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Educational Curriculum for Peripheral Nerve Stimulation Developed by the North American Neuromodulation Society

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ABSTRACT

Background: Peripheral nerve stimulation (PNS) is an effective neuromodulation therapy for chronic neuropathic and nociceptive pain. Although the total number of PNS implantations has increased over the last decade, no curriculum exists to guide training and learning of this therapy. The goal of the North American Neuromodulation Society (NANS) education committee is to develop a series of competency-based curriculums for neuromodulation therapies. The PNS curriculum is the latest part of such series, following the curriculums for spinal cord stimulation and intrathecal drug delivery system.

Materials and Methods: A multidisciplinary task force (anesthesiology, physical medicine and rehabilitation, neurosurgery, preventive medicine and public health, and neurology) was created by the educational committee of NANS to develop a PNS curriculum in accordance with the Accreditation Council for Graduate Medical Education (ACGME) milestones. The curriculum was created based on the best available evidence and expert knowledge (from our task force members) of available PNS systems. The final PNS curriculum was approved by the NANS board.

Results: A PNS curriculum was developed by the task force. Milestones included professionalism, practice-based learning, interpersonal communication, medical knowledge, systems-based practice, procedural skills, and patient care. Each milestone was defined into three categories: early learner, advanced learner, and practitioner.

Conclusions: This manuscript provides a PNS training curriculum developed by a multidisciplinary task force of the NANS educational committee in accordance with the milestones described by ACGME for basic learners, advanced learners, and practitioners. This curriculum will help provide a structured training and evaluation process for obtaining proficiency in PNS treatment(s).

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INTRODUCTION

Peripheral nerve stimulation (PNS) is a neuromodulation therapy focused on pain management by electrically modulating peripheral nerves.[1,2] PNS continues to evolve with accrual of prospective studies. Our understanding of this nascent and burgeoning therapy has increased significantly over the past decade with the development of novel waveforms and identification of new neural targets.[3] PNS now most often involves a minimally invasive procedure where an electrode array (lead) is implanted using ultrasound and/or fluoroscopic guidance or open surgical approach along a named peripheral nerve or branches of a named nerve. Peripheral nerve field stimulation (PNfS) is a similar neurostimulation modality that involves stimulation of fine branches of terminal nerves,[4] but there is no implantable system that is specifically approved by the US Food and Drug Administration for PNfS applications.

Much of the prospective data in support of PNS therapies has been produced within the past five years. Until that time, most studies were performed with repurposed spinal cord stimulation (SCS) technology. Recently, the number of manufacturers of specifically engineered PNS systems has increased in tandem with the number of clinical (procedural) approaches, resulting in an expansion of indications and implantation techniques. The increased complexity and utilization of diverse technologies mandate proper training of physicians in its application for better patient outcomes.

The training, experience, and conceptual knowledge may vary vastly among a diverse background of specialties that deal with PNS in clinical practice. As with any other neuromodulation therapy, appropriate patient selection, surgical implantation technique, and follow-up care are the key to success with PNS therapy.

American Council of Graduate Medical Education (ACGME) – accredited Multidisciplinary Pain Management fellowship programs and Neurosurgical training programs are responsible for providing competency-based training in advanced neuromodulation therapies, including PNS.[5,6] The Education Committee of the North American Neuromodulation Society (NANS) convened to create a training curriculum for the specialists who will be involved with PNS therapy (Tables 1–6).

This current document provides a roadmap for a competency-based curriculum analogous to the training requirements created for SCS and intrathecal drug delivery systems (IDDS).[6,7]

MATERIALS AND METHODS

An international multidisciplinary diverse task force was formed by the members of education committees of NANS and the International Neuromodulation Society (INS), which included neurosurgeons, anesthesiologists, physiatrists, neurologists, and preventive medicine/public health specialists. All participating members were volunteers solicited through the education committees of NANS and INS based on their expertise in PNS supported by practice volumes, research, and scientific publications. Although the curriculum is conceptualized with the existing competency and educational milestones-based American graduate medical education model, the task force was international, with representation from other countries.[8]

The core attributes of neuromodulation competencies share a considerable overlap of constructs among the other two published curriculums (SCS and IDDS) by NANS educational committee, as evidenced in Table 7.[6,7]

A hybrid meeting that included in-person and virtual platforms was convened in September 2021. The proposed competencies were discussed and debated among members of the task force. All proposed competencies were developed using iterative contribution, vetting, and in-depth discussion. Quorum consensus was used to mitigate differences among task force members. In rare cases, when a consensus could not be reached, the executive leadership of the committee decided on the final recommendations. The structure of the document progresses vertically and includes six competencies: patient care and procedural skills, systems-based practice, medical knowledge, interpersonal and communication skills, practice-based learning, and professionalism (Table 1). The levels of training progress horizontally from the stage of the early learner to the established practitioner.

The entire document was exhaustively reviewed for accuracy, inclusion, and relevance by the task force members. The curriculum was finally peer-reviewed by the educational committees of both NANS and INS before being reviewed by the NANS board.

DISCUSSION AND RECOMMENDATIONS

PNS is a minimally invasive image-guided treatment modality that is not as widely practiced by pain management practitioners and neurosurgeons compared to SCS therapy. The field of PNS and its technologic advancements are evolving at a very rapid pace.[9,10] The proposed curriculum is an attempt to standardize educational competencies for PNS application. The progressive levels of training are at the forefront of consideration during the development of this document such that a natural path of lateral progression from early learner to practitioner evolves. The proposed path of lateral progression is also in accordance with the ACGME milestone documents.[11]

Table 1. Patient Care and Procedural Skills.

	Early learner	Advanced learner	Practitioner
Patient selection[2,3,6,7,10,12–16]	i. Recognize evidence-based indications for peripheral nerve stimulation ii. Conduct comprehensive history, clinical examination, and recognize signs/symptoms of common indication	i. Identify medical, surgical, and psychologic requirements for candidacy ii. Describe the effect of other treatments (opioids) on outcomes	i. Develop individualized neuromodulation treatment plan ii. Provide adequate patient counseling/education and manage patient expectations to encourage compliance iii. Define benefits of peripheral nerve stimulation compared to other forms of therapy. iv. Counsel patients about peripheral nerve stimulation vs other surgical and neuromodulation options v. Identify the role of diagnostic peripheral nerve blocks in patient selection
Radiographic knowledge and interpretation[6,7,17,18]	i. Interpret radiographic anatomy ii. Identify different radiographic modalities (x-ray, CT) available to augment decision-making process iii. Demonstrate basic knowledge of MRI safety with implanted devices	i. Determine appropriate preoperative radiographic evaluation ii. Practice principles of radiation safety iii. Practice principles of MRI safety with implanted devices	i. Identify hardware migration/malfunction on radiographic imaging ii. Incorporate radiographic imaging results in decision-making and complication management iii. Formulate individualized therapy and device plans based on MRI conditionality/compatibility and patient conditions iv. Identify conditions that alter MRI compatibility (lead fracture, high impedance, etc)
Ultrasound knowledge and interpretation[6,7,19–21]	i. Describe basic ultrasonography principles ii. Describe basic sonoanatomy iii. Demonstrate hand-eye coordination for basic ultrasound-guided musculoskeletal and pain procedures	i. Recognize methods for ultrasonic image optimization ii. Identify variability in sonoanatomy iii. Demonstrate ability to target specific structure under direct ultrasound guidance	i. Apply ultrasonography principles to obtain appropriate target anatomy ii. Interpret hardware migration/malfunction on ultrasound imaging iii. Incorporate ultrasound evaluation in decision-making and complication management
Trialing[6,7,15–17,22]	i. Recognize the indications for trialing ii. Perform preoperative evaluation	i. Recognize optimal trialing technique ii. Identify risks, benefits, cost-effectiveness of performing a trial	i. Define validity and identify parameters of trial success ii. Manage trial complications and troubleshooting
Surgical skills[6,7,17,22–24]	i. Identify basic instrument sets and practice basic surgical skills ii. Describe basic aseptic practices and describe principles of wound healing	i. Master advanced surgical skills, including tunneling techniques if warranted ii. Identify optimal lead location based on individual systems available iii. Adopt proper anchoring systems if indicated iv. Utilize intraoperative image guidance for optimal lead placement	i. Develop individualized neuromodulation plan in complicated and previously trialed or permanently implanted patient ii. Define appropriate surgical approach for procedure based on individual characteristics iii. Identify and manage complex anatomic situations and/or comorbidities
Intraoperative troubleshooting[6,7,12,17,22,25]	i. Identify intraoperative concerns (patient positioning, nerve injury, hemostasis, etc)	i. Optimize use of intraoperative imaging modality (ultrasound vs fluoroscopy) ii. Describe nerve stimulation parameters and its role in lead location	i. Identify system malfunction through sequential troubleshooting ii. Identify the factors that could necessitate the replacement of malfunctioning hardware iii. Confirm and document final lead location
Complication management[6,7,16,17,22,26]	i. Describe preoperative screening, decolonization, and proper use of antibiotics	i. Identify early signs and symptoms of complications (infection, loss of efficacy, and neurological dysfunction)	i. Practice in accordance with the latest evidence-based guidelines for complication management

(Continued)

Table 1. *Continued*

	Early learner	Advanced learner	Practitioner
	ii. Recognize guidelines for anti-platelet and anticoagulant when operating close to peripheral nerves	ii. Practice timely management of complications iii. Counsel family and patient regarding complications and management options iv. Perform adequate, transparent, and appropriate documentation	ii. Identify unique patient factors that would necessitate deviation from guidelines iii. Identify conditions requiring shared decision-making and multi-disciplinary management iv. Participate in multi-disciplinary peer conferences in relation to complications
Long term care[6,7,27]	i. Identify interactions with other therapies and treatments (pace-makers, diathermy, other implant-able devices, etc)	i. Perform evaluation for loss of efficacy (progression of disease vs device malfunction vs new pathology) ii. Demonstrate knowledge and understanding of reprogramming process	i. Distinguish device vs therapy failure from loss of efficacy or new pathology ii. Formulate treatment plan for loss of efficacy

CT, computed tomography; MRI, magnetic resonance imaging.

Recommendations

We hereby suggest similar recommendations as provided in our initial guiding document developed for the SCS curriculum.[6]

Recommendation 1: Adoption of Horizontal Framework Curriculum

The Curriculum provides a framework that can be used to stratify trainees into early learner, advanced learner, and practitioner categories based on areas of competency delineated in the document.

Recommendation 2: Adoption of a Vertical Framework Curriculum

Training in PNS includes not only medical knowledge but also procedural competence to successfully implant a device in a patient. The curriculum delineates six competency categories as provided by the ACGME and its respective milestones project.

Recommendation 3: Adoption of Modular Content Segments Curriculum

The curriculum provides a modular framework to assess level of knowledge and skill necessary to transition from one group to another, for example, early learner to advanced learner.

Recommendation 4: Curriculum as an Evaluation Tool

The curriculum can be used as guidance for developing evaluation tools for trainees.

Recommendation 5: Curriculum as Credentialing and Certification Tool

The curriculum provides an outline to develop examination and assessment tools that can be administered to ascertain competencies needed to obtain certification/privileges for PNS procedures.

Table 2. System-Based Practice.

	Early learner	Advanced learner	Practitioner
Coding and billing[6,7,28–30]	i. Use accurate diagnosis and proper documentation	i. Describe cost-effectiveness, pre-authorization/pre-certification of neuromodulation therapies	i. Describe local coverage determinants, policies, and optimal reimbursement regarding peripheral nerve stimulation
Practice management[6,7,28,31–33]	i. Work with other team members (trainees, APPs, etc) ii. Identify and use various telehealth platforms.	i. Identify site of service differential (office-based, hospital-based outpatient department or ambu-latory surgery center) ii. Identify billing and compliance requirements of various telehealth platforms.	i. Develop referral network and relation-ships with complementary specialists ii. Incorporate telehealth and virtual pro-gramming in clinic workflows and research protocols. iii. Create safe and reliable systems for managing complications
Economics[6,7,15,16,29]	i. Uses resources responsibly	i. Cites literature data when appli-cable on cost-effectiveness and outcomes to support utilization	i. Designs and implements cost-effective care pathways
Safety and systems[6,7]	i. Define medical errors, near misses, and sentinel events ii. Utilize protocols and checklists for patient hand-offs, medication orders, and emergencies	i. Identify the principles of con-ducting root cause analysis ii. Participate in process improve-ment activities	i. Analyze and implement processes driven by root cause analysis recommendation ii. Design and lead process improvement activities

APP, advanced practice provider.

Table 3. Medical Knowledge.

	Early learner	Advanced learner	Practitioner
Physiology of pain[6,7,34–37]	i. Describe neurobiology of pain	i. Application of pain pathophysiological basis of disease to specific presentation of pain syndromes ii. Describe natural history/temporal course of pain presentations	i. Comprehend underlying relationship between individual painful etiologies and peripheral/central pain sensitization
Targets of stimulation[6,7,10,15,16,21,38–41]	i. Demonstrate knowledge of peripheral nerve system	i. Identify optimal peripheral nerve targets for specific indications	i. Individualize applications of stimulation targets based on anatomical variability and case complexity
Modes of Stimulation[6,7]	i. Identify waveforms and novel sites of stimulating peripheral nerves	i. Describe differences between programming parameters specific to PNS	i. Design a salvage plan for failures or loss of efficacy by altering programming parameters
Anatomic consideration[6,7,15,16]	i. Describe anatomy of peripheral nervous system and associated structures	i. Identify various anatomic variabilities of peripheral nervous systems ii. Identify anatomical alterations due to surgical interventions	i. Anticipates anatomic variability and barriers within subjects, which can be potential surgical risks

Table 4. Interpersonal and Communication Skills.[6,7]

	Early learner	Advanced learner	Practitioner
Relational[6,7]	i. Describe the requirements of proper consent ii. Communicate clearly and compassionately with patients, families, and colleagues iii. Acknowledge procedural pause iv. Perform adequate and transparent documentation	i. Identifies and incorporates patient preference in shared decision-making in complex patient care conversations and the plan of care ii. Recognize the appropriate components of procedural pause iii. Document appropriately unexpected events iv. Establish a therapeutic relationship with patients and caregivers, including persons of different socioeconomic and cultural backgrounds	i. Obtains proper consent ii. Role models effective communication and development of therapeutic relationships in both routine and challenging situations iii. Lead procedural pause iv. Develop systematic process for documentation
Technology[6,7,32,33]	i. Uses HIPPA safeguards for PHI and EMR ii. Uses EMR and radiology access systems for timely reporting of clinical information and documentation of patient care	i. Designs and implements an EMR template ii. Uses electronic medical record to close the loop on communication internally and externally	i. Uses EMR and documentation for research ii. Utilize EMR to optimize care pathway for PNS iii. Utilize appropriate telemedicine and remote programming methods

EMR, electronic medical record; HIPAA, Health Insurance Portability and Accountability Act; PHI, protected health information.

Table 5. Practice-Based Learning.[3,7]

	Early learner	Advanced learner	Practitioner
Research[3,7]	i. Perform literature review ii. Identify gaps in literature to formulate a research question iii. Demonstrate ability to write a research protocol	i. Describe the ethics and regulatory aspects of human subject research ii. Critically analyze published literature	i. Setting research in practice location ii. Identify levels of evidence and implement into practice
Lifelong learning[6,7]	i. Awareness of practice improvement data (systematic reviews, practice guidelines, etc)	i. Participate in evidence-based practice improvement ii. Organize educational activities at program level iii. Teach colleagues and other health professionals in both formal and informal settings	i. Develop educational curriculum and/or assessment tools

Table 6. Professionalism.[6,7]

	Early learner	Advanced learner	Practitioner
Compassion[6,7]	i. Demonstrate good patient care, autonomy, respect, and respond to patients' needs	i. Able to appropriately handle ethical challenges and serve as a mentor	i. Participate in improving quality of care, mitigate impact of diverse patient characteristics on patients' outcomes and develop physicians' wellness programs
Accountability[6,7]	i. Admit to committing any errors, recognize own limitations, seek assistance, accept feedback, and lead effective M&M discussions	i. Assume effective leadership, able to resolve conflicts, and effectively manage personal stressors	i. Serve as a role model, manages COI effectively, recognize and respond to physician impairment, whether in self or others

COI, conflict of interest; M&M, mortality and morbidity.

Table 7. Core Attributes of Neuromodulation Competencies.

- Patient care and procedural skills
  - Patient selection
  - Ultrasound knowledge and interpretation
  - Radiographic knowledge and interpretation
  - Trialing
  - Surgical skills
  - Intraoperative troubleshooting and management
  - Complication management
  - Long term care
- System-based practice
  - Coding and billing
  - Practice management
  - Economics
  - Safety and systems
- Medical knowledge
  - Physiology of pain
  - Targets of stimulation
  - Modes of stimulation and programming
  - Anatomical and physiological knowledge of peripheral nerves
- Interpersonal and communication skills
  - Relational
  - Technology
- Practice-based learning
  - Research
  - Lifelong learning
- Professionalism
  - Diversity and inclusion
  - Compassion
  - Accountability

CONCLUSIONS

An international multidisciplinary task force of NANS and INS education committee members created a PNS training curriculum that defines ACGME milestones for early learners, advanced learners, and practitioners. The curriculum can be adopted by training programs, hospitals, or any other entities to ascertain that appropriate standards are met by physicians performing PNS procedures. The document represents a core framework for the holistic development of the necessary skills and traits that the task force is recommending by expert consensus. We believe further work will be necessary to adjust these standards as the field of peripheral neuromodulation continues to evolve.

Authorship Statements

Hemant Kalia, Alaa Abd-Elsayed, Mark Malinowski, and Rany T. Abdallah designed and conducted the study. Hemant Kalia prepared the manuscript draft with important intellectual input from Alaa Abd-Elsayed, Mark Malinowski, Rany T. Abdallah, Adam Burkey, Eellan Sivanesan, Tariq Malik, Reda Tolba, Yashar Eshraghi, Kris Ferguson, Maricela Schnur, Ahmed Raslan, Maged Guirguis, Marc Russo, and Konstantin V. Slavin. All authors approved the final manuscript.

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COMMENTS

This work represents a "core framework" as the authors themselves put it. As a well-structured reference endorsed by an international multidisciplinary task force, we expect this work to foster education and standard quality in the field of peripheral nerve neurostimulation. Attention to the human, relational and ethical aspects is appreciated. As minor comments, one could regret that the present structure contains little about basic engineering aspects of the devices themselves, where a little more cross-discipline knowledge would have been welcome. In contrast, the health and medical organizational aspects have received much attention, but these aspects might be more difficult to generalize in different countries.

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This manuscript is a step in the right direction to improving physician training and professionalism in the field of neuromodulation. I look forward to all training programs using this manuscript as a template for peripheral nerve physician education.

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