NEURORADIOLOGY RESIDENT TRAINING OBJECTIVES

Residents may rotate through the Division of Neuroradiology with the general radiology department during each of their four years of training. The timing and structure of neuroradiology rotations will vary among training programs and therefore it is not possible to provide program-specific goals for each level of training. It is expected that residents will progressively develop their abilities to perform and interpret imaging studies of the central nervous system. Residents will be taught the practical clinical skills necessary to interpret neuroradiologic studies, including plain radiographs, computed tomography (CT) scans, magnetic resonance (MR) imaging and ultrasound examinations of: 1) brain and skull; 2) head and neck; and 3) spinal cord and vertebral column. They will be instructed in the performance and interpretation of invasive procedures including cerebral angiography, myelography/spinal canal puncture, and image-guided biopsies of the spine and skull base.

The residents will be introduced to the science that underlies clinical neuroradiology, in particular neuroanatomy and neuropathology. They will learn the physical principles of CT, MR, plain radiography, and digital angiography. They will learn the relative value of each modality, enabling them to choose the appropriate study and the appropriate protocol for each patient.

It is expected that residents will participate in the performance of the full range of examinations done by the division. They will obtain consents and perform intravenous injections of contrast. The residents will learn the indications and contraindications for contrast administration and to recognize and treat adverse reactions. Residents will protocol and monitor CT and MR exams after they have demonstrated a sufficient level of knowledge and experience to perform these tasks. Residents will aid in the performance of invasive procedures including angiograms, myelograms, spinal taps and other minimally invasive procedures such as image-guided vertebral and skull base biopsies. They will learn to explain these procedures to patients and their families, obtain pre-procedure consent and write pre- and post-procedure orders. They will learn techniques of arterial puncture, catheter choice and manipulation, and contrast dosage. They will learn to recognize and treat complications of these invasive procedures.

The residents will learn to dictate concise and appropriate radiographic reports and to serve as consultants to referring physicians.

Knowledge-Based Objectives

I) Anatomy:

A. Intracranial
Early rotations: Become familiar with the appearance of major intracranial structures as visualized on axial CT and MR scans. Be able to identify all major structures and components of the brain, ventricles and subarachnoid (cisterns) space.

**Middle rotations:** Develop more detailed knowledge of intracranial anatomy as displayed on multi-planar images.

**Late rotations:** Be able to identify subdivisions and fine anatomic details of the brain, the ventricles, subarachnoid space, vascular structures, sella turcica, and cranial nerves.

B. Head and Neck

Early rotations: Learn the anatomy of the calvarium, skull base and soft tissues of the neck as displayed on plain radiographs.

Middle rotations: Become familiar with the complex anatomy of the orbit, petrous bone, skull base and soft tissues of the neck as displayed on CT and MR in multiple planes.

Late rotations: Be able to identify all key structures and have knowledge of established anatomic classification systems for each area.

C. Spine

Early rotations: Become familiar with the normal appearance of the spine on plain radiographs and axial CT scans. Be able to assess spinal alignment and be able to identify all osseous components of the spinal canal by completion of first rotation.

Middle rotations: Learn to identify normal osseous structures, intervertebral discs, support ligaments and the contents of the thecal sac (spinal cord and nerve roots) on CT, MR, and myelography.

Late rotations: Be able to identify all normal structures on multi-planar images.

D. Vascular

Early rotations: Learn to identify the large vessels of the cervical and intracranial regions (carotid, vertebral and basilar arteries, jugular veins and dural venous sinuses) as they appear on routine CT and MR studies of the head and neck.

Middle rotations: Learn to identify these same structures and their key branches on catheter, MR angiography and sonography (extra-cranial vessels).

Late rotations: Be able to identify all important extra- and intra-cranial arteries (secondary and tertiary branches of the carotid and basilar arteries) and veins (cortical and deep cerebral veins) on all imaging modalities.
II) Pathology and Pathophysiology:

Learn the basic pathology and pathophysiology of diseases of the brain, spine, and head and neck.

Early rotations: Become familiar with the common traumatic, ischemic and inflammatory conditions of the brain, skull base, neck and spine.

Middle rotations: Learn the pathophysiology of rapidly evolving processes, in particular cerebral infarction and inflammation.
Late rotations: Learn the pathologic and histologic features that allow for characterization of neoplastic lesions and learn the accepted classification system (WHO) of tumors.

III) Imaging Technology:

A. CT

Early rotations: Become familiar with imaging parameters, including window and level settings, slice thickness, inter-slice gap, and helical imaging parameters, and image reconstruction algorithms (e.g., soft tissue and bone). Learn the typical CT density of commonly occurring processes such as edema, air, calcium, blood and fat.
Middle rotations: Learn the appropriate imaging protocols used for assessment of the full range of lesions encountered in Neuroradiology.
Late rotations: Learn the principles and utility of multi-planar reconstruction and CT angiography.

B. MR

Early rotations: Learn the basic physical principles of MR. Be able to identify commonly used pulse sequences and become familiar with standard MR protocols. Learn the intensity of normal tissues on routine pulse sequences.
Middle rotations: Learn the clinical utility of each routine pulse sequence. Learn how to combine pulse sequences to produce effective and efficient imaging protocols for common disease processes. Learn the intensity encountered in hemorrhage, fat and calcium.
Late rotations: Learn to protocol complex clinical cases. Become familiar with more advanced imaging techniques such as MR angiography, fat suppression, diffusion/perfusion, activation studies, and MR spectroscopy.

IV) Image interpretation:
A. Intracranial

**Early rotations:** Develop skills in the interpretation of plain films of the skull. Learn to interpret CT scans with a particular emphasis on studies performed on individuals presenting with acute or emergent clinical abnormalities (infarction, spontaneous intracranial hemorrhage, aneurysmal subarachnoid hemorrhage, traumatic brain injury, infection, hydrocephalus, and brain herniation).

**Middle rotations:** Learn the CT and MR findings of hyperacute infarction (including findings on diffusion weighted MRI). Learn to identify and characterize focal lesions and diffuse processes and be able to provide a short differential diagnosis for the potential causes of these processes.

**Late rotations:** Develop the ability to use imaging findings to differentiate different types of focal intracranial lesions (neoplastic, inflammatory, vascular) based on anatomic location (e.g., intra- vs. extra-axial), contour, intensity and enhancement pattern. Learn to identify and differentiate diffuse intracranial abnormalities (e.g., hydrocephalus and atrophy). Lean to recognize treatment-related findings (e.g., post-surgical and post-radiation). Become familiar with the utility of new MR sequences (diffusion/perfusion, functional MR and MR spectroscopy).

B. Head and Neck

**Early rotations:** Learn to identify common acute emergent lesions. Become familiar with the plain film and CT appearance of (a) traumatic (fractures and soft tissue injuries) of the orbit, skull base, face and petrous bones and (b) inflammatory (sinusitis, orbital cellulitis, otitis, mastoiditis, cervical adenitis and abscess) lesions. Learn to identify airway compromise and obstruction.

**Middle rotations:** Expand knowledge of the appearance of traumatic lesions on CT. Be able to characterize fractures based on clinical classification systems (e.g., Le Fort fractures). Learn to identify neoplastic masses arising in the orbit, skull base, petrous bone and soft tissues of the neck. Be able to use standard anatomic classification schemes to accurately describe the location of mass lesions.

**Late rotations:** Learn the differential diagnosis of mass lesions. Understand and be able to identify patterns of disease spread within and between areas of the head and neck (e.g., perineural and nodal spread). Learn to recognize treatment-related findings (e.g., post-surgical and post-radiation). Learn to identify pathologic processes on multi-planar MR studies.

C. Spine

**Early rotations:** Learn the appearance of traumatic lesions on plain radiographs with an emphasis on findings of spinal instability. Become familiar with the CT and MRI findings of degenerative disease.

**Middle rotations:** Learn the CT, MRI and myelographic findings of spinal cord compression. Become familiar with findings on all three modalities that allow for
accurate spatial localization of spinal lesions (extra-dural, intra-dural, extra-medullary, and intra-medullary). Be able to identify and differentiate discogenic and arthritic degenerative diseases. Learn to identify and characterize traumatic lesions (e.g., stable vs. unstable, mechanism of injury) using routine and reformatted CT scans.

Late rotations: Learn the imaging findings that allow for the differentiation of inflammatory and neoplastic lesions. Learn the imaging features of intraspinal processes, including syringomyelia, arachnoiditis and spinal dysraphism. Learn to recognize post-surgical and other treatment-related findings.

D.    Vascular

Early rotations: Learn to recognize the angiographic features of extra- and intracranial atherosclerosis utilizing catheter angiography, MRA and sonography.

Middle rotations: Learn the indications, limitations, risks and benefits for each technique used for visualization of vascular anatomy and pathology. Learn the angiographic appearance of aneurysms, vascular malformations, occlusive diseases and neoplasms.

Late rotations: Learn the indications, risks and benefits for neurointerventional procedures including embolization, angioplasty and stenting.

E.    Pediatrics

Early rotations: Learn to recognize the normal appearance of the brain (e.g., myelination), spine (e.g., ossification) and head and neck (e.g., sinus development) encountered in the newborn, infant, and child. Be able to identify the features of hydrocephalus on CT and MR.

Middle rotations: Learn to recognize congenital lesions and malformations. Be able to detect disorders of the perinatal period on sonography, CT, and MR.

Late rotations: Be able to identify and differentiate acquired lesions (traumatic, ischemic, inflammatory and neoplastic) of the newborn, infant, child, and adolescent.

Technical and Non-interpretive Objectives:

1) Patient care

Early rotations: Learn to obtain informed consent, by explaining the risks and benefits of contrast-enhanced CT/MR to the patient. Learn appropriate techniques for injection of contrast (including use of power injectors). Learn to recognize and treat contrast reactions.
Middle rotations: Learn to obtain informed consent for invasive procedures including angiography, spinal punctures/myelography and image-guided biopsies. Be able to explain the risks, benefits and complications of these procedures to patients and their families.
Late rotations: Learn to write pre- and post-procedure orders. Be able to evaluate the clinical status of patients prior to, during and after the procedure. Learn to recognize complications of these procedures and to initiate appropriate treatment.

2) Catheter angiography

Early rotations: Observe the performance of diagnostic angiograms of the cervical and cranial vessels.
Middle rotations: Learn the basic techniques of arterial puncture and catheter manipulation. Assist senior residents, fellows, and attendings in the performance of angiograms.
Late rotations: Learn to safely position catheters within extra-cranial vessels. Learn the appropriate dose of contrast material for angiography of each vessel. Learn the angiographic protocols for the evaluation of a variety of disease processes (e.g., aneurysmal subarachnoid hemorrhage). Be able to perform diagnostic angiography under the supervision of an attending radiologist.

3) Image-guided biopsies and spinal canal

Early rotations: Learn to perform fluoroscopically guided punctures of the lumbar spinal canal for the purpose of myelography, spinal fluid collection, and intrathecal injection of medications.
Middle rotations: Assist senior residents, fellows, and attendings in the performance of image-guided biopsies. Be able to perform myelography under the supervision of an attending radiologist.
Late rotations: Be able to perform image-guided biopsies of the spine and skull base under the supervision of an attending radiologist.

Decision making/Value judgment skills

Early rotations: Learn the appropriate format for dictation of reports of neuroradiologic imaging studies. Provide consultations for house staff and referring physicians on imaging studies after reviewing the exam with an attending radiologist.

Middle rotations: Protocol and monitor CT studies. Be able to modify imaging protocols based on identification of unexpected or novel findings. Provide
provisional interpretations and consultations of plain radiographs, CT scans and MR scans performed in the Emergency Department. Learn the clinical and imaging indications for acute stroke intervention including intra-arterial thrombolysis.

Late rotations: Direct the choice of imaging modality and protocol neuroradiologic studies. Act as a consultant to junior radiology residents. Learn to identify those cases that require the additional expertise in assessment of imaging studies.