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# Program Requirements for Residency/Fellowship Education in Neuroendovascular Surgery/Interventional Neuroradiology: A Special Report on Graduate Medical Education

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**BACKGROUND AND PURPOSE:** Neuroendovascular surgery/interventional neuroradiology is a relatively new subspecialty that has been evolving since the mid-1970s. During the past 2 decades, significant advances have been made in this field of minimally invasive therapy for the treatment of intracranial cerebral aneurysms; acute stroke therapy intervention; cerebral arteriovenous malformations; carotid cavernous sinus fistulas; head, neck, and spinal cord vascular lesions; and other complex cerebrovascular diseases. Advanced postresidency fellowship programs have now been established in North America, Europe, and Japan, specifically for training in this new subspecialty.

**METHODS:** From 1986 to the present, an ad hoc committee of senior executive committee members from the American Society of Interventional and Therapeutic Neuroradiology, the Joint Section of Cerebrovascular Neurosurgery, and the American Society of Neuroradiology met to establish, by consensus, general guidelines for training physicians in this field.

**RESULTS:** In April 1999, the Executive Committee of the Joint Section of Cerebrovascular Neurosurgery voted unanimously to endorse these training standard guidelines. In May 1999, the Executive Committee of the American Society of Interventional and Therapeutic Neuroradiology and the American Society of Neuroradiology also unanimously voted to endorse these guidelines. In June 1999, the Executive Council of the American Association of Neurological Surgeons and the Congress of Neurological Surgeons unanimously voted to endorse these guidelines.

**CONCLUSION:** The following guidelines for residency/fellowship education have now been endorsed by the parent organization of both the interventional and diagnostic neuroradiology community, as well as both senior organizations representing neurosurgery in North America. These guidelines for training should be used as a reference and guide to any institution establishing a training program in neuroendovascular surgery/interventional neuroradiology.

The field of neuroendovascular surgery/interventional neuroradiology has now become established as a separate and new subspecialty in the field of

minimally invasive therapy involving the central nervous system. Prior to this time, other names for this specialty were proposed and included “endovascular surgical neuroradiology,” “surgical neuroangiography,” and “neurointerventional radiology” (1–4). Devices specifically approved for treatment of intracranial cerebral aneurysms, cerebral arteriovenous malformations, head and neck tumors, and traumatic vascular lesions, have all gained FDA approval, with specific indications for therapy in the brain, head and neck, and spinal cord region. These devices include microcatheters, microguidewires, detachable coils, detachable balloons, particulate embolic materials, and other newer embolic agents (5–29). In addition, newer drugs and devices are on the horizon for other indications, including intraarterial thrombolytic agents for acute stroke therapy interventions, balloon angioplasty and stents for intracranial and extracranial applications, liquid tissue adhesives, vertebroplasty materials, and other medical devices ranging from

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intracranial laser devices, cerebral protection and perfusion devices, and newer embolic materials to treat complex cerebrovascular disorders (30–56).

Training programs throughout the United States, Canada, Europe, and Japan have now become established, specifically to train physicians with a background in the neurosciences, particularly in neuroradiology and vascular neurosurgery, in these newer techniques. In North America, program requirements have not yet been formally established to provide a uniform recommendation for training in this field. The potential for therapy is enormous, with stroke affecting over 700 000 individuals per year in North America alone, representing the third-leading cause of death and the leading cause of adult disability (57–65).

To ensure that these postdoctoral training programs will meet the minimally recommended standards for training in this field, an ad hoc committee of senior members from the American Society of Interventional and Therapeutic Neuroradiology (ASITN), the American Association of Neurological Surgeons and the Congress of Neurological Surgeons (AANS/CNS) Section of Cerebrovascular Neurosurgery, and the American Society of Neuroradiology (ASNR) met from 1986–1999 to establish mutually agreeable standards for training.

In April 1999, this ad hoc committee reached a final consensus for program requirements for residency and fellowship education in neuroendovascular surgery/interventional neuroradiology. In April 1999, the Executive Committee of the AANS/CNS Section of Cerebrovascular Neurosurgery voted unanimously to endorse these training standard guidelines. In May 1999, the Executive Committee of the ASNR and ASITN unanimously voted to endorse these guidelines. In June 1999, the Executive Council of the AANS/CNS unanimously voted to endorse these guidelines.

The following document is now provided as a guideline to existing and future programs that have or are planning to develop a postdoctoral residency/fellowship-training program in neuroendovascular surgery/interventional neuroradiology at their institution.

### **Definitions and Objectives**

Neuroendovascular surgery/interventional neuroradiology, is a subspecialty that uses catheter technology, radiologic imaging, and clinical expertise to diagnose and treat diseases of the central nervous system. The unique clinical and invasive nature of this subspecialty requires special training and skills. The program must include training in: 1) signs and symptoms of disorders amenable to diagnosis and treatment by neuroendovascular surgery/interventional neuroradiology techniques; 2) neurologic examinations of patients to evaluate neurologic disorders; 3) pathophysiologic mechanisms and natural history of these disorders; 4) indications and contraindications to neuroendovascular surgery/intervention-

al neuroradiology procedures; 5) clinical and technical aspects of neuroendovascular surgery/interventional neuroradiology procedures; 6) medical and surgical alternatives; 7) preoperative and postoperative management of neurovascular patients; 8) neurointensive care management; 9) fundamentals of imaging, radiation physics, and radiation biology; and 10) integration of information available from imaging studies, pertinent to the neurovascular practice. In this subspecialty, the objective of training is to give residents an organized, comprehensive, supervised, full-time educational experience in neuroendovascular surgery/interventional neuroradiology. This experience includes the management of patients with neurologic disease, the performance of neuroendovascular surgery/interventional neuroradiology procedures, and the integration of neuroendovascular surgery/interventional neuroradiology therapy into the clinical management of patients. This training program is not meant to duplicate or replace the Accreditation Council for Graduate Medical Education (ACGME)-approved program in diagnostic neuroradiology.

Training in neuroendovascular surgery/interventional neuroradiology should be conducted in an environment conducive to investigative studies of a clinical or basic science nature.

A program in neuroendovascular surgery/interventional neuroradiology must be administered by an ACGME-accredited program in either neurologic surgery or diagnostic radiology.

### **Duration of Training**

The program shall offer 1 year of graduate medical education in neuroendovascular surgery/interventional neuroradiology.

### **Program Director**

The program director must be certified by either the American Board of Radiology or the American Board of Neurological Surgery or possess equivalent qualifications. The program director must have special expertise in neuroendovascular surgery/interventional neuroradiology techniques and concentrate at least 50% of his/her practice in neuroendovascular surgery/interventional neuroradiology therapy. In addition, the program director must devote sufficient time to the program to fulfill all the responsibilities inherent in meeting its educational goals. It is desirable that the program director hold faculty positions in both neurologic surgery and radiology. The program director is responsible for establishing and maintaining the curriculum, selecting and supervising the residents, and selecting faculty members.

The director of the neuroendovascular surgery/interventional neuroradiology training program should be appointed by and be responsible to the program director of the sponsoring training program.

## Faculty

In addition to the program director, the program faculty must include at least one full-time member with expertise in neuroendovascular surgery/interventional neuroradiology techniques, who 1) is certified/board-eligible by either the American Board of Radiology or the American Board of Neurological Surgery or 2) possesses equivalent qualifications. The faculty must provide didactic teaching and direct supervision of residents' performance in clinical patient management and in procedural, interpretive, and consultative aspects of neuroendovascular surgery/interventional neuroradiology therapy. The faculty also should stimulate scholarly activities and be able to direct residents in the conduct of such activities. It is desirable that faculty members hold appointments jointly in radiology and neurologic surgery departments. Periodic evaluation of the faculty should be accomplished at least annually.

## Faculty-to-resident Ratio

The total number of residents in the program must be commensurate with the capacity of the program to offer an adequate educational experience in neuroendovascular surgery/interventional neuroradiology therapy. To ensure adequate teaching, supervision, and evaluation of a resident's academic progress, the faculty-to-resident ratio must be at least one full-time faculty person for every two residents.

## Educational Program

### *Curriculum*

The training program must offer didactic and clinical experiences that encompass the full clinical spectrum of neuroendovascular surgery/interventional neuroradiology therapy.

*Preparatory Requirements.*—The neuroendovascular resident must have completed either an ACGME-accredited residency in neurologic surgery or an ACGME-accredited fellowship in neuroradiology, or equivalent training.

Before entering the ACGME-approved year of neuroendovascular surgery/interventional neuroradiology, trainees must have spent at least 12 months in preparatory training acquiring the basic skills needed to learn neuroendovascular surgery/interventional neuroradiology.

Specifically, preparatory training must provide trainees with a "hands-on" experience in which they learn knowledge-based and procedural skills from a neuroendovascular surgery/interventional neuroradiology specialist in the following areas: 1) the use of needles, catheters, guidewires, and angiographic devices and materials; 2) the basic radiologic sciences, including radiation physics, radiation protection, and the pharmacologic characteristics of radiographic contrast materials; 3) angiography and basic image evaluation relevant to the specialty of neuroendovascular surgery/interventional neuroradiology; 4) the proper use of and indications for laboratory tests and methods that are adjunctive to neuroendovascular surgery/interventional neuroradiology procedures, such as physiologic monitoring, noninvasive neurovascular testing, and noninvasive neurovascular imaging; 5) the evaluation of patients with neurologic disease; 6) the basic and clinical neurosciences, including neuroanatomy, neurobiology, and the pathophysiology and natural history of neurologic disorders, especially cerebrovascular and neoplastic conditions; 7) the clinical aspects of patient assessment, treatment planning, and patient management related to neuroendovascular surgery/interventional neuroradiology therapy, including the fundamentals of invasive monitoring and neurointensive care management; 8) the clinical indications, risks, and limitations of neuroendovascular surgery/interventional neuroradiology procedures; and 9) the use and administration of analgesics, antibiotics, anticoagulative agents, neuroanesthetic agents, and other drugs commonly used in neuroendovascular surgery/interventional neuroradiology procedures.

This "hands-on" experience must include catheter-based diagnostic angiography. Each resident must have been involved in the performance of at least 100 catheter-based diagnostic angiographic procedures before entering neuroendovascular surgery/interventional neuroradiology training.

The director of the neuroendovascular surgery/interventional neuroradiology program is responsible for documenting that the applicant has completed the appropriate preparatory training.

*Clinical Training.*—A period of 12 continuous months must be spent in clinical neuroendovascular surgery/interventional neuroradiology training, during which the trainee has the opportunity to perform all of the following under close supervision: clinical preprocedural examinations of patients, evaluation of preliminary diagnostic studies, consultation with clinicians on other services, diagnostic and therapeutic neuroendovascular surgery/interventional neuroradiology procedures, generation of procedural reports, and participation in short-term and long-term postprocedural follow-up care, including neurointensive care. The continuity of care must be of sufficient duration to ensure that the resident is familiar with the outcome of all neuroendovascular surgery/interventional neuroradiology procedures. Residents should serve as consultants under the supervision of staff neuroendovascular surgery/interventional neuroradiology practitioners. Direct interactions of trainees with patients must be closely observed to ensure that appropriate standards of care and concern for patient welfare are strictly maintained. Communication, consultation, and coordination of care with the referring clinical staff and clinical services must be maintained and documented with appropriate notes in the medical record.

The program must provide adequate opportunity for residents to participate in and personally perform and analyze a broad spectrum of endovascular procedures in adults, children, and neonates. Spe-

cific training should be provided in the following areas:

1. Anatomic and physiologic basic knowledge
  - a) Basic knowledge in arterial angiographic anatomy of the brain, spine, spinal cord, and head and neck
  - b) Venous angiographic anatomy of the brain, spine, spinal cord, head and neck
  - c) Collateral circulation
  - d) Dangerous anastomosis
  - e) Cerebral blood flow
  - f) Autoregulation
  - g) Pharmacologic mechanisms of CNS vasculature
2. Technical aspects of neuroendovascular surgery/interventional neuroradiology, including:
  - a) Catheter and delivery systems
  - b) Embolic agents in cerebral, spinal, and head and neck embolization
  - c) Flow-controlled embolization
  - d) Complications of cerebral embolization
  - e) Flow control between the extracranial and intracranial circulation
  - f) Electrophysiologic processes
  - g) Provocative testing (pretherapeutic evaluation)
  - h) Complications of head and neck, brain, spine, and spinal cord embolization
  - i) Imaging of vascular system
3. Pharmacologic agents
  - a) Contrast materials
  - b) Provocative testing with anesthetics and barbiturates
  - c) Anticoagulants
  - d) Thrombolytics
4. Coagulation cascade
5. Brain and spinal cord arteriovenous malformation, arteriovenous fistulas of the brain, spine, spinal cord, and head and neck vascular malformations; ischemic stroke; and cerebral aneurysms
  - a) Classification
  - b) Clinical presentation
  - c) Natural history
  - d) Epidemiologic data
  - e) Hemodynamic basis
  - f) Indications for treatment
  - g) Contraindications for treatment
  - h) Therapeutic techniques
  - i) Combined therapies
6. Tumors of the head, neck, spine, and central nervous system
7. Revascularization for occlusive vascular diseases
  - a) Arteriopathies
  - b) Atherosclerotic lesions
  - c) Techniques of revascularization: balloon angioplasty, thrombolytics, and stenting
8. Embolization for epistaxis or other causes of hemorrhage
9. Invasive functional testing

## 10. Balloon test occlusions

### *Conferences and Didactic Training*

Residents must make daily rounds with the attending faculty during which patient management decisions are discussed and made. Conferences should be organized by the faculty and held to allow discussion of topics selected to broaden knowledge in the field of neuroendovascular surgery/interventional neuroradiology. Specifically, teaching conferences should embrace the scope of neuroendovascular surgery/interventional neuroradiology as outlined in Section I of these program requirements. Conferences should include journal clubs, pathology meetings, and neuroanatomy dissection courses related to neuroendovascular surgery/interventional neuroradiology.

There must be didactic and interactive conference time, including interdepartmental meetings with neurosurgeons and neuroradiologists.

Regular review of all mortality and morbidity related to the performance of neuroendovascular surgery/interventional neuroradiology procedures must be documented. Residents must participate actively in these reviews, which should be held monthly. Residents should be encouraged to attend and participate in local extramural conferences and should attend at least one national meeting or postgraduate course in neuroendovascular surgery/interventional neuroradiology therapy while in training.

### **Patient Population**

The institution's patient population must have a diversity of illnesses from which broad experience in neuroendovascular surgery/interventional neuroradiology therapy can be obtained. The case material should encompass a range of neurologic diseases, including the neurovascular. An adequate variety and number of neuroendovascular surgery/interventional neuroradiology procedures must be available for each resident. Each program must perform a minimum of at least 100 therapeutic neuroendovascular surgery/interventional neuroradiology procedures per year. These procedures include the treatment of aneurysms, brain arteriovenous malformations, arteriovenous fistulas of the brain, tumors of the central nervous system, occlusive vascular diseases, revascularization, traumatic injury, and maxillofacial vascular malformation and tumors. In addition, the program must provide adequate training and experience in invasive functional testing.

Each resident must maintain a personal case log, which the program director must certify at the completion of training.

The program director must submit the entire clinical experience of the neuroendovascular surgery/interventional neuroradiology program and the residents in the format prescribed by a residency review committee (RRC). The list of procedures must be made available to the RRC at the time of

its review of the core program and the endovascular neuroradiology training program.

The subspecialty program in neuroendovascular surgery/interventional neuroradiology must not have an adverse impact on the educational experience of neuroradiology or neurologic surgery residents in the sponsoring program.

### **Equipment and Facilities**

Modern imaging/procedure rooms and equipment must be available and must permit the performance of all neuroendovascular surgery/interventional neuroradiology procedures. Rooms in which neuroendovascular surgery/interventional neuroradiology procedures are performed should be equipped with physiologic monitoring and resuscitative equipment. The following state-of-the-art equipment should be available: an MR scanner, a CT scanner, high-resolution digital subtraction angiography equipment with live subtraction/road-mapping capability, simultaneous biplane fluoroscopy and filming (highly desirable), and sonographic equipment. Facilities for storing catheters, guidewires, contrast materials, embolic agents, and other supplies must be next to or within procedure rooms. There must be adequate space and facilities for film display and film interpretation and consultation with other clinicians.

The institutions where neuroendovascular surgery/interventional neuroradiology training is conducted must include appropriate inpatient, outpatient, emergency, and intensive care facilities for direct resident involvement in providing comprehensive neuroendovascular surgery/interventional neuroradiology care.

### **Scholarly Activity**

Graduate medical education must take place in an environment of inquiry and scholarship in which residents participate in the development of new knowledge, learn to evaluate research findings, and develop habits of inquiry as a continuing professional responsibility. The responsibility for establishing and maintaining an environment of inquiry and scholarship rests with the teaching staff. Although not all members of a teaching staff must be investigators, the staff as a whole must demonstrate broad involvement in scholarly activity. This activity should include:

1. Active participation of the teaching staff in clinical discussions, rounds, and conferences in a manner that promotes a spirit of inquiry and scholarship. Scholarship implies an in-depth understanding of basic mechanisms of normal and abnormal states and the application of current knowledge to practice.
2. Participation in journal clubs and research conferences.
3. Active participation in regional or national professional and scientific societies, particularly through presentations at the organiza-

tions' meetings and publications in their journals.

4. Participation in research, particularly in projects that are funded following peer review or result in publications or presentations at regional and national scientific meetings.
5. Guidance and technical support (eg, research design, statistical analysis) for residents involved in research.
6. Provision of support for resident participation in scholarly activities.

### **Research**

A subspecialty program should have an investigational component such that the residents may become familiar with the design, implementation, and interpretation of clinical research studies. Facilities should be made available for research activity.

### **Research Facilities**

The institution should provide laboratory facilities to support research projects pertinent to endovascular therapies.

### **Interchange with Residents in Other Specialties and Students**

Residents should be encouraged to participate in research activities with residents and staff in other related specialties. They also should be encouraged to attend and participate in clinical conferences. It is desirable that they participate in the clinical teaching of neurologic surgery, radiology residents, and medical students.

### **Duty Hours and Conditions of Work**

The program director must establish an environment that is optimal both for resident education and for patient care, including the responsibility for continuity of care, while ensuring that undue stress and fatigue among residents are avoided. It is the program director's responsibility to ensure assignment of appropriate in-hospital duty hours so that residents are not subjected to excessively difficult or prolonged working hours. It is desirable that residents' work schedules be designed so that on average, excluding exceptional patient care needs, residents have at least 1 day out of 7 free of routine responsibilities and be on call in the hospital no more often than every third night.

During the on-call hours, residents should be provided with adequate sleeping, lounge, and food facilities. There must be adequate backup so that patient care is not jeopardized during or after assigned periods of duty. Support services and systems must be such that the resident does not spend an inordinate amount of time in noneducational activities that can be discharged properly by other personnel.

## Evaluation

### Residents

Subspecialty program directors must establish clearly defined procedures for regular evaluation of residents' knowledge, skills, and overall performance, including the development of professional attitudes consistent with being a physician. The assessment must include cognitive, motor, and interpersonal skills as well as judgment.

The program director, with participation of members of the teaching staff, shall:

1. At least semiannually evaluate the knowledge, skills, and professional growth of the residents, using appropriate criteria and procedures.
2. Communicate evaluation results to the resident in a timely manner.
3. Advance residents to positions of higher responsibility only on the basis of evidence of their satisfactory progressive scholarship and professional growth.
4. Maintain a permanent record of evaluation for each resident and have it accessible to the resident and other authorized personnel.
5. Provide a written final evaluation for each resident who completes the program. The evaluation must include a review of the resident's performance during the final period of training and should verify that the resident has demonstrated sufficient professional ability to practice competently and independently. This final evaluation should be part of the resident's permanent record maintained by the institution.

### Faculty

Faculty must be evaluated at least annually to review teaching abilities, commitment to the educational program, clinical knowledge, and scholarly activities. Residents should participate in these evaluations.

### Program

The educational effectiveness of a program must be evaluated in a systematic manner. In particular, the quality of the curriculum and the extent to which the educational goals have been met by residents must be assessed by the subspecialty program director and institutional review committee on a regular basis. Written evaluations by residents should be used in this process.

## Summary

Neuroendovascular surgery/interventional neuroradiology has now become established as a viable new subspecialty involving special advanced training in newer devices, techniques, and applications that are not part of the normal training program offered in either diagnostic neuroradiology or vascular neurosurgery. For these reasons, uniform,

mutually acceptable training standards have now been developed by senior members of the neuro-radiology and neurosurgery community. As this specialty continues to grow and develop, there will be a significant impact on improving care and quality of life for patients with complex cerebrovascular diseases requiring the care of well-qualified physicians in this field.

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