

# FELLOWSHIP CURRICULUM

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Should also review everything in the R1 – R3 and R4 curricula

## I. TECHNIQUES AND INDICATIONS

A. In depth understanding (or awareness) of the physics, imaging principles, data processing, clinical indications, artifacts, limitations, and contrast properties, patient safety aspects and utilization for the following CT, MRI, US and nuclear medicine techniques

### 1. CT

- a. Conventional
- b. Dual Energy CT
- c. Perfusion CT
  - i. CBV, CBF, MTT, Tmax, TTP, permeability
  - ii. Use in stroke, stroke mimics, neoplasms
- d. 4D CT (for parathyroid adenomas)
- e. Awareness of the following CT techniques
  - i. Cone beam CT
  - ii. Cerebrovascular reactivity

### 2. MRI

- a. Conventional
- b. MR Spectroscopy
  - i. SVS, 2D-CSI, 3D-CSI
  - ii. Localization of normal and abnormal metabolites at different field strengths
- c. Functional MRI
  - i. BOLD technique
  - ii. Ability to perform paradigms, post processing and interpret results
- d. DWI/Diffusion Tensor Imaging
  - i. Metrics - ADC, FA, Eigen values
  - ii. Ability to perform fiber tracking
- e. MR Perfusion Imaging
  - i. Use in stroke, stroke mimics, neoplasms
  - ii. DSC with calculations of CBV, CBF, MTT, Tmax, TTP, permeability
  - iii. DCE - CBF and Ktrans map generation,
  - iv. ASL - PASL, PCASL
- f. Some awareness of the following MR techniques (iii - viii optional)
  - i. Resting state fMRI/connectivity
  - ii. Cerebrovascular reactivity
  - iii. T1 Rho imaging
  - iv. Quantitative Susceptibility Mapping
  - v. Restriction Spectrum Imaging
  - vi. Neurite Orientation Dispersion and Density Imaging
  - vii. Neurovascular Uncoupling

- viii. MR fingerprinting
  - ix. High-angular-resolution diffusion imaging and Q-ball vector analysis
- 3. Nuclear Medicine
  - a. Positron Emission Tomography
    - i. FDG - PET
    - ii. PET - CT
    - iii. PET - MRI
    - iv. Amyloid imaging (awareness)
  - b. Tc-99m-pertechnetate scintigraphy for thyroid imaging
  - c. Tc-99m sestamibi scintigraphy for parathyroid imaging
- 4. Ultrasound
  - a. Carotid US
  - b. Transcranial Doppler

B. Should have an in depth knowledge (or awareness) of the indications, contrast utilization, catheter/needle selection, radiation exposure and risks of the following procedures and should be able to perform (or have awareness of how to perform) them

1. Digital Subtraction Angiography
2. Myelography
3. Cisternography
4. Minimally invasive spine procedures (awareness)
  - a. Epidural steroid injections
  - b. Facet injections
  - c. Bone biopsies
5. Head and Neck Procedures
  - a. Videofluoroscopy/pharyngoesophagrams
  - b. Modified barium swallows
  - c. Sialograms (awareness)
  - d. Dacrocystograms (awareness)
  - e. US and/or CT guided biopsies - thyroid, salivary gland, nodes
  - f. Sclerotherapy (awareness)
  - g. Ablations (awareness)

C. Should understand the indications for, have knowledge of use of therapeutic agents, and observe and participate in the following procedures

1. Neuroendovascular procedures
  - a. Acute stroke embolectomy with stent retrievers
  - b. Aneurysm Coiling
  - c. AVM/AVF treatment with liquid embolic agents
  - d. Carotid stenting/angioplasty
  - e. Particle embolization for epistaxis, of vascular tumors
2. Vertebroplasty/Kyphoplasty

## **II. ANATOMY**

1. Brain - Have a detailed understanding of the following on CT, MRI and multiplanar 2D and 3D reconstructions

- a. Gyral and sulcal anatomy of the supratentorial and infratentorial brain
  - b. Deep gray nuclei, brainstem and cranial nerves
  - c. Functional neuroanatomy of the brain
  - d. White matter tracts of the supratentorial and infratentorial brain
  - e. Arteries and veins of the supratentorial and infratentorial brain
2. Head and Neck - Have a detailed understanding of the following anatomy on CT, MRI and multiplanar 2D and 3D reconstructions and where appropriate on cone beam CT, PET CT, US, and DSA
- a. Cranial Nerves
  - b. Skull base and cranial nerves
  - c. Temporal bone, middle and inner ear
  - d. Face, Sinonasal cavity
  - e. Oral cavity, Pharynx and Larynx
  - f. Thyroid and parathyroid glands, thoracic inlet and brachial plexus
  - g. Orbit and visual pathways
  - h. Mandible, temporomandibular joint
  - i. Neck, including spaces of the suprahyoid and infrahyoid neck, lymph nodes
  - j. Salivary glands
  - k. Vascular supply to the major structures of the head and neck
3. Spine - Have a detailed understanding of the following anatomy on CT, MRI, myelography and multiplanar 2D and 3D reconstructions
- a. Spinal cord and nerve roots, including the functional neuroanatomy and dermatomes
  - b. Meninges and thecal sac
  - c. Vertebral column
  - d. Ligaments
  - e. Paraspinal musculature
  - f. Vascular supply to the spinal cord, meninges and vertebral bodies
4. Pediatric - Have a detailed understanding of the normal developmental processes of the central nervous system and know the normal appearance on US, CT and MRI (including DWI and MRS) of the brain, spinal cord, vertebral column and head and neck structures during fetal development and during various stages of childhood.
- a. Brain/skull - normal gyration, myelination, pituitary changes, suture closure, growth
  - b. Spine - normal changes in marrow, ligaments, conus position, growth
  - c. Head and neck - normal changes in nodes, lymphoid tissue, cartilages, growth

### **III. BRAIN PATHOLOGY**

1. Stroke/ischemia - have a detailed understanding of:
- a. Appearance of stroke in all major arterial territories with associated functional deficits
  - b. Clinical and imaging scales to assess stroke - NIHSS, ASPECTS, collateral scores
  - c. Accurate interpretation of NCCT/CTA, MR/MRA, CT/MR perfusion, ASL, SWI images
  - d. Management decisions to administer IA or IV therapy based on imaging and

- clinical characteristics, including understanding of embolectomy with stent retrievers
- e. Common and uncommon causes of stroke and their appearances on US, MR/MRA, CT/CTA and DSA - atherosclerosis, dissection, cardioembolic, FMD, Takayasu's, Ehlers Danlos, Erdheim Chester, primary CNS vasculitis, Infectious vasculitis, RCVS, Susac's, CADASIL, Moya Moya, vasospasm from vasoactive drugs
  - f. Stroke mimics - hemiplegic migraine, seizures, hypoglycemia
  - g. Global ischemia/hypoxia
  - h. Evaluation and treatment of cervical carotid artery disease - imaging with US, CTA, MRA, DSA; NASCET criteria; treatments - angioplasty, stenting; pathologies - atherosclerosis, dissection, FMD, Takayasu's, Ehlers Danlos, Erdheim Chester
  - i. Neonatal and pediatric stroke
2. Brain tumors - have a detailed understanding of:
    - a. All tumor pediatric and adult tumor types identified in the WHO 2016 classification of brain tumors and their appearance on MRI, MRP, MRS, SWI, DWI, CT, DSA
    - b. Brain tumor genomics, and the relation of specific genes to location, biology outcome, and treatment response
    - c. Treatment options; treatment related changes including radiation necrosis, radiation angiopathy, pseudoprogression and pseudoresponse; and treatment response according to the RANO criteria
    - d. Understand the basic concepts of texture analysis
  3. Hemorrhage/Vascular malformations - have a detailed understanding of:
    - a. (1) All of the following vascular lesions on CT/CTA, MRI, MRA and DSA; (2) etiologies of these vascular lesions, (3) clinical scales for grading these lesions and (4) endovascular and surgical treatments
      - i. Arteriovenous Malformations/Arteriovenous Fistulas - Spetzler-Martin AVM grading, Borden and Cognard DAVF classification, treatment with liquid embolic agents versus surgical treatment
      - ii. Aneurysms - etiologies - congenital, mycotic, oncotic, Fisher Scale (subarachnoid hemorrhage), Hunt-Hess score, coiling, flow diverting devices, surgical treatments
      - iii. Moya Moya - Encephaloduroarteriosynangiosis
      - iv. Cerebral venous sinus thrombosis - including IV therapy and endovascular clot lysis and clot retrieval
      - v. Congenital vascular malformations (vein of Galen, etc)
      - vi. Small vessel vasculopathies (RCVS, primary CNS angiitis)
    - b. All of the hemorrhagic lesions listed below with emphasis on: (1) their appearances on CT including dual energy CT, MRI including SWI, and DSA; (2) etiologies of these lesions including genetics, and (3) treatments
      - i. Amyloid angiopathy
      - ii. Hypertension
      - iii. Coagulopathy, including DIC
      - iv. Hemorrhagic primary and secondary tumors

- v. Hemorrhagic infections
- vi. Cavernous malformations
- c. The principles and clinical utility of the following techniques
  - i. Dual Energy CT - differentiating calcification from hemorrhage and contrast blush from hemorrhage
  - ii. SWI - including differentiating calcification from hemorrhage on phase images
  - iii. CTA - contrast extravasation, spot sign
- 4. Infection/Inflammation - have a detailed understanding of:
  - a. Pathophysiology and appearance of bacterial, viral, parasitic, fungal and prion infections on MRI, MRP, MRS, SWI, DWI, and CT in pediatric and adult patients
  - b. Noninfectious granulomatous diseases affecting the CNS
  - c. Different organisms and patterns of infection in immunocompromised versus immunocompetent hosts
  - d. Inflammatory conditions associated with dysregulated immunity - e.g. IRIS, autoimmune syndromes such Anti-NMDA receptor (NMDAR), Pediatric Autoimmune Neuropsychiatric Disorders Associated with Streptococcal infection (PANDAS), limbic encephalitis, neuromyelitis optica spectrum disorders, etc.
  - e. Treatment options
- 5. White Matter Diseases - have a detailed understanding of:
  - a. The application of MRI including volumetric FLAIR and DIR sequences, MRP, MRS, DWI, DTI and DSI in the evaluation of white matter diseases in pediatric and adult patients
  - b. Multiple sclerosis and all of its variants including clinical assessment with the McDonald criteria
  - c. Other demyelinating diseases such as ADEM
  - d. Leukodystrophy (Classic, Demyelinating), and Hypomyelination
  - e. Myelinolysis syndromes
  - f. Toxic injury to the white matter - e.g. heroin, cocaine, toluene, metronidazole, methotrexate, Marchiafava Bignami, delayed hypoxia
  - g. Ischemic injury - chronic including assessment with the Fazekas score; delayed hypoxia
  - h. Small vessel vasculopathies (Susac's, CADASIL, Primary angiitis of the CNS)
  - i. Other infectious/inflammatory causes - PML, HIV, SSPE
  - j. PRES
  - k. Treatment options
- 6. Neurodegenerative - have a detailed understanding of:
  - a. The application of MRI including volumetric T1 sequences, MRP, MRS, DWI, DTI, resting state fMRI, PET, SPECT and amyloid imaging in the evaluation of neurodegenerative diseases
  - b. The clinical assessment of patients with ND conditions including neurocognitive tests such as the MMSE
  - c. Primary conditions - Alzheimer's, frontotemporal dementia, Lewy body

- disease, Parkinson's, multisystem atrophy, progressive supranuclear palsy, amyotrophic lateral sclerosis, cerebellar degeneration syndromes, iron deposition Diseases, Huntington's disease
- d. Normal pressure hydrocephalus including CSF flow imaging and treatment options
- e. Importance of quantitative MR in neurodegenerative diseases
- 7. Trauma - have a detailed understanding of:
  - a. SDH, EDH, IPH, DAI, fat emboli in pediatric and adult patients
  - b. Brain herniation patterns
  - c. Calvarial/skull base fractures
  - d. Use of DTI, DWI, and SWI in the evaluation of TBI
  - e. Chronic traumatic encephalopathy
  - f. Use of GCS in the evaluation of patients with TBI
  - g. Quick brain assessment of pediatric patients with TBI
  - h. Abusive head trauma
  - i. Traumatic venous and arterial vascular injury
- 8. Congenital - have a detailed understanding of:
  - a. Malformations in cortical development (MCD) - lissencephalies, heterotopia, focal cortical dysplasias, schizencephaly, polymicrogyria, hemimegalencephaly and newer classifications of MCD (awareness)
  - b. Malformations of the corpus callosum and interhemispheric cysts
  - c. Holoprosencephaly - alobar, semilobar, lobar, middle interhemispheric variant
  - d. Septo-optic dysplasia
  - e. Midbrain–hindbrain anomalies - Dandy-Walker malformation spectrum, Joubert syndrome, cerebellar vermian dysgenesis/hypoplasia, rhombencephalosynapsis
  - f. Chiari I and Chiari II anomalies of the craniocervical junction
  - g. Mesenchymal malformations - calvarial, skull base defects, cephaloceles, lipomas, arachnoid cysts
  - h. Phakomatoses - Neurofibromatosis type 1 and 2, von Hippel-Lindau syndrome, tuberous sclerosis, Sturge-Weber
- 9. Toxic/Metabolic - have a detailed understanding of:
  - a. The application of CT/CTA and MRI/MRA, MRS, DWI, and DTI in the evaluation of toxic and metabolic diseases
  - b. Inborn errors of metabolism/hereditary disorders
  - c. Hypoglycemia
  - d. Hepatic encephalopathy
  - e. Radiation injury
  - f. Chemotherapy (Methotrexate) toxicity
  - g. Carbon monoxide poisoning
  - h. Opiate (heroin, cocaine) toxicity
  - i. Other medication toxicity - Vigabatrin, metranidazole
  - j. Alcohol toxicity- Wernicke's, Marchiafava Bignami, cerebellar atrophy
  - k. Immunosuppressant (cyclosporin) toxicity - PRES
  - l. Antiepileptic medication toxicity - cerebellar atrophy
- 10. Hydrocephalus-understand pathophysiology of obstructive and communicating

hydrocephalus

- a. Recognize signs of increased intracranial pressure
- b. Recognize signs of intracranial hypotension
- c. Slit ventricle syndrome

#### **IV. HEAD AND NECK PATHOLOGY**

1. Orbit and visual pathways - have a detailed understanding of:
  - a. Congenital lesions, including microphthalmia, PPHV, coloboma, NF-1, dermoid and epidermoid cysts
  - b. Tumors including rhabdomyosarcoma, retinoblastoma, meningioma, optic/chiasmal glioma, ocular melanoma, orbital lymphoma, and lacrimal gland tumors
  - c. Inflammatory disorders of the orbits including optic neuritis, sarcoidosis, idiopathic inflammatory disorders (pseudotumor)
  - d. Orbital infections - bacterial and invasive fungal
  - e. Vascular and lymphatic malformations including hemangioma, lymphangioma and venolymphatic malformations
  - f. Orbital prostheses and post-surgical and post treatment changes
2. Nose, nasopharynx and paranasal sinuses- have a detailed understanding of:
  - a. Congenital lesions including choanal atresia and frontoethmoidal encephalocele
  - b. Infectious and inflammatory disorders of the nose and paranasal sinuses including acute and chronic bacterial sinusitis, fungal sinusitis, polyposis, mucocele and Wegener granulomatosis
  - c. Neoplasms including inverted papilloma, juvenile angiofibroma, hemangioma, osteoma, fibrous dysplasia, squamous cell carcinoma, adenocarcinoma, melanoma, esthesioneuroblastoma, and lymphoma
  - d. Functional endoscopic sinus surgery and other procedures and treatment related changes
3. Temporal bone - have a detailed understanding of:
  - a. Congenital disorders - common cavity, cochlear aplasia/hypoplasia, IP-I, IP-II, IP-III deformities, large vestibular aqueduct and sac syndrome, EAC atresia and its associations, ossicular deformities
  - b. Temporal bone tumors and CPA tumors
  - c. Temporal bone fractures
  - d. Cholesteatoma and other inflammatory lesions
  - e. Mastoiditis, otitis media, malignant otitis externa, petrous apicitis and other infections of the temporal bone
  - f. Vascular and non-vascular lesions leading to tinnitus
  - g. Otosclerosis/otospongiosis
  - h. Tegmen thinning, meningoceles, and semicircular canal dehiscence
  - h. Surgical procedures related to inner ear, middle ear and mastoid and other treatment related changes
4. Parotid space - have a detailed understanding of:
  - a. Infectious and inflammatory lesions of the parotid space including parotitis, Sjogren syndrome, and benign lymphoepithelial lesions in HIV.

- b. Neoplasms of the parotid space including Warthin tumor, benign mixed tumor, adenoid cystic carcinoma, mucoepidermoid carcinoma, lymphoma, lymph node metastases and malignant tumors of the skin
  - c. Facial nerve pathology
  - d. Surgical procedures and other treatment related changes.
- 5. Masticator space and face (mandible and maxilla) - have a detailed understanding of:
  - a. Neoplasms/mass lesions including benign and malignant peripheral nerve sheath tumors of the trigeminal nerve, mandibular and maxillary neoplasms and cystic lesions
  - b. Infectious and inflammatory lesions of the mandible and maxilla including osteomyelitis, osteoradionecrosis, bisphosphonate osteonecrosis
  - c. Facial fractures
  - d. Denervation atrophy
  - e. Surgical procedures and other treatment related changes.
- 6. Carotid space - have a detailed understanding of:
  - a. Neoplasms of the carotid space including carotid body paraganglioma, glomus vagale paraganglioma, schwannoma, and neurofibroma
  - b. Vascular lesions of the carotid space including carotid artery pseudoaneurysm, carotid artery dissection, and jugular vein thrombosis
- 7. Oral cavity, oropharynx and retropharyngeal space - have a detailed understanding of:
  - a. Congenital lesions including dermoid and epidermoid cysts, accessory salivary tissue, lymphangioma and lingual thyroid gland
  - b. Inflammatory and infectious lesions of the oral cavity and oropharynx including abscesses, sialadenitis and ranula; and retropharyngeal abscesses
  - c. Neoplasms including squamous cell carcinoma, malignant tumors of the minor salivary glands and benign mixed lesions of the minor salivary glands
  - d. Surgical procedures and treatment related changes.
- 8. Hypopharynx, larynx and cervical esophagus - have a detailed understanding of:
  - a. Neoplasms of the hypopharynx and larynx, including squamous cell carcinoma of the hypopharynx, of the supraglottic, glottic and subglottic regions, chondrosarcoma and other malignant tumors of the larynx; esophageal carcinoma
  - b. Post-surgical and post radiation changes of the hypopharynx and larynx
  - c. Vocal cord paralysis
  - d. Laryngeal trauma
  - e. Laryngocele, pharyngocele, laryngeal web, laryngeal stricture, tracheal stenosis
  - f. Swallowing disorders
  - g. Zenker diverticulum
  - h. Epiglottitis and croup
- 9. Thyroid and parathyroid glands - have a detailed understanding of:
  - a. Thyroiditis
  - b. Multinodular goiter
  - c. Neoplasms including thyroid and parathyroid adenomas, thyroid carcinoma, and thyroid lymphoma
  - d. Surgical procedures and other treatment related changes

10. Lymph nodes of the head and neck region - have a detailed understanding of:
  - a. Nomenclature of the lymph nodes and nodal regions
  - b. Infectious and inflammatory disorders including reactive lymph node enlargement, suppurative lymph nodes, Kimura disease, Castleman disease
  - c. Neoplasms including lymphoma and nodal metastases
  - d. Neck dissections
11. Skull base and cranial nerves - have a detailed understanding of:
  - a. Skull base neoplasms/diffuse diseases - meningioma, macroadenoma, chordoma, chondrosarcoma, plasmacytoma, metastases, Langerhans cell histiocytosis, fibrous dysplasia
  - b. Jugular foramen neoplasms/other lesions - glomus tumor, schwannoma, meningioma, jugular vein diverticulum
  - c. Skull base fractures
  - d. Cavernous sinus neoplasms and inflammatory lesions
  - e. Common and uncommon pathologies affecting cranial nerves 1 - 12
  - f. Perineural tumor spread
  - g. Surgical procedures and other treatment related changes
12. Congenital and trans-spatial lesions - have a detailed understanding of:
  - a. Embryology of the head and neck region
  - b. Congenital cystic lesions - branchial cleft, thymic, thyroglossal duct
  - c. Congenital vascular and lymphatic malformations
  - d. Neurocutaneous syndromes in the head and neck
  - e. Fibromatosis coli
  - f. Congenital malformations of the skull base and face

## **V. SPINE PATHOLOGY**

1. Degenerative Disease - have a detailed understanding of:
  - a. The application of CT, MRI myelography and discography in the evaluation of degenerative disease of the spine
  - b. Nomenclature for degenerative changes
  - c. Intervertebral disc degeneration and herniation - annular fissure, protrusion, extrusion, sequestration, location - central, subarticular, foraminal, far lateral, anterior
  - d. Vertebral marrow changes and osteophyte formation - Modic classification
  - e. Facet arthropathy/synovial cysts
  - f. Spondylolisthesis, spondylolysis and segmental instability
  - g. Spinal canal and neural foraminal stenosis - grading schemes for mild, moderate and severe
  - h. Other degenerative conditions - OPLL, DISH
2. Spine tumors - have a detailed understanding of:
  - a. The application of CT, MRI, bone scans, and PET in the evaluation of spinal tumors
  - b. Treatment options and treatment related changes/complications- surgery, chemotherapy, vertebroplasty
  - c. Intramedullary lesions - ependymoma, astrocytoma, oligodendroglioma, ganglioglioma, hemangioblastoma, metastatic disease

- d. Intradural extramedullary lesions - meningioma, nerve sheath tumors, hemangioma, paraganglioma, carcinomatosis (from primary CNS tumors and non CNS tumors)
  - e. Extradural lesions - osteoid osteoma, osteoblastoma, ABC, osteochondroma, hemangioma, giant cell tumors, osteosarcoma, chondrosarcoma, chordoma, Ewing sarcoma, lymphoma, leukemia, multiple myeloma, metastatic disease
  - f. Treatment options and treatment related changes
3. Spine trauma - have a detailed understanding of:
- a. The application of CT, MRI, STIR, GRE, DWI, DTI, and myelography to spine trauma, including the identification of spinal cord, ligamentous, spinal column, vascular
  - b. Mechanisms of injury to the cervical, thoracic and lumbar spinal columns
  - c. Stable versus unstable fractures
  - d. Upper cervical spine fractures - Classification of atlanto-occipital dislocation, occipital condyle fractures, odontoid fractures, and traumatic spondylolisthesis of C2 (Hangman's); Jefferson and other C1 fractures
  - e. Lower cervical spine fractures - hyperflexion, hyperextension injuries
  - f. Thoraco-lumbar fracture classification - hyperflexion compression injuries, burst fractures, flexion-distraction injuries, fracture-dislocation injury
  - g. How to differentiate acute from chronic compression
  - h. Nerve root and brachial plexus injury
  - i. Pediatric spine trauma
  - j. Treatment options and treatment related changes
4. Infectious and inflammatory diseases of the spinal column and spinal cord – have detailed understanding of:
- a. The application of CT, MRI, STIR, GRE, DWI, DTI, and myelography to spinal column infectious and inflammatory diseases
  - b. Hematogenous and nonhematogenous routes of infection
  - c. Vertebral discitis-osteomyelitis +/- epidural abscess - bacterial, mycobacterial (tuberculosis), fungal (aspergillus, candida), parasitic causes (hydatid)
  - d. Vertebral column inflammatory conditions - Ankylosing spondylitis, Psoriatic arthritis, rheumatoid arthritis, sarcoidosis, dialysis related amyloidosis
  - e. Leptomeningeal infections - bacterial, mycobacterial (tuberculosis), fungal (cryptococcus), parasitic (cysticercosis)
  - f. Infectious myelitis - Nonviral (spinal cord abscess), viral - herpes, CMV, HIV
  - g. Inflammatory diseases of the spinal cord and leptomeninges - multiple sclerosis, ADEM, neuromyelitis optica, acute transverse myelopathy, Guillain Barre, CIDP, Charcot Marie Tooth, neurosarcoidosis
5. Vascular lesions of the spinal column and spinal cord -
- a. The application of CT, CTA, MRI, MRA, DSA and myelography to spinal column infectious and inflammatory diseases
  - b. Spinal AVMs/AVFs types I - IV - classification, imaging features and endovascular therapy versus surgical options.
  - c. Cavernous malformations
  - d. Spinal cord infarctions - arterial and venous

6. Congenital - have a detailed understanding of:
  - a. The application of CT and MRI to evaluate congenital lesions
  - b. Open spinal dysraphism (myelocele, myelomeningocele) - surgical repairs
  - c. Closed spinal dysraphism associated with a mass - lipomyelocele, lipomyelomeningocele, meningocele, myelocystocele - surgical repairs
  - d. Closed spinal dysraphism spectrum - segmental spinal dysgenesis, dorsal dermal sinus, split cord malformation (diplomylelia and diastematomyelia)
  - e. Tethered cord - spinal cord release surgery
  - f. Anomalies of vertebral formation and segmentation (vertebra, hemivertebra) - Associated thoracic insufficiency syndrome
  - g. Cystic lesions - Neurenteric cyst, arachnoid cyst, epidermoid
7. Post-operative spine
  - a. Scarring versus recurrent disc
  - b. Hardware failure
  - c. Nonunion
  - d. Infection
  - e. CSF leak
8. Toxic/metabolic disease of the spinal cord - have a detailed understanding of:
  - a. The application of CT and MRI to toxic and metabolic diseases of the spine and spinal cord
  - b. Subacute combined degeneration
  - c. Radiation myelopathy