

AMERICAN ACADEMY OF NEUROLOGY NEUROIMAGING FELLOWSHIP CORE CURRICULUM

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Introduction:

Neuroimaging plays a major role in the evaluation of patients with neurologic disorders. The utility of various neuroimaging studies is rapidly increasing in both clinical and research settings. Neurologists should learn about the technical aspects, indications, and interpretation of these studies. The major neuroimaging modalities include computed tomography (CT), magnetic resonance imaging (MRI), single photon emission computed tomography (SPECT), positron emission tomography (PET), carotid and transcranial ultrasound as well as interventional neuroimaging. Interventional neuroimaging procedures include catheter angiography and myelography. This curriculum could be satisfied during neurology residency training with supplementary training as needed in neurology/neuroimaging fellowships.

Goals and Objectives:

The overall intent of the program is to provide trainees with specific knowledge of clinical utility, interpretation, and standards of performance of neuroimaging studies. The program objectives include acquiring specific skills to perform/interpret neuroimaging studies. Neurology residents should develop knowledge of technical aspects, indications, and interpretation of commonly used neuroimaging studies. This knowledge will enhance patient care because neurologists will know which test is most appropriate for a given clinical situation. Defining the scope of the neuroimaging body of knowledge will facilitate the demonstration of competence on the part of neurologists. Neurologists having completed the appropriate curriculum will be eligible for accreditation or for competency examinations, such as the examinations of the American Society of Neuroimaging. For fellowships, two different objectives may be accomplished. One is to acquire expertise in all clinical and basic aspects of a given modality. This degree of expertise is generally needed to operate an imaging center independently. A second objective is to gain additional expertise in the research, indications, performance and interpretation of imaging studies of a given disorder (e.g., stroke) by working in subspecialty units.

Definitions:

The major neuroimaging modalities include computed tomography (CT), magnetic resonance imaging (MRI), single photon emission computed tomography (SPECT), positron emission tomography (PET), carotid doppler, and transcranial doppler (TCD), Interventional neuroimaging procedures include catheter angiography and myelography. In-depth neuroimaging training after residency may be obtained in neurology fellowships, both in dedicated neuroimaging fellowships listed and approved by the AAN and American Society of Neuroimaging, and as a part of clinical neurology subspecialty fellowships.

Content of the subjects to be taught:

The contents are modality-specific. In general, each modality requires training in the technical/basic aspects of imaging. This may require formal lectures given by imaging scientists and independent study. Clinical aspects include normal anatomy, artifacts, and disease states. Contents are listed by topic according to modality in the Appendix.

Prerequisites for the trainee:

Neuroimaging training is enhanced by correlation with clinical neurology, neurophysiology, neuroanatomy, neurochemistry, neuropharmacology, neuropathology, and cerebrospinal fluid findings. Therefore it is highly desired that neuroimaging trainees have obtained or are obtaining such multidisciplinary experience in a formal neurology residency-training program. The trainee should have an MD degree, or equivalent and be enrolled into clinical neurology residency or neuroimaging-related postgraduate education program (fellowship, accredited CME course).

Personnel needed for the training and qualifications:

Attending physicians competent in the training of such individuals could be derived from a number of specialties such as radiology, nuclear medicine, neurology, and neurosurgery departments. These individuals should be board-eligible or board-certified in the appropriate specialty. Subspecialty certification is desirable but not required such as that offered by the American Society of Neuroimaging or the American Board of Radiology.

Facilities/volume needed for training:

To obtain the appropriate breadth of exposure to the full spectrum of neurologic diseases, neuroimaging should be learned in both inpatient and outpatient settings. Facilities should have a sufficient volume and variety of patient material to train residents. To obtain practical experience for credentialing purposes, the suggested minimum number of studies performed and interpreted under supervision in either residency or fellowship settings should be 100 for neurosonology, 150 for CT, 250 for MRI, 150 for SPECT, 250 for PET, and 100 for catheter angiography. A teaching file of 100 representative cases in each modality, with case histories and images, should be available to the trainee, either from the training institution itself or on electronic media. Training should include daily interpretation sessions and clinical rounds with faculty.

Setup for the training:

Neurology residents should learn neuroimaging in conjunction with patient care experiences. Correlating clinical and neuroimaging findings in one's patients is the most valuable source of training during neurology residency. Residents should formulate their own interpretations and then correlate these with the official reading or the reading of the attending physician and keep a log of each image seen. Formal rotations are highly desirable where the resident spends a month dedicated to a specific modality. This may require cooperation by non-neurologic departments that should be arranged by the neurology program director. Fellows may obtain dedicated training in neuroimaging or learn neuroimaging in conjunction with a clinical neurology

subspecialty fellowship. The AAN and American Society of Neuroimaging list neuroimaging fellowships. In addition, with the assistance and cooperation of other departments, neurology departments may be able to arrange neuroimaging training for interested neurology fellows.

Methods of training:

1. Lectures
2. Individual interpretation session of 100 representative cases (a teaching file).
3. Daily self-studies of course materials and reference textbooks or papers (acquiring knowledge of basic principles, applied anatomy, pathophysiology, diagnostic criteria, and clinical applications).
4. Daily interpretation sessions
5. Weekly conferences with faculty (discussion of current cases, Q&A, differential diagnosis).
6. Individual skill assessment (performing a test under direct supervision).
7. Interpretation skill assessment (answering multiple choice questions and interpreting cases under direct supervision).

Neuroimaging is best learned as an integrated aspect of the clinical care of patients. More in-depth neuroimaging through formal preceptorships and rotations at neuroimaging centers is also desirable. Trainees should independently review the neuroimaging studies of their own patients and document their interpretation. The written evaluation should be checked against the interpretation of an attending neurologist, neuroimager, or neuroradiologist. The trainee should record the interpretations of each patient into a personal log. Formal rotations through structural or functional imaging departments should be arranged for the trainee. Here the trainee should receive formal instruction and should do reading about the technical aspects of imaging. This may require separate one-month rotations in structural imaging, functional imaging/nuclear neurology, neurosonology, and interventional neuroimaging. Correlation of neuroimaging data with clinical, anatomic, and pathologic data is recommended. Thus, the trainee should participate in neurology, neurosurgery, neuropathology, and neuroimaging/neuroradiology conferences, especially those with multidisciplinary participation. The trainee should log attendance of these conferences. For fellowships, clinical fellows should learn neuroimaging along with patient care activities. Dedicated neuroimaging fellowships and preceptorships are available for neurology residents to gain in-depth knowledge to perform independent operation of neuroimaging centers.

Timetable for training:

Neuroimaging should be an integral part of a three-year neurology residency. If the neurology training program follows the AAN Neuroimaging Training Guidelines and the curriculum specified in this document, graduating residents will generally have enough knowledge and experience to interpret images independently. Additional experience in fellowship training is highly desirable to become competent in directing a neuroimaging laboratory and may require a one to two year fellowship. The length of a fellowship should be ideally one to two years, but if a trainee can document extensive neuroimaging training during residency, a shorter fellowship or preceptorship may suffice in accordance with the AAN credentialing guidelines.

Methods of evaluation of trainee:

On-going evaluation:

- Performance and interpretation skills assessment by the training personnel (daily or weekly).
- Interpretation skills assessment using multiple-choice questions and case reviews (weekly or monthly).

Final evaluation of proficiency in interpretation:

- American Society of Neuroimaging certification examinations.

Individual attendings should provide written evaluation of trainees who have completed formal rotations in neuroimaging. The neurology residency in-service training examination (RITE) given by the American Academy of Neurology has a major component dedicated to neuroimaging. Performance on this section can give the trainee an annual guide of performance. After fellowship and residency training, certification examinations given by the American Society of Neuroimaging allow demonstration of competency in MRI/CT, Neurosonology, and, in the future, functional imaging.

Methods of evaluation of the training process:

The neurology residency in-service training examination (RITE) given by the American Academy of Neurology has a major component dedicated to neuroimaging. Performance on this section of a group of trainees can give the program director a method of evaluating the training process.

Mechanisms for feedback:

1. Evaluation forms required for a CME activity filled out by a trainee upon course completion.
2. Discussion of multiple-choice questions answered incorrectly.
3. Repeat assessment of hands-on skills under direct supervision and demonstration.

Trainees should be encouraged to evaluate their neuroimaging exposure during residency training and should evaluate their more formal neuroimaging rotations.

Methods of constantly upgrading knowledge/CME:

During the training course, rotation, or fellowship, trainees are required to perform self-studies of selected textbooks and papers, and participate in weekly discussions with faculty of current cases. Upon completion of the course, rotation, or fellowship, trainees are expected to prepare for the American Society of Neuroimaging certification examination, if necessary. Knowledge should be constantly upgraded by attending of conferences - both institutional and national conferences. Multi-disciplinary imaging, neurologic, and neuropathologic local conferences are especially valuable. National conferences with strong neuroimaging components such as the American Academy of Neurology, American Society of Neuroimaging, and American Society of Neuroradiology offer coursework and scientific sessions with CME credits. After initial training, the neurologist who interprets and/or performs neuroimaging studies should participate annually

in category I, ACCME-approved CME in the appropriate discipline. At least 25 hours every 5 years is recommended.

List of references/resources:

1. An excellent summary of training of neurologists in neuroimaging is provided in the following article:
 - Masdeu JC for the AAN Workshop on Neuroimaging Training. *Neurology* 1997;49:1738-1740.
2. The AAN has published official AAN guidelines for credentialing of neurologists in neuroimaging:
 - Gomez C, Kinkel P, Masdeu J, McKinney W, Polachini I, Tegeler C, Yadav S. American Academy of Neurology guidelines for credentialing in neuroimaging - report from the task force on updating guidelines for credentialing in neuroimaging. *Neurology* 1998;49:1734-1737
3. Certification examinations and courses offered by the American Society of Neuroimaging:

American Society of Neuroimaging
5841 Cedar Lake Rd., suite #108
Minneapolis, MN 55416
612-545-6291

Appendix: Modality specific topics and suggested reading:

1. MRI/CT:

A. TECHNICAL ASPECTS OF MRI/CT:

- X-ray production
- Collimation
- Interaction of X-ray in tissue
- Electricity and nuclear magnetism
- Radiofrequency pulse sequences
- MRI signals and parameters
- Fourier transforms
- MRI and CT hardware and safety
- Conventional spin-echo technique
- Gradient-echo technique
- Fast spin-echo and fast imaging
- Echo planar imaging
- MRA
- MRI and CT Contrast agents

- MRI and CT artifacts

Suggested reading:

1. Bushong SC. Magnetic Resonance Imaging: Physical and biological principles. Mosby, St. Louis, 1996
2. Bradley WG, Bydder GM, eds. Advanced MR imaging techniques. St. Louis: Mosby, 1997
3. Westbrook and Kaut, MRI in Practice. Blackwell, London, 1993
4. Kinkel WR, Bates VE. Computed Tomography in Clinical Neurology. In: Clinical Neurology, Joynt RJ, Griggs RC (editors), Lippincott-Raven, Philadelphia, 1994;1(4):1-134.
5. Lee SH, Rao KCVG. Cranial Computed Tomography. McGraw-Hill, New York, 1993.
6. Orrison WW. Neuroimaging. WB Saunders, Philadelphia, 2000

B. CLINICAL ASPECTS OF MRI/CT NEUROIMAGING:

1. Primary Tumors/Masses/Cysts
 - Astro-Glial (Glioma)
 - Astrocytoma
 - Choroid plexus papilloma
 - Ependymoma/Subependymoma
 - Glioblastoma multiforme
 - Gliomatosis cerebri
 - Oligodendroglioma
 - Germ Cell
 - Germinoma
 - Teratoma
 - Maldevelopmental
 - Craniopharyngioma
 - Lipoma
 - Meningeal
 - Meningioma
 - Mesenchymal and Lymphoreticular
 - Hemangioblastoma
 - Hemangiopericytoma
 - Lymphoma
 - Neuronal Origin
 - Ganglioglioma
 - Hamartoma
 - Neurocytoma
 - PNET
 - Esthesioneuroblastoma
 - Medulloblastoma
 - Peripheral Nervous System
 - Neurofibroma
 - Schwannoma (neuroma)
 - Regional Neoplasms
 - Pineoblastoma

- Pineocytoma
 - Pituitary adenoma
 - Non-neoplastic Cysts
 - Arachnoid (leptomeningeal) cyst
 - Colloid cyst
 - Dermoid
 - Epidermoid
 - Neuroepithelial (neuroglial) cyst
 - Pineal cyst
 - Rathke's cleft
 - Spinal tumors
 - Intramedullary
 - Extramedullary/intradural
 - Extramedullary/extradural
2. Cerebrovascular Diseases
- Infarction
 - Thromboembolism
 - Watershed Infarction
 - Lacunar syndromes
 - Venous thrombosis
 - Arterial Dissection
 - MR Angiography
 - Advanced MRI Techniques
 - Paraventricular and Subcortical White Matter Disease
3. Vascular Lesions/Malformations
- Aneurysms
 - Saccular, Giant
 - Dolichoectasia
 - Vascular malformations
 - Arteriovenous malformation
 - Cavernous Angioma
 - Capillary Telangiectasia
 - Venous Angioma
4. Infectious/Granulomatous Diseases
- Pyogenic/Bacterial
 - Viral
 - Fungal
 - Parasitic
 - Sarcoidosis
 - Prion-associated
 - Myelitis
5. Hemorrhage/Trauma

- Intraparenchymal Hemorrhage
 - Subdural Hemorrhage
 - Subarachnoid Hemorrhage
 - Intratumoral and Secondary Hemorrhage
 - Cerebral contusions/Traumatic Brain injury
 - Spinal Hemorrhage/Spinal Trauma
6. Toxic/Metabolic Diseases
- Chemotherapeutic/Immunosuppressive agents
 - Ethanol-related:
 - Degeneration/atrophy
 - Wernicke's encephalopathy
 - Hallervorden-Spatz disease
 - Hepatic failure
 - Mitochondrial disorders
 - Radiation injury
 - Toxin exposure
 - Wilson's disease
7. Degenerative Diseases
- Aging
 - Alzheimer's disease
 - Amyotrophic lateral sclerosis
 - Friedreich's ataxia
 - Huntington's disease
 - Parkinsonian states
 - Pick's disease
 - Wallerian degeneration
 - Spinal degenerative diseases
 - Disc herniation
 - Spinal stenosis
8. Seizures/Epilepsy
- Mesial Temporal Lobe Sclerosis
9. Hydrocephalus/CSF Disorders
- Benign Intracranial Hypertension
 - Hydrocephalus
 - Noncommunicating
 - Communicating
 - Intracranial Hypotension
10. Neurocutaneous Syndromes
- Neurofibromatosis
 - Sturge-Weber Syndrome

- Tuberos scleriosis
 - Von Hippel-Lindau and Hemangioblastomas
11. Demyelinating/Inflammatory Diseases
- Multiple Sclerosis
 - Acute Disseminated Encephalomyelitis
 - Central Pontine Myelinolysis
 - Myelitis
12. Metastatic Diseases
- Brain/spinal parenchymal metastases.
 - Calvarial and meningeal metastases
 - Extra-axial spinal metastases
13. Congenital Anomalies/Developmental Disorders
- Brain malformations
 - Spinal cord and spinal canal malformations
14. Miscellaneous
- Normal tomographic imaging anatomy of head and spine
 - Imaging of head and neck diseases relevant to neurology
 - Brain death

Suggested reading:

MRI (clinical)

- Bakshi R, Ketonen L. Brain MRI in Clinical Neurology. In: Clinical Neurology, Joynt RJ, Griggs RC (editors), Philadelphia: Lippincott Williams &Wilkins, 2001 (in press).
- Greenberg JO. Neuroimaging: A Companion to Adams and Victor's Principles of Neurology. 2nd ed. New York: McGraw-Hill, Inc., 1999
- Orrison WW. Neuroimaging. WB Saunders, Philadelphia, 2000
- Osborn AG. Diagnostic Neuroradiology. St. Louis: Mosby-Year Book, Inc., 1994
- Runge VM, Brack MA, Garneau RA, Kirsch JE. Magnetic Resonance Imaging of the Brain. Philadelphia: J.B. Lippincott Company, 1994
- Runge VM, et al. Magnetic Resonance Imaging of the Spine. Philadelphia: J.B. Lippincott Company, 1995
- Yock, Magnetic Resonance Imaging of CNS Disease: A Teaching File. Mosby-Year Book, Inc., 1995

CT (clinical)

- Greenberg JO. Neuroimaging: A Companion to Adams and Victor's Principles of Neurology. 2nd ed. New York: McGraw-Hill, Inc., 1999
- Osborn AG. Diagnostic Neuroradiology. St. Louis: Mosby-Year Book, Inc., 1994
- Woodruff WW. Fundamentals of Neuroimaging. Philadelphia: W.B. Saunders Company, 1993
- Yock, Computed Tomography of CNS Disease: A Teaching File. Mosby-Year Book, Inc.

2. NUCLEAR NEUROLOGY (SPECT/PET):

A. TECHNICAL ASPECTS OF NUCLEAR NEUROLOGY:

- Physics and instrumentation
- Radiation Biology
- Radiation Dosimetry
- Radiation Safety
- Mathematics and Statistics
- Radionuclide Chemistry and Radiopharmacy
- Image Generation and Display
- SPECT Principles
- PET Principles

Suggested reading:

- Sorenson & Phelps, Physics in Nuclear Medicine, 2nd Edition, 1987
- Early and Sodee, Principles and Practice of Nuclear Medicine, 2nd Edition, 1995
- Fundamentals of Nuclear Medicine. New York: The Society of Nuclear Medicine, Inc., 1988:
- English and Brown, SPECT: A Primer. New York: Society of Nuclear Medicine, 1990

B. CLINICAL ASPECTS OF NUCLEAR NEUROLOGY:

1. Tumors/Masses/Cysts
 - Grading of primary and metastatic neoplasms
 - Differentiation of radiation injury from tumor recurrence
2. Cerebrovascular Diseases
 - Assessment of cerebrovascular reserve
 - Diagnosis of ischemia and infarction
 - Determination of stroke subtypes
 - Vasospasm following SAH
 - Prognosis/recovery from stroke
3. Infectious/Granulomatous Diseases
 - Differentiation of abscess versus neoplasm
 - Diagnosis of viral encephalitis
4. Hemorrhage/Trauma
 - Altered brain metabolism or blood flow in posttraumatic encephalopathy
5. Toxic/Metabolic Diseases
 - Cerebral radiation injury versus recurrent neoplasm
6. Degenerative Diseases/Aging
 - Aging
 - Alzheimer's disease
 - Huntington's disease

- Parkinsonian states
 - Pick's disease
7. Seizures/Epilepsy
 - Ictal localization
 - Interictal localization
 - Mesial temporal sclerosis
 8. Hydrocephalus/CSF Disorders
 - Brain metabolism/perfusion pattern in hydrocephalic states including NPH
 - Use of cisternography to diagnose hydrocephalus and CSF leakage
 9. Psychiatric Disorders
 - Mood disorders
 - Schizophrenia
 - Obsessive-compulsive disorders
 10. Miscellaneous
 - Normal anatomy and physiology
 - Ligand tracer studies
 - Brain death

Suggested reading:

- Masdeu JC et al. Brain single photon emission computed tomography. *Neurology* 1994;44:1970-1977.
- Mazziotta JC, Gillman S (eds). *Clinical Brain Imaging: Principles and Applications*. Philadelphia: FA Davis, 1992.
- Phelps ME, Mazziotta JC, Schelbert HR (eds). *Positron Emission Tomography and Autoradiography*. New York: Raven Press, 1986.

3. NEUROSONOLOGY (CAROTID DOPPLER/TCD):

1. Basic principles of Doppler physics
2. Continuous wave (CW) Doppler principles
3. Pulsed wave (PW) Doppler principles
4. Physical principles of brightness-modulated (B-mode) real time ultrasound imaging
5. Principles of color Doppler imaging
6. Principles of color velocity imaging
7. Basic principles of emboli detection
8. Ultrasound artifacts
9. Ultrasound equipment/hardware
10. Ultrasound bioeffects and safety
11. Cerebrovascular hemodynamics and anatomy
12. Pulsed Doppler techniques
13. Spectral analysis

14. Pulsed Doppler interpretation principles
15. Clinical applications of duplex sonography
16. Plaque morphology
17. Duplex sonography interpretation/criteria
18. Color flow imaging techniques
19. Color flow clinical applications
20. Interpretation extracranial and transcranial color flow studies
21. Power Doppler techniques
22. Power Doppler applications
23. Techniques of adult transcranial Doppler
24. Techniques of transcranial Doppler in children with sickle cell disease
25. Interpretation of transcranial Doppler
26. Applications of transcranial Doppler

Reference Textbooks

1. Tegeler CH, Babikian VL, Gomez CR. Neurosonology. St Louis: Mosby, 1996.
2. Kremkau FW. Diagnostic Ultrasound: Principles, Instruments, and Exercises. Philadelphia: WB Saunders 1994.
3. Edelman SK. Understanding Ultrasound Physics: Fundamentals and Exam Review. Houston: D. Armstrong Co, Inc 1992.
4. Hennerici M, Neuerburg-Heusler D. Vascular Diagnosis With Ultrasound: Clinical References with Case Studies. Stuttgart: Thieme 1998.
5. Babikian VL, Wechsler LR (eds). Transcranial Doppler Sonography. St Louis: Mosby 1993.

Other Textbooks

1. Caplan LR, Shifrin EG, Nicolaidis AN, Moore WS (eds). Cerebrovascular ischemia: investigation and management. London: Med-Orion, 1996.
2. Toole JF. Cerebrovascular Disorders. 5th edition. New York: Lippincott Williams and Wilkins Philadelphia 1999.
3. Von Reutern GM, von Budingen HJ. Ultrasound Diagnosis of Cerebrovascular Disease: Doppler Sonography of the Extra- and Intracranial Arteries, Duplex Scanning. Stuttgart: Georg Thieme: 1993.

Selected Papers

1. Aaslid R, Markwalder TM, Nornes H. Noninvasive transcranial Doppler ultrasound recording of flow velocity in basal cerebral arteries. J Neurosurg 1982;57:769-774.
2. Adams RJ, McKie V, Nichols F, et al. The use of transcranial ultrasonography to predict stroke in sickle cell disease. N Engl J Med 1992;326:605-610.
3. Adams RJ, McKie VC, Carl EM, et al. Long-term stroke risk in children with sickle cell disease screened with transcranial Doppler. Ann Neurol 1997;42:699-704.
4. Adams RJ, McKie VC, Hsu L, Files B, Vichinsky E, Pegelow C, Abboud M, Callagher D, Kutlar A, Nichols FT, Bonds DR, Brambilla D. Prevention of a first stroke by transfusions in children with sickle cell anemia and abnormal results on transcranial Doppler ultrasonography. N Engl J Med 1998;339:5-11.
5. Alexandrov AV. Transcranial Doppler sonography: principles, examination technique, normal values, and waveform patterns. Vascular Ultrasound Today 1998;3(10):141-160.

6. Alexandrov AV, Brodie DS, McLean A, Hamilton P, Murphy J, Burns P. Correlation of peak systolic velocity and angiographic measurement of carotid stenosis revisited. *Stroke* 1997;28:339-342.
7. Babikian V, Sloan MA, Tegeler CH, DeWitt LD, Fayad PB, Feldmann E, Gomez CR. Transcranial Doppler validation pilot study. *J Neuroimag* 1993;3:242-249.
8. De Bray JM, Glatt B. Quantitation of atheromatous stenosis in the extracranial internal carotid artery. *Cerebrovasc Dis* 1995;5:414-426.
9. Hunink MGM, Polak JF, Barlan MM, O'Leary DH. Detection and quantitation of carotid artery stenosis: efficacy of various Doppler velocity parameters. *Am J Roentgenol* 1993;160:619-625.
10. Moneta GL, Edwards JM, Chitwood RW, Taylor LM, Lee RW, Cummings GA, Porter JM. Correlation of North American Symptomatic Carotid Endarterectomy Trial (NASCET) angiographic definition of 70 to 99% internal carotid artery stenosis with duplex scanning. *J Vasc Surg* 1993;17:152-159.
11. Spencer MP, Reid JM. Quantitation of carotid stenosis with continuous wave (CW) Doppler ultrasound. *Stroke* 1979;10:793-798.
12. Wilterdink JL, Feldmann E, Furie KL, Bragoni M, Benavides JG. Transcranial Doppler ultrasound battery reliably identifies severe internal carotid artery stenosis. *Stroke* 1997;28:133-136.

4. INTERVENTIONAL NEUROIMAGING (ANGIOGRAPHY):

A. Technical Aspects:

1. Radiologic Principles
 - a. Basic Principles of Fluoroscopy
 - b. Fluoroscopic and Angiographic Equipment
 - c. Principles of Digital Subtraction
 - d. Principles of Radiation Safety
 - e. Contrast Agents: Utilization and Safety
2. Endovascular Techniques
 - a. Preprocedural Preparation of Patients
 - b. Principles of Endovascular Access: Arterial and Venous
 - c. Manifolds and Air-Free Systems
 - d. Intravascular Pressure Recordings
 - e. Catheter Types and Materials
 - f. Catheter Techniques
 - g. Guidewire technology
 - h. Guidewire Manipulation and Safety
 - i. Endovascular Navigation
 - j. Balloon Occlusion Testing
 - k. Wada Testing
 - l. Complications of Catheterization: Diagnosis and Management
 - m. Post-Procedural Management of Access Site

3. Angiographic Techniques

- a. Angiographic Imaging of the Cerebral Vessels
- b. Views and Projections
- c. Roadmapping Techniques
- d. Digital Parenchymography
- e. Dynamic Aspects of Angiography

B. Clinical Aspects:

- 1. General Aspects of Angiography
 - a. Principles of Angiography Interpretation
 - b. Normal Arterial Anatomy
 - c. Normal Venous Anatomy
 - d. Congenital Anatomic Variants
 - e. Congenital Anomalies
- 2. Cerebrovascular Disorders
 - a. Occlusive Pathology
 - b. Defining Degree of Stenosis
 - c. Emergency Angiography of Ischemic Stroke
 - d. Atherosclerotic vs. Non-Atherosclerotic Pathology
 - e. Traumatic Injuries and Dissection
 - f. Fibromuscular Dysplasia
 - g. Moya-Moya
 - h. Cerebral Aneurysms
 - i. Cerebral Vasospasm
 - j. Arteriovenous Malformations
 - k. Venous Angiomas
- 3. Neoplastic Conditions
 - a. Typical Angiographic Findings in Brain Tumors
 - b. Vascularity of Brain Tumors
- 4. Inflammatory Conditions
 - a. Cerebral Vasculitis
 - b. Meningeal Infections
- C. Interventional Procedures
 - a. Balloon Angioplasty
 - b. Stenting
 - c. Coiling of Aneurysms
 - d. Embolization: AVMs
 - e. Embolization: Tumors
 - f. Intra-arterial Thrombolysis

D. Suggested Reading

Connors JJ, Wojak JC. *Interventional Neuroradiology: Strategies and Practical Techniques*. WB Saunders, Philadelphia, 1999