NEURORADIOLOGY CORE CURRICULUM

I. Intracranial

A. CNS Infections

1) *Imaging strategies*
2) Pyogenic infections
   - Meningitis
   - Cerebritis
   - Abscess
   - Subdural and Epidural Empyema (abscess)
3) Encephalitis
   - Herpes (HSVI&II)
   - Sporadic and epidemic
   - Lyme
   - Chronic – Subacute Sclerosing Panencephalitis (SSPE)
   - Prion disease - (Creutzfeldt Jakob)
3) Granulomatous infections
   - Meningeal (basal) - hydrocephalus
   - Parenchymal - granuloma and abscess
   - Vasculitis – infarction
   - Etiology – TB, Sarcoid, Fungi
4) Parasitic infections
   - Cysticercosis
   - Hydatid disease
5) Infections in the immunocompromised host
   - HIV
   - PML
   - CMV
   - Toxoplasmosis
   - Cryptococcus
   - Aspergillosis
   - Other opportunistic organisms (e.g. Candida and Nocardia)
   - Lymphoproliferative disease (complication of immunocompromise)

B. White Matter Disease

1) Multiple sclerosis
2) Acute Disseminated Encephalomyelitis (ADEM)
3) Osmotic myelinolysis (Central pontine myelinolysis)
4) Small vessel ischemic disease, hypertension, vascular disease
5) White matter changes in the elderly
6) Radiation/chemotherapy changes
8) Infection – Viral encephalitis (see above)
7) Trauma (axonal injuries)
8) Dysmyelinating Disorders
   - Adrenoleukodystrophy

Krabbe
Metachromatic Leukodystrophy (MLD)
Alexander
Canavan

C. Trauma

1) Imaging strategies: CT/MR/Skull films
2) Mechanisms
3) Primary vs. Secondary
4) Focal lesions
   Cortical contusions
   Diffuse axonal injury (DAI) - shearing
   Subarachnoid hemorrhage (SAH)
   Subdural hemorrhage (SDH)
   Epidural hemorrhage (EDH)
   Parenchymal hemorrhage with differentials
5) Ages of hemorrhage by CT/MR
6) Intraventricular hemorrhage
7) Diffuse cerebral swelling & edema
8) Herniation syndromes
9) Skull fractures: types, complications
10) Vascular injuries - dissection, pseudoaneurysm
    penetrating injuries, lacerations, complications
11) Non-accidental trauma
12) Superficial and soft tissue injuries (e.g. Cephalohematoma)

D. Neoplasms and other masses

1) Tumor classification by histology
   Glial - Diffuse
      Astrocytoma
      Glioblastome Multiforme (GBM)
      Oligodendroglioma
      Ependymoma
      Subependymoma
   Glial – Focal
      Pilocytic astrocytoma
      Giant Cell astrocytoma
      Pleomorphic xanthoastrocytoma (PXA)
   Neuro-glial
      Central neurocytoma
      Ganglioglioma/ Ganglioneuroma
      Primitive Neuroectodermal tumor (PNET)
      Dysembryoplasitic Neuroectodermal tumor (DNET)
   Lymphoma
      Primary or secondary
   Metastases
   Meningioma

- Choroid plexus tumors
- Other mesenchymal tumors

2) Tumor evaluation by location
   - Intra-axial vs. Extra-axial
   - Infra-tentorial intra-axial masses - Pediatric
     - Medulloblastoma
     - Ependymoma
     - Brainstem glioma
     - Cerebellar Juvenile Pilocytic Astrocytoma (JPA)
   - Infra-tentorial masses - Adult
     - Hemangioblastoma
     - Metastasis
   - Sellar/Parasellar
     - Pituitary adenoma
     - Craniopharyngioma
     - Rathke's cleft cyst
     - Meningioma
     - Arachnoid cyst
     - Hypothalamic and chiasmatic glioma
     - Hamartoma
     - Teratoma/Germinoma
     - Chordoma
     - Lymphoma
     - Inflammatory lesions (Sarcoid, Langerhans Cell Histiocytosis, Immune Hypophysitis)
     - Pituitary hypoplasia with ectopic posterior pituitary gland.
     - Pituitary hemorrhage (apoplexy)
     - Pituitary abscess
   - Pineal Region
     - Germ cell tumors (e.g. Germinoma, Teratoma)
     - Pineocytoma & Pineoblastoma
     - Pineal cyst
     - Meningioma
     - Glioma
     - Vein of Galen aneurysm (AVM, AV fistula)
   - Cerebellopontine angle tumor
     - Vestibular Schwannoma
     - Meningioma
     - Epidermoid
     - Arachnoid cyst
     - Metastases
     - Ependymoma lateral recess (children)
     - Intra-axial lateral cerebellar tumors (e.g. adult Medulloblastoma)
     - Schwannomas of other cranial nerves (V-X)
     - Aneurysm (AICA)
   - Intraventricular Tumors

Choroid plexus papilloma and carcinoma
Colloid cyst
Giant cell astrocytoma
Subependymoma
Central Neurocytoma
Meningioma
Glioma
Metastases
AVM
Cysticercosis

Skull Base
Chordoma
Chondrosarcoma
Other mesenchymal sarcomas (e.g. rhabdomyosarcoma)
Nasopharyngeal Carcinoma
Myeloma, Lymphoma and Leukemia
Metastases (e.g. Neuroblastoma)
Schwannoma (Lower cranial nerves)
Glomus tumors
Meningiomas
Fibrous dysplasia
Paget's disease

E. Cerebrovascular disease

1) Infarction
   - Strategies for imaging
     - CT – signs of hyperacute infarction
     - MR – value of Diffusion Weighted Images (DWI)
   - Etiology
     - Occlusions, large/small vessel
     - Embolic
     - Watershed (Hypoperfusion)
     - Hypoxia/anoxia
     - Hypertension
     - Dissection
     - Fibromuscular Dysplasia (FMD)
     - Vasculitis
     - Venous thrombosis
     - Vasospasm
     - Migraine
   - Hemorrhagic vs. bland
   - Appearance over time: CT/MR, MRA, CTA, angiography
2) Spontaneous hemorrhage
   - Aneurysm
   - Non-aneurysmal perimesencephalic subarachnoid hemorrhage
   - AVM

- Tumor
- Hematological causes
- Drugs
- Infarct
- Congophylic (Amyloid) angiopathy
- Hypertension
- Imaging of hemorrhage over time on CT/MR
    - Serial changes on MR.

3) Aneurysms
    - Types, locations, associated conditions
    - Incidence by location, multiple aneurysms
    - Complication: rupture, mass effect, hydrocephalus, and spasm
    - Imaging, MRI, MRA, CT, Catheter angiography and CT angiography
4) Cerebrovascular Malformations
    - Capillary Telangiectasia
    - Cavernous Malformation (CM)
    - Developmental Venous Anomaly (DVA)
    - Arteriovenous Malformation (AVM)
        - Classification by location (e.g. pial, dural or mixed)
        - Classification based on size of components
        - Intranidal aneurysms
    - Vein of Galen Malformation (AVM, AV fistula)
5) Angiography
    - Film screen, DSA, catheters, injection rates, projections, filming sequences, complications
    - Normal anatomy & variants
        - Common Carotid artery (CCA)
        - External Carotid artery (ECA) and branches
        - Internal Carotid artery (ICA)
            - Cavernous branches
            - Persistent fetal connections
            - Circle of Willis
            - ACA, MCA, PCA branches
        - Vertebro-basilar (VB) arteries
        - ECA, ICA, VB collaterals & anastamoses
        - Spinal vasculature, anterior and posterior spinal arteries
    - Pathologic processes
        - Stenosis and occlusion (ASCVD, FMD, Takayasu, emboli)
        - Neoplasms
        - Fistulas
        - AVM
        - CA
        - DVA (Association with CA)
        - Ectasia (Marfan's, Ehlers-Danlos)
        - Aneurysms (Berry, atherosclerotic, mycotic and traumatic)
        - Trauma (AV fistulas, transections, dissections)

Dissection (spontaneous)
Arteritis
Spasm
Venous thrombosis (Venous sinuses, cortical veins, deep veins)
Infants/Children
Occlusions
Arteritis (Moya, Moya)
Sickle Cell Disease

F. Congenital CNS Lesions

1) Embryology of Brain Development
2) Disorders of organogenesis
   - Anencephaly
   - Cephaloceles
   - Chiari malformations (I-IV)
   - Corpus callosum anomalies: dysgenesis, lipomas
   - Hydranencephaly
   - Porencephaly
3) Disorders of neuronal migration & sulcation
   - Lissencephaly
   - Cortical dysgenesis: agyria-pachygyria, polymicrogyria
   - Heterotopia
   - Schizencephaly
   - Unilateral megalencephaly
4) Disorders of diverticulation and cleavage
   - Holoprosencephaly (alobar, semilobar, lobar)
   - Septo-optic dysplasia
   - Absent septum pellucidum
5) Posterior fossa cystic disorders
   - Dandy-Walker complex
   - Mega cisterna magna
   - Arachnoid cyst
6) Disorders of histogenesis (Phakomatoses)
   - Neurofibromatosis Type I & Type II
   - Tuberous sclerosis
   - Sturge-Weber-Dimitri syndrome
   - Von Hippel-Lindau
   - Ataxia-Telangiectasia: Louis-Bar syndrome
   - Rendu-Osler-Weber syndrome
   - Basal cell nevus syndrome

II. HEAD AND NECK RADIOLOGY

A) Paranasal Sinuses

1) Anatomy of paranasal sinuses
2) Congenital disease

Dermal sinus tract
Encephalocele
Choanal atresia
Dacrocystocele
Nasal glioma (dehiscence of anterior skull base)

3) Inflammation/Infection
   - Acute sinusitis
   - Chronic sinusitis - (Allergic, Fungal, Granulomatous)
   - Polyposis
   - Mucocele
4) Benign Sinus Tumors
   - Osteoma
   - Antrochoanal polyp
   - Juvenile angiofibroma
   - Inverted Papilloma
   - Schwannoma
   - HemangiomaMeningioma
5) Malignant Sinus Tumors
   - Squamous cell carcinoma
   - Esthesioneuroblastoma
   - Adenocarcinoma
   - Lymphoma
   - Metastases
   - Minor Salivary gland tumors
   - Rhbdomyosarcoma
   - Lethal midline granuloma

B. Oral Cavity, Oropharynx, Hypopharynx

1) Anatomy, contents
2) Masses
   - Squamous cell carcinoma
   - Dermoid/Epidermoid
   - Lingual thyroid
   - Thyroglossal duct cyst
   - Ranula
   - Hemangioma
3) Infection
   - Cellulitis, tonsillitis, abscess (Ludwig's angina)
   - Ranula

C. Paraphayngeal Space

1) Location, contents, anatomy and importance in relation to other spaces
2) Pharyngeal Mucosal Space (Anatomy, contents)
   - Infection (tonsilar abscess, adenitis)
   - Pleomorphic adenoma (minor salivary glands)
   - Squamous cell CA

Non-Hodgkin's lymphoma
Thornwaldt cyst
Hemangioma

3) Masticator Space (Anatomy, contents)
   - Tumors (mesenchymal)
   - Infection
4) Parotid Space (Anatomy, contents)
   - 1st Brachial cleft cyst
   - Infection
     - Sialadenitis
     - Sialodochitis, ductal stricture, stone
   - Lymphoepithelial lesions
   - Sjogren's
   - Pleomorphic adenoma
   - Warthin's tumors
   - Mucoepidermoid carcinoma
   - Adenoid cystic carcinoma
   - Metastases
   - Lymphoma
5) Carotid Space (Anatomy, contents)
   - Aneurysm
   - Paragangliomas (Glomus tumors)
   - Schwannoma
   - Neurofibroma
   - Nodal Metastases
2) Retropharyngeal Space (Anatomy, contents)
   - Neoplastic and reactive lymph nodes
   - Infection ("Danger space")
6) Perineural spread

D. Larynx

1) Squamous cell carcinomas
   - Staging
   - Supraglottic, glottic, subglottic
   - Treatment effects (surgery and radiation)
   - Airway obstruction
2) Trauma (laryngeal fractures)

E. Thyroid

1) Masses
   - Multinodular goiter
   - Adenoma
   - Cyst
   - Carcinoma

F. Cystic Neck Masses

1) Second brachial cleft cyst
2) Thyroglossal duct cyst
3) Cystic hygroma
4) Laryngocele, internal, external
3) Abscess
4) Ranula
5) Dermoid/Epidermoid

G. Lymphadenopathy

1) Graded by level and/or anatomic space.
2) Size criteria for pathologic nodes
3) Etiology
    - HIV
    - Lymphoma
    - Metastases (aerodigestive carcinoma)
    - Cat scratch fever
    - Atypical mycobacterium
    - Mononucleosis
    - Castleman's disease

H. Temporal bones

1) Imaging Techniques (Multi-planar CT/MR)
2) Anatomy/Embryology
3) Trauma
    - Transverse and longitudinal fractures
    - CSF leaks, brain herniation
4) Tumors
    - Schwannoma
        - Vestibular (8th) (common)
        - Facial (7th) and trigeminal (5th)
    - Meningioma
    - Lipoma
    - Dermoid/Epidermoid
    - Metastases
5) Pulsatile Tinnitus
    - Glomus tympanicum
    - High riding/dehiscent jugular bulb
    - Ectopic carotid, persistent stapedial artery
    - AVM, AV fistula
    - Venous tinnitus
    - Atherosclerotic disease
    - Dissection
    - FMD
6) Inflammatory Diseases
    - Otitis media

Mastoiditis
Cholesteatoma (acquired or congenital)
Malignant external otitis
Cholesterol granuloma
Hemorrhage or inflammation cochlea, vestibule (labrynthitis)

6) Congenital anomalies
   Cochlear hypoplasia/aplasia, Mondini
   External ear atresia/hypoplasia (ossicular anomalies)
   Enlarged vestibular/cochlea aqueducts
   Cochlear/vestibular aplasias-hypoplasias
   Internal Auditory Canal anomalies

I. Orbits

1) Imaging Techniques
2) Anatomy/Embryology
   Lesion localization based on relationship to muscle cone
3) Lacrimal Gland Tumors
   Epithelial
   Pleomorphic adenomas
   Carcinomas
   Lymphoma
   Dermoid
   Metastases
4) Extra-conal Masses
   Orbital wall or sinus neoplasms with extension
   Subperiosteal abscess/orbital cellulitis from sinusitis/osteomyelitis
   Metastases
   Lymphoma/Leukemia/Myeloma
   Lymphangioma/Hemangioma
   Rhabdomyosarcoma
   Histiocytosis
   Pseudotumor and granulomatous disease
   Hematoma
5) Extra-ocular Muscles (Conal)
   Grave's Disease
   Orbital myositis (Pseudotumor)
   Granulomatous disease
   Lymphoma/Leukemia
   Metastases
   Carotid cavernous fistula
6. Intra-conal lesions
   Related to optic nerve
      Glioma
      Meningioma
      Optic neuritis
      Increased intracranial pressure

Pseudotumor
Grave's disease
Meningeal carcinomatosis
Leukemia

Separate from optic nerve (well defined)
Cavernous angioma, capillary angioma
Varix
Neurofibroma/Schwannoma
Meningioma
Pseudotumor
Lymphoma

Separate from optic nerve (ill defined –infiltrative)
Infection
Metastases
Pseudotumor

7. Intra-ocular
   - Adult
     - Melanoma
     - Metastases
     - Drusen
   - Child
     - Retinoblastoma
     - Retrolental fibroplasia
     - Coat's disease
     - Primary Hypertrophic Persistent Vitreous (PHPV)
   - Any age
     - Metastases
     - Retinal detachment
     - Infection and inflammation (endopthalmitis), AIDS
     - Phthsis bulbi
8. Trauma
   - Fractures of the orbital wall
     - Extra-ocular muscle entrapment
     - Orbital emphysema
     - Intra-orbital hematoma
   - Penetrating soft tissue injuries
     - Laceration of the optic nerve or muscles
     - Ocular - Ruptured globe, intra-ocular hemorrhage, dislocated lens
   - Foreign Body

III. Spinal Imaging

A. Anatomy and Biomechanics

1. Vertebral bodies
2. Facet joints and transverse processes
3. Lamina and spinous processes

4. Support ligaments
5. Specific characteristics of cervical, thoracic, and lumbar segments
6. Cranio-vertebral and lumbo-sacral junctions
7. Normal stability and motion

B. Imaging Modalities

1) Role and relative merit of non-invasive imaging studies.
   Plain radiography, CT, MR, nuclear medicine, PET imaging
1) Role of invasive procedure
   Myelography (including CT) angiography, biopsies, facet injections, nerve root blocks, discography

C. Trauma

1) Mechanism of injury
   Flexion
   Extension
   Axial loading
   Compression
   Distraction
   Rotation
2) Stable fractures and ligamentous injuries
   Compression fracture
   Isolated anterior column
   Isolated posterior column
   Unilateral locked facet
   Hyperextension, teardrop
   Clay Shoveler's (Spinous process C7)
3) Unstable injuries (Involvement of the middle column and ligaments)
   Hyperflexion teardrop
   Facet joint disruption and dislocation (bilateral locked facets)
   Hyperflexion ligamentous injury without fracture
   Odontoid fracture
   Distraction fracture (Hangman's) (C2/C3)
   Chance
   Burst
4) Traumatic disc herniation
5) Extrinsic cord compression
6) Cord contusion
7) Intra-spinal hemorrhage
   Epidural hematoma (EDH)
   Subdural hematoma (SDH)
   SAH Subarachnoid hemorrhage (SAH)
   Cord hematoma (hematomyelia)
8) Post-traumatic abnormalities
   Instability with spondylolithesis
   Syringomyelia

Arachnoiditis
Pseudomeningocele and root avulsion

D. Degenerative disease

1) Epidemiology
2) Disc degeneration
3) End plate degeneration
4) Disc herniation
   - Distribution
   - Imaging findings
5) Spinal stenosis
   - Distribution
   - Imaging findings
6) Post-operative changes
   - Epidural scar
   - Arachnoiditis
   - Recurrent herniation or stenosis

E. Inflammatory and Demyelinating Disease

1) Discitis/osteomyelitis
   - Acute (Spontaneous and Post-operative)
   - Epidural and paravertebral abscess
   - Chronic low grade discitis
2) Vertebral body Tuberculosis (Potts Disease)
3) Meningitis (Arachnoiditis)
   - TB, Sarcoid, CMV, AIDS
4) Spinal cord lesions
   - Abscess, granuloma
   - Transverse myelitis
   - Multiple Sclerosis
   - ADEM

E. Neoplastic Disease

1) Osseous
   - Primary tumors - Benign
     - Hemangioma
     - Osteoid Osteoma/Osteoblastoma
     - Chondroid tumors
     - Giant Cell
     - Aneurysmal Bone Cyst (ABC)
     - Chordoma
   - Primary tumors – Malignant
     - Osteoid
     - Chondroid
   - Metastases
   - Lymphoma

Myeloma
Leukemia

2) Extradural
Neurofibroma
Lymphoma
Metastases

3) Intradural extramedullary
Meningioma
Schwannoma
Neurofibroma
Dermoid
Lipoma
Epidermoid
Epidermal inclusion Cyst
Metastases (Carcinomatous Meningitis)
Lymphoma

5) Intramedullary
Ependymoma
Astrocytoma
Hemangioblastoma
Metastases
Lymphoma

F. Cystic lesions

1) Extradural
Meningocele
Pseudo-meningocele (post-operative and post-traumatic)
Root sleeve cysts (Tarlov) and terminal Meningocele

2) Intradural extramedullary
Arachnoid cyst
Post inflammatory and post hemorrhagic arachnoiditis

3) Intramedullary
Syringomyelia/Hydromyelia
Chiari malformation, post traumatic, post infectious, neoplastic

G. Vascular lesions

1) Dural venous fistula
2) AVM
3) Cavernous Angioma
4) Spinal cord infarct

H. Developmental Spine Disease

1) Normal embryological development of spine
2) Open dysraphisms
3) Myelomeningocele
4) Lipomyelomeningocele (tethered cord)

5) Myelocele
6) Diastemometamyelia
7) Occult spinal dysraphisms
8) Tight filum, thick filum
9) Intradural lipoma
10) Dorsal dermal sinus

NEURORADIOLOGY

Developed by the
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Neuroradiology Resident Rotation
Training Goals & Learning Objectives

General Goals

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

The residents will receive instruction in 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 to 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 contra-indications 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, soft tissue neck 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 or 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 (gray matter structures, white matter tracts) , 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 & 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. Learn the accepted classification system (WHO) of tumors and staging for squamous cell carcinomas of the head and neck.

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 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 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 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). Learn 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 thrombolysis, 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 &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.