resident shall, however, acquire good theoretical knowledge of these investigations to be able to decide when it is worthwhile to perform them and where to turn if the method is not available in the home laboratory.

- Electrocorticography
- Deep brain stimulation (DBS)
- Intracranial EEG recordings incl. subdural leads, depth-electrodes, stereotactic EEG
- Investigations during DBS implantation (microelectrode recordings, MER)
- Amytal/ Methohexital test during EEG (Wada-test)
- Functional MRI, DTI tractography, PET (positron emission tomography), SPECT (single photon emission computerized tomography)
- Magnetoencephalography (MEG) and somatosensory evoked fields (SEF)
- Actigraphy for determination of sleep-wake patterns (diurnal rhythm)
- High-density EEG-and evoked potential recordings (64 channels or more)
- Digitized electrical source analysis of EEG and EP signals
- LEP - laser evoked potential
- Axon reflex flare response
- Sudomotor reflex recording
- tDCS (transcranial direct current stimulation)
- Motor cortex and speech mapping during wake craniotomy

SPECIFIC AIMS OF TRAINING: Peripheral nerves and muscles

The specialist in clinical neurophysiology shall

Have knowledge of:

- Different indications for electromyography (EMG) and electro-neurography (ENG/NCS).
- The anatomic localization of different muscles as to be able to perform needle electromyography, and the locations for stimulating and recording of different nerves.

- All types of acquired, traumatic, and hereditary disorders at various levels of the peripheral nervous system, neuromuscular junction, and muscles
- Different types and aetiologies of peripheral neuropathies and neuronopathies in children and adults, e.g., Guillain-Barré syndrome and the various hereditary neuropathies.
- Entrapment neuropathies.
- Toxic and metabolic neuropathies.
- Amyotrophic lateral sclerosis and other motor neuron diseases
- Myasthenia gravis and myasthenic syndromes (neuromuscular transmission disorders).
- Hereditary and acquired myopathies and myositis.
- Myotonic disorders

- ION channel diseases
- Different reinnervation processes and their timetable, relationship to prognosis
- Critical illness neuropathy and myopathy
- Pure sensory and autonomic neuropathies, small fiber neuropathies
- Cranial nerve and brainstem disorders
- Chronic pain, especially neuropathic pain
- Psychophysical testing algorithms and signal detection theory (method of limits/ levels, forced choice)
- Electrical safety, technical artefacts and trouble shooting

A. Be able to independently perform/ score:

- Needle EMG of extremity muscles with scoring of interference patterns, and identification of different types of spontaneous activity.
- Needle EMG with quantitative and qualitative motor unit potential analysis, i.e., identification of potentials typical of neurogenic and myogenic disorders by means of manual methods and the most common automatic methods of EMG analysis
- Surface electrode EMG to analyse e.g. tremor, hyperkinesia, torticollis in mobility disorders and dystonia
- EMG of bulbar innervated musculature (muscles of the face, jaw, tongue, larynx, etc.)
- Nerve conduction velocity studies, motor and sensory, surface and needle techniques
- Repetitive nerve stimulation, decrement analysis
- F-responses, H-reflex
- Transcranial magnetic stimulation of motor cortex and spinal cord with recording of peripheral motor responses (MEP).
- Botulin toxin treatment with EMG guidance
- Quantitative sensory testing (QST) of vibratory, thermal, and tactile modalities including pain thresholds and wind-up

B. Have good knowledge of and some experience in performing/scoring

All specialists are not expected to have an independent command of the examination methods below since they are used more or less frequently in central laboratories. Residents should, however, have extensive knowledge concerning the fundamentals of the tests, their technical details and indications for which they are to be used and be aware where to refer their patients for further investigations when necessary.

- Single-fibre EMG with jitter analysis and assessment of fibre density
- EMG of anal sphincter musculature, diaphragm, laryngeal muscles
- Blink reflex, masseter reflex, masseter inhibitory reflex, corneal reflex, T-reflex, long-loop reflex
- Autonomic nervous system tests (RR-intervals, sympathetic skin response, etc.)
- Needle neurography (to diagnose e.g. meralgia paresthetica and Mortonôs metatarsalgia, and to detect nerve regeneration after nerve repair surgery)
- Long-term monitoring of BAEP, ENMG, MEP and SEP during surgery of spinal cord and brain stem surgery

- Reflex-and latency measurements in sacral segments (bulbocavernosus reflex, pudendal neurography and SEP)
- Assessment of cortical excitability and inhibition with TMS techniques
- Muscle and skin biopsies

C. Have been present during, or have theoretic knowledge of, management and performance of

These investigations below are performed less frequently, not at every central laboratory, and sometimes for scientific purposes only. The resident shall, however, acquire good knowledge of these examinations to be able to judge when it is worthwhile to perform the examinations and where to turn if the method is not available in the home laboratory.

- Urinary sphincter EMG
- Monitoring of integrated EMG in relation to urodynamic investigation
- MUNE
- Macro-EMG
- Extra-ocular muscle EMG
- Measurements of sensibility thresholds in sacral segments
- ENFD ï epithelial nerve fibre density measurements
- Methods for measurement of muscle strength
- Gait analysis, movement recordings
- Microneurography and other methods of determination of conduction velocity in slowly conducting fibres
- Measurement of axonal excitability

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