Diagnostic Radiology
CORE Examination Study Guide
Updated 1/11/2017
Contents

Contents ........................................................................................................................................... 2
Preamble ........................................................................................................................................... 3
Exam Purpose Statements ............................................................................................................... 4
Breast Imaging ................................................................................................................................ 5
Cardiac Imaging .............................................................................................................................. 7
Gastrointestinal Imaging .................................................................................................................. 12
Interventional Radiology ................................................................................................................ 18
Musculoskeletal Imaging ................................................................................................................. 20
Neuroradiology .............................................................................................................................. 30
Nuclear Radiology .......................................................................................................................... 45
Pediatric Radiology ........................................................................................................................ 57
Physics ............................................................................................................................................. 77
Radioisotope Safety Examination (RISE) ....................................................................................... 94
Reproductive/Endocrine Imaging and Therapy .............................................................................. 97
Noninterpretive Skills ..................................................................................................................... 99
Thoracic Imaging ............................................................................................................................ 100
Ultrasound ..................................................................................................................................... 108
Urinary Imaging .............................................................................................................................. 130
Vascular Imaging ............................................................................................................................. 133
Preamble

This study guide is a resource to guide your preparation for the Core Examination in diagnostic radiology.

The Core Examination is designed to evaluate a candidate’s core radiology knowledge and clinical judgement, across both the subspecialties and imaging modalities of diagnostic radiology. It tests knowledge and comprehension of anatomy, pathophysiology, diagnostic radiology, and physics concepts important for the practice of diagnostic radiology. The purpose of this exam relative to that of other ABR exams is given on the next page.

The 18 categories are: breast imaging, cardiac imaging, computed tomography (CT), gastrointestinal (GI) imaging, interventional radiology, magnetic resonance (MR), musculoskeletal imaging, neuroradiology, nuclear radiology, pediatric radiology, physics, radiography/fluoroscopy, reproductive/endocrine imaging, safety, thoracic imaging, ultrasound (US), urinary imaging, and vascular imaging.

- Individual category study guides are presented for 15 categories.
- For the three modalities of CT, MR and radiography/fluoroscopy, the relevant portion of the study guides in each of the other categories should be used to guide preparation.

In general, the Core Examination is based on material in this study guide. However, not all material in the study guide is included on every form of the examination. Items that are not included in this study guide may appear on the examination.

If you are reviewing this in printed format, please be sure to check the ABR website, www.theabr.org, for updated study guide materials and questions.

Nonprofit educational programs have permission to use or reproduce all or parts of this document for educational purposes only. Use or reproduction of this document for commercial use or for-profit use is strictly prohibited.

©American Board of Radiology, 2013
Exam Purpose Statements

Core Exam:
The purpose of the ABR Core (qualifying) Exam is to validate that the candidate has acquired the knowledge, skills, and understanding basic to the entire field of diagnostic radiology, including physics.

Certifying Exam:
The purpose of the ABR Certifying Exam is to validate that the candidate has acquired and is able to apply the requisite knowledge, skills, and understanding that:

1. every practicing physician should possess (20%).
2. every practicing radiologist should possess (20%).
3. this particular practicing radiologist should possess to begin independent practice in his or her chosen clinical practice area(s) (60%).

Subspecialty Certifying Exams:
The purpose of the subspecialty certifying exam is to validate that the candidate has acquired and is able to apply the requisite knowledge, skills, and understanding essential to the practice of the subspecialty.

Maintenance of Certification (MOC) Exam:
The purpose of the MOC exam is to validate that the certified diplomate has maintained and applies the essential knowledge, skills, and understanding in the major clinical areas in which the diplomate currently practices.
Breast Imaging

1) Regulatory/Standards of Care
   a) Components and desired goals of the medical audit for breast cancer detection
   b) Appropriate application of the Breast Imaging Reporting and Data System (BI-RADS) terminology and assessment categories
   c) Mammography Quality Standards Act (MQSA) requirements
   d) Quality determinants of mammography, breast ultrasound, and breast MR, including positioning, image processing, artifacts, optimal technique, and equipment

2) Screening
   a) Indications
   b) Normal anatomy (mammography, ultrasound, MR)
   c) Lesion detection and localization
   d) Computer-aided detection
   e) Breast cancer risk factors, including the identification and management of women at high risk for breast cancer

3) Diagnostic Breast Imaging
   a) Appropriate mammographic views for work-up of a breast lesion
   b) Evaluate and manage women and men with breast symptoms
      i) Palpable masses
      ii) Breast thickening
      iii) Nipple discharge
      iv) Nipple retraction
      v) Skin changes
   c) Appearance and management of inflammatory processes in the breast
      i) Benign
      ii) Malignant
   d) Role of imaging in surgical staging and surgical planning in women with recently diagnosed breast cancer
   e) Normal and abnormal appearance after surgical procedures
      i) Breast implants
      ii) Breast augmentation
      iii) Breast reduction
      iv) Breast reconstruction
      v) Normal and abnormal appearance of breast-conserving therapy

4) Pathology
   a) Appearance and management of benign breast lesions, high-risk lesions, ductal carcinoma in situ, invasive ductal carcinoma, and other special types of breast carcinoma
   b) Appearance and causes of benign and malignant male breast disease

5) Imaging findings
a) Characteristics of benign and malignant breast calcifications
b) Characteristics of benign and malignant breast masses
c) Identify and appropriately manage imaging findings
   i) Mammography
      (1) Abnormal calcifications
      (2) Masses
      (3) Asymmetries
      (4) Architectural distortion
   ii) Ultrasound
   iii) Breast MR
      (1) Masses
      (2) Non-mass findings
d) Identify and understand the causes of abnormal lymph nodes on mammography, ultrasound, or MRI

6) Breast Intervention
   a) Percutaneous breast biopsy techniques
      i) Wire localization
      ii) Core biopsy
      iii) Vacuum-assisted biopsy
      iv) Fine-needle aspiration
      v) Galactography
      vi) Cyst aspiration
   b) Specimen radiography
   c) Concordant versus discordant percutaneous biopsy results for imaging appearance of a breast abnormality and appropriate management
   d) Patient safety

7) Physics
   a) Mechanism of obtaining and optimizing film-screen or digital mammograms
      i) Target/filter combinations
      ii) Use of a grid
      iii) Reduction of scatter
      iv) Radiation dose
   b) Adjustment of mammography techniques for special cases, including thin breasts
   c) Mechanism of obtaining and optimizing breast US images
   d) Mechanism of obtaining and optimizing breast MR images
   e) Recognizing, understanding, and correcting artifacts in breast imaging, including mammography, US, and MR imaging
   f) Workstation display of digital mammograms
      i) Required equipment parameters
      ii) Image processing

Computer-assisted display software for breast MRI, including the role of dynamic enhancement characteristics
Cardiac Imaging

1) Basics of Imaging: Radiography, CT, and MR
   a) Indications and limitations of the modalities and comparison to echocardiography, angiography and cardiac catheterization, SPECT, and PET.
   b) Physics behind image creation and potential artifacts on radiography, CT, and MR
      i) X-ray physics
      ii) CT physics
         (1) Multidetector CT artifacts relevant to cardiac imaging
         (2) Tradeoffs between noise, dose and image quality
         (3) Spatial resolution, contrast resolution, and imaging reconstruction algorithms
         (4) Temporal resolution, half scan, and multi-segment reconstruction
         (5) Contrast injection—principles, protocols, bolus geometry, and iodine flux
      iii) MR physics
         (1) MR artifacts relevant to cardiac and vascular imaging
         (2) Trade-off between spatial resolution, temporal resolution, contrast resolution, and acquisition time
         (3) Principles of black blood, edema, and scar imaging
         (4) Steady-state free precession cine imaging
         (5) Velocity-encoded cine (phase contrast) imaging—principles, applications, and limitations
   c) 3D imaging and post-processing
      i) Multiplanar reconstruction (MPR)
      ii) Maximum intensity projection (MIP)
      iii) Volume rendering (VR)
   d) Patient safety
      i) Radiation exposure and how technical modifications may modify dose
      ii) Drugs and contrast agents used for cardiac imaging
      iii) Cardiac devices and the effect of the magnetic field of the MR unit

2) Normal Anatomy, Including Variants, Encountered on Radiography, CT, and MR
   a) Heart, including chambers, valves, pericardium, and coronary arteries
   b) Aorta and pulmonary arteries
   c) Venae cavae and pulmonary veins

3) Physiological Aspects of Cardiac Imaging as Assessed with Radiography, CT, and MR
   a) Normal cardiac cycle
   b) Physiological anatomy of cardiac muscle
   c) Mechanics of cardiac contraction
   d) Physical basis for blood flow, pressure, and resistance
      i) Ventricular volume and pressure relationship
      ii) Functional cardiac measurements
(1) Ejection fraction
(2) Stroke volume
(3) Left ventricular mass
(4) Flow (Q = V x A)
(5) Pressure gradient (modified Bernoulli equation, \( \Delta P = 4v^2 \))
(6) Pulmonary-to-systemic flow (Qp/Qs) ratio
(7) Regurgitant volume and regurgitant fraction
(8) Diastolic heart function
   iii) Normal cardiac and pulmonary pressures
   iv) Vascular regions supplied by the coronary arteries

4) Ischemic Heart Disease
   a) Risk factors, primary prevention, and screening
   b) Roles of echocardiography, angiography, SPECT, PET, CT, and MR in the evaluation of a patient with suspected ischemic heart disease, including the advantages and limitations of each modality
   c) Inducible myocardial ischemia
   d) Acute myocardial infarction
   e) Chronic myocardial infarction
   f) Post-myocardial infarction complications
      i) Cardiac rupture
      ii) Left ventricular aneurysm and pseudoaneurysm
      iii) Papillary muscle rupture
      iv) Congestive heart failure
      v) Dressler syndrome
   g) Myocardial perfusion and viability
      i) Stunned myocardium
      ii) Hibernating myocardium
   h) Role of myocardial delayed-enhancement imaging in guiding management of left ventricular dysfunction
      i) Coronary artery stenosis and aneurysm
      j) Role of coronary CT angiography in guiding management of chest pain
     k) Therapeutic and interventional options

5) Cardiomyopathy
   a) Hypertrophic
   b) Dilated
   c) Restrictive
      i) Distinguish restrictive cardiomyopathy from constrictive pericarditis
   d) Arrhythmogenic right ventricular dysplasia
   e) Therapeutic and interventional options

6) Cardiac Masses
   a) Thrombus
i) Distinguish thrombus from tumor  
b) Primary benign tumors  
   i) Myxoma  
   ii) Lipoma  
   iii) Rhabdomyoma  
   iv) Fibroma  
   v) Lipomatous hypertrophy of the interatrial septum  
c) Primary malignant tumors  
   i) Angiosarcoma  
   ii) Lymphoma  
d) Metastasis  
e) Therapeutic and interventional options  

7) Valvular Disease  
a) Myxomatous degeneration  
b) Rheumatic heart disease  
c) Infective endocarditis  
d) Congenital valve disease  
e) Specific lesions  
   i) Aortic stenosis  
   ii) Aortic regurgitation  
   iii) Mitral stenosis  
   iv) Mitral regurgitation  
   v) Mitral annular calcification  
   vi) Tricuspid regurgitation  
   vii) Pulmonary stenosis  
   viii) Pulmonary regurgitation  
f) Therapeutic and interventional options  

8) Pericardial Disease  
a) Acute pericarditis  
b) Constrictive pericarditis  
   i) Distinguish restrictive cardiomyopathy from constrictive pericarditis  
c) Pericardial effusion  
   i) Hemopericardium  
   ii) Tamponade  
d) Pericardial cyst  
e) Pericardial defect  
f) Pneumopericardium  
g) Therapeutic and interventional options  

9) Congenital Heart Disease  
a) Left-to-right shunts  
   i) Atrial septal defect
ii) Ventricular septal defect
iii) Partial anomalous pulmonary venous connection
   1) Scimitar syndrome
iv) Patent ductus arteriosus
b) Eisenmenger syndrome
c) Admixture lesions (bidirectional shunts)
   i) Transposition of the great arteries
   ii) Truncus arteriosus
   iii) Total anomalous pulmonary venous connection
d) Right-to-left shunts
   i) Tetralogy of Fallot and pulmonary atresia with ventricular septal defect
   ii) Ebstein anomaly
e) Great vessel anomalies
   i) Coarctation of the aorta
      1) Distinguish from pseudocoarctation
   ii) Double aortic arch
   iii) Right aortic arch
      1) Mirror image
      2) Non-mirror image
   iv) Pulmonary sling
   v) Persistent left superior vena cava
f) Coronary artery anomalies
   i) Retroaortic course
   ii) Interarterial course
g) Miscellaneous anomalies
   i) Cardiac malposition, including situs abnormalities
   ii) Congenitally corrected transposition of the great arteries
h) Therapeutic and interventional options

10) Acquired Disease of the Thoracic Aorta and Great Vessels
a) Aneurysms
   i) Atherosclerotic
   ii) Marfan syndrome
   iii) Ehlers-Danlos syndrome
b) Pseudoaneurysms
   i) Mycotic
   ii) Post-traumatic and post-surgical
c) Dissection
   i) Intramural hematoma
d) Aortitis and arteritis
e) Atherosclerosis
   i) Plaque
   ii) Ulcerated plaque
   iii) Penetrating ulcer
f) Thromboembolism  
   i) Acute pulmonary embolism  
   ii) Chronic pulmonary embolism  

g) Pulmonary hypertension  

h) Pulmonary arteriovenous malformation  

i) Compression  
   i) Superior vena cava syndrome  

j) Pulmonary vein complications after radiofrequency ablation  

k) Therapeutic and interventional options  

11) Devices and Postoperative Appearance  

a) Monitoring and support devices  
   i) Intra-aortic balloon pump  
   ii) Pacemaker generator and pacemaker leads  
   iii) Implantable cardiac defibrillator  
   iv) Left ventricular assist device  
   v) Pericardial drain  

b) Postoperative chest  
   i) Coronary artery bypass graft surgery  
   ii) Cardiac valve replacement  
   iii) Transluminal septal closure  
   iv) Aortic graft and aortic stent  
   v) Heart transplant
Gastrointestinal Imaging

1) Pharynx
   a) Benign diseases
      i) Zenker diverticulum
      ii) Foreign bodies
      iii) Trauma
   b) Motility disorders

2) Esophagus
   a) Benign diseases
      i) Diverticula
      ii) Trauma
      iii) Esophagitis
         (1) Reflux
         (2) Infectious
         (3) Caustic
         (4) Drug-induced
      iv) Barrett esophagus
   v) Rings, webs, and strictures
   vi) Varices
   vii) Benign tumors and tumor-like conditions
   viii) Extrinsic processes affecting the esophagus
      (1) Pulmonary lesions
      (2) Mediastinal structures
   ix) Hiatal hernia (types and significance)
   b) Malignant tumors
      i) Squamous
      ii) Adenocarcinomas
      iii) Other malignant tumors
         (1) Lymphoma
         (2) Kaposi
         (3) Metastases (lymphatic and hematogenous)
   c) Motility disorders
      i) Primary motility disorders
      ii) Secondary motility disorders
   d) Postoperative esophagus

3) Stomach
   a) Benign diseases
      i) Diverticula
      ii) Gastritis
         (1) Erosive
(2) Atrophic
(3) Infectious
(4) Other
   (a) Crohn disease
   iii) Peptic ulcer disease
   iv) Hypertrophic gastropathy
   v) Varices
   vi) Volvulus
   vii) Entrapment after diaphragmatic injury
b) Malignant diseases
   i) Primary
      (1) Adenocarcinoma
      (2) Lymphoma
      (3) GI stromal tumors
      (4) Carcinoid
   ii) Metastatic
c) Postoperative stomach
   i) Expected surgical appearance
      (1) Bariatric, including gastric banding
      (2) Nissen and other fundoplications
      (3) Whipple
      (4) Billroth procedures
d) Complications

4) Duodenum
   a) Benign diseases
      i) Congenital abnormalities
      ii) Diverticula
      iii) Trauma
      iv) Inflammation (1)
         Duodenitis (2)
         Ulcer disease
         (3) Crohn disease
   v) Aortoduodenal fistula
   vi) Benign tumors
b) Malignant diseases
   (1) Adenocarcinoma
   (2) Lymphoma
   (3) Metastatic disease

5) Small Intestine
   a) Benign diseases
      i) Congenital disorders
      ii) Diverticula
iii) Trauma
iv) Vascular diseases
   (1) Intestinal ischemia and infarction
   (2) Radiation enteritis
   (3) Scleroderma
   (4) Vasculitides
      (a) Henoch-Schönlein purpura
      (b) Polyarteritis nodosa
      (c) Systemic lupus erythematosus
v) Malabsorption
   (1) Sprue
   (2) Lymphangiectasia
vi) Inflammatotary diseases
   (1) Crohn disease
   (2) Infectious and parasitic diseases
vii) Benign tumors
   (1) Sporadic
   (2) Associated with polyposis syndromes
viii) Malrotation/Volvulus
ix) Obstruction
x) Hemorrhage
xi) Other
   (1) Status post bone marrow transplant
   (2) Drug effects
      (a) NSAIDs enteritis
      (b) ACE inhibitors
b) Malignant tumors
   i) Adenocarcinoma
   ii) Lymphoma
   iii) Carcinoid
   iv) GI stromal tumors
   v) Metastases

6) Colon and Appendix
a) Benign disease
   i) Congenital abnormalities
   ii) Diverticular disease
   iii) Inflammatotary diseases
      (1) Crohn disease
      (2) Ulcerative colitis
      (3) Infectious colitis
         (a) Pseudomembranous
         (b) Viral
         (c) Bacterial
(d) Colitis in AIDS
(4) Appendicitis
iv) Ischemic colitis
v) Benign neoplasms
   (1) Adenoma
   (2) Mesenchymal tumors
   (3) Polyposis syndromes
b) Malignant diseases
   i) Adenocarcinoma
   ii) Other malignant tumors
      (1) Lymphoma
      (2) Carcinoid
      (3) Melanoma
      (4) Squamous (anal)
      (5) Metastases

7) Pancreas
   a) Congenital abnormalities and variants
   b) Pancreatitis
      i) Acute
      ii) Chronic
      iii) Complications
      iv) Autoimmune
c) Pancreatic neoplasms
   i) Duct cell adenocarcinoma
   ii) Cystic pancreatic neoplasms
      (1) Intraductal papillary mucinous neoplasm (IPMN)
      (2) Mucinous cystadenomas
      (3) Serous cystadenomas
   iii) Islet cell tumors
   iv) Lymphoma
   v) Metastases

8) Liver
   a) Normal anatomy
   b) Diffuse diseases of the liver
      i) Cirrhosis
      ii) Diseases associated with infiltration
         (1) Fatty infiltration/nonalcoholic steatohepatitis (NASH)/NAFLD
         (2) Hemochromatosis
         (3) Storage diseases
      iii) Vascular diseases
         (1) Portal hypertension
         (2) Portal vein occlusion
(3) Hepatic venous hypertension/Budd Chiari syndrome, and nutmeg liver
c) Focal diseases of the liver
   i) Benign
      (1) Cavernous hemangioma
      (2) Liver cell adenoma
      (3) Focal nodular hyperplasia
   ii) Malignant
      (1) Hepatocellular carcinoma
      (2) Metastases
      (3) Other malignant liver lesions
d) Liver transplantation
      (1) Surgical candidates
      (2) Expected postoperative appearance
      (3) Complications

9) Spleen
   a) Splenomegaly
   b) Focal lesions
      i) Cysts
      ii) Hemangioma
      iii) Infarction
      iv) Abscess/microabscesses
      v) Granulomatous disease
   c) Trauma

10) Bile Ducts and Gallbladder
   i) Congenital abnormalities and variants
      (1) Choledochal cysts
      (2) Caroli disease
   ii) Inflammatory diseases
      (1) Gallbladder
         (a) Acute cholecystitis
         (b) Emphysematous cholecystitis
         (c) Porcelain bladder
      (2) Biliary ducts
         (a) Primary sclerosing cholangitis
         (b) Ascending cholangitis
         (c) Recurrent pyogenic cholangitis
         (d) AIDS cholangiopathy
         (e) Ischemic injury
         (f) Surgical injury
         (g) Stone disease
   iii) Tumors
      (1) Gallbladder cancer
(2) Cholangiocarcinoma
(3) Metastases

11) Peritoneal Spaces
   a) Normal anatomy
   b) Fluid collections
   c) Diseases of the peritoneum
      i) Inflammatory diseases
         (1) Bacterial peritonitis
         (2) Tuberculosis
         (3) Other
      ii) Primary tumors
      iii) Metastatic tumors
   d) Mesenteries
      i) Normal anatomy
      ii) Pathologic conditions
         (1) Sclerosing mesenteritis/misty mesentry
         (2) Mesenteric fibromatosis
   e) Retroperitoneum
      i) Normal anatomy
      ii) Retroperitoneal spaces
      iii) Benign diseases
         (1) Fibrosis
         (2) Inflammatory diseases
      iv) Malignant tumors

12) Multisystem Disorders
   a) Acute abdomen
   b) Trauma to the abdomen
   c) Syndromes involving the GI tract
   d) Hernias, including internal hernias
   e) All obstruction
Interventional Radiology

1) Basic Procedures
   Questions will assess whether the candidate possesses the knowledge, skills, and abilities needed for safe and effective care before, during, and after the procedure. Candidates are expected to have a detailed knowledge of the procedure itself, as well as pre- and postprocedure care.
   a) Biopsies: neck, chest, abdomen, pelvis, and extremities, including thyroid, lung, chest wall, liver, pancreas, renal, retroperitoneal, pelvic, and extremity. Note: breast biopsies will be covered in the mammography section. Bone biopsies will be covered in the musculoskeletal section.
   b) Aspirations: neck, chest, abdomen, pelvis, and extremities including thyroid, pleural, peritoneal, and abdominal/pelvic/extremity cysts. Note that lumbar puncture and myelography will be covered in the neuroradiology section.
   c) Central venous: PICCs and uncomplicated non-tunneled catheters
   d) Abscess drainage: uncomplicated chest, abdomen, pelvic, and superficial abscesses
   e) Extremity venography
   f) Catheter injections: cholangiography, abscessogram, nephrostograms, and feeding tube checks

2) Complex Procedures
   Because these procedures are typically performed by radiologists with more specialized training, Core Exam candidates are not expected to possess the knowledge, skills, and abilities required to perform these procedures. However, candidates are responsible for a general knowledge of these procedures. Test items will also cover pre- and postprocedure care in more detail because general radiologists are often the first to encounter patients whose clinical presentation and imaging findings warrant these complex interventions. Candidates are also expected to correctly distinguish between expected and unexpected clinical and imaging findings after these procedures.
   a) Arteriography and arterial interventions, including angioplasty, stent placement, stent graft placement, lysis, embolization, thrombectomy, and therapeutic infusion
   b) Central venography and venous interventions, including inferior vena cava (IVC) filter placement, IVC filter retrieval, angioplasty, stent placement, lysis, thrombectomy, sclerosis, tunneled/implanted catheter placement, dialysis interventions, and TIPS
   c) Biliary interventions, including percutaneous transhepatic cholangiography (PTC), internal/external drainage, stent placement, stone removal, and percutaneous cholecystostomy
   d) Nephrostomy and ureteral stent placement, manipulation, and exchange
   e) Tumor ablation (radiofrequency, cryoablation, bland embolization, chemoembolization, and radioembolization)
   f) Feeding tube placement, manipulation, and exchange
   g) Complicated drainages, including transrectal drainage, tunneled catheter placement for pleural/peritoneal collections, and pediatric procedures
3) Physics Knowledge Needed to Safely Perform These Procedures
   a) Optimal use of radiation
   b) Imaging artifacts
1) Imaging Techniques—Indications and Limitations
   a) Musculoskeletal modalities
      i) Radiography
      ii) CT
      iii) MRI
      iv) Nuclear scintigraphy/PET
      v) Ultrasound
      vi) Fluoroscopy
      vii) Considerations for musculoskeletal modalities
           (1) Appropriateness, limitations, contraindications, and safety issues
           (2) Protocols, standard positioning, technique
           (3) Indications for contrast with MRI and CT
           (4) Scintigraphic agents
           (5) Artifacts and pitfalls
   b) Interventional musculoskeletal procedures
      i) Types
         (1) Arthrography
         (2) Joint aspiration and injection
         (3) Percutaneous biopsy
         (4) Therapeutic procedure
      ii) Considerations for musculoskeletal procedures
         (1) Appropriateness, limitations, contraindications, and safety issues
         (2) Universal protocol
         (3) Approach and technique
         (4) Injectate (composition and amount)
         (5) Laboratory studies
         (6) Complications
   c) Dual-energy X-ray Absorptiometry (DEXA)
      i) Indications and follow-up
      ii) WHO classification
      iii) DEXA positioning
      iv) DEXA artifacts and pitfalls

2) Normal/Normal variants
   a) Musculoskeletal anatomy pertinent to the various imaging modalities
   b) Primary and secondary ossification centers and sequence of ossification
   c) Physiologic radiolucencies and radiodensities
   d) Physiologic bowing
   e) Sesamoids, accessory ossicles, and related syndromes
   f) Accessory muscles
   g) Tug lesions
   h) Cortical desmoid
i) Dorsal defect of the patella
j) Glenoid labrum variants

3) Congenital Anomalies and Dysplasias
   a) Lower extremity
      i) Developmental hip dysplasia
      ii) Discoid meniscus
      iii) Talipes equinovarus
      iv) Metatarsus adductus
      v) Pes cavus and planus
      vi) Tarsal coalition
      vii) Proximal focal femoral deficiency
      viii) Protrusio acetabuli
      ix) Acetabular version
      x) Patella baja and alta
   b) Upper extremity
      i) Madelung deformity
      ii) Congenital dislocation of the radial head
      iii) Carpal coalition
      iv) Sprengel deformity
      v) Supracondylar process
      vi) Radial ray anomaly
      vii) Ulnar variance
   c) Spine (see neuroradiology section)
   d) Diffuse/multifocal
      i) Achondroplasia
      ii) Osteogenesis imperfecta
      iii) Sclerosing osseous dysplasias
         (1) Melorheostosis
         (2) Osteopathia striata
         (3) Osteopoikilosis
      iv) Osteopetrosis
      v) Cleidocranial dysplasia/dysostosis
      vi) Neurofibromatosis
      vii) Cerebral palsy
      viii) Mucopolysaccharidosis
      ix) Trisomy 21
      x) Macrodystrophia lipomatosa
      xi) Nail-patella syndrome
      xii) Wormian bones
      xiii) Thanatophoric dwarf
      xiv) Marfan syndrome
      xv) Tuberous sclerosis

4) Infections (including routes of spread and predisposing factors)
   a) Osteomyelitis
5) Tumors and Tumor-Like Conditions
   a) Demographics
   b) Imaging features and description
   c) Benign and malignant primary bone lesions
      i) Cartilaginous tumors
         (1) Osteochondroma
         (2) Enchondroma
         (3) Chondroblastoma
         (4) Periosteal chondroma
         (5) Chondromyxoid fibroma
         (6) Chondrosarcoma
      ii) Osteogenic tumors
         (1) Osteoid osteoma
         (2) Osteoblastoma
         (3) Osteoma
         (4) Osteosarcoma
            (a) Conventional osteosarcoma
            (b) Telangiectatic osteosarcoma
            (c) Parosteal (surface) osteosarcoma
      iii) Fibrohistiocytic tumors
         (1) Non-ossifying fibroma
      iv) Ewing sarcoma
      v) Hematopoietic tumors
         (1) Plasma cell myeloma (Myeloma)
         (2) Solitary plasmacytoma of bone
         (3) Primary non-Hodgkin lymphoma of bone
         (4) Giant cell tumor of bone
      vi) Notochordal tumors
         (1) Chordoma
      vii) Vascular tumors
Core Examination Study Guide

(1) Hemangioma

viii) Lipogenic and epithelial tumors
   (1) Lipoma
   (2) Adamantinoma

ix) Tumors of undefined neoplastic nature
   (1) Aneurysmal bone cyst (primary and secondary)
   (2) Unicameral bone cyst
   (3) Fibrous dysplasia
   (4) Osteofibrous dysplasia
   (5) Langerhans cell histiocytosis

d) Bone metastases
   i) Primary bone tumor vs metastases
   ii) Blastic vs lytic and other differentiating features

e) Tumor syndromes
   i) Enchondromatosis (Ollier and Maffucci)
   ii) Polyostotic fibrous dysplasia, McCune-Albright, and Mazabraud
   iii) Hereditary multiple osteochondromas
   iv) Neurofibromatosis

f) Malignant transformation
   i) Paget
   ii) Radiation induced
   iii) Tumor syndromes (see above)

(g) Benign and malignant soft tissue tumors
   i) Adipocytic tumors
      (1) Lipoma
      (2) Liposarcoma
      (3) Lipomatosis of nerve (fibrolipomatous hamartoma of nerve)
   ii) Fibroblastic/myofibroblastic tumors
      (1) Nodular fasciitis
      (2) Fibromatosis
      (3) Elastofibroma
      (4) Dermatofibrosarcoma protuberans
      (5) Fibrosarcoma
   iii) So-called fibrohistiocytic tumors
      (1) Tenosynovial giant cell tumor (includes localized and diffuse forms of pigmented villonodular synovitis as well as extra-articular giant cell tumor)
   iv) Smooth-muscle tumors
      (1) Leiomyosarcoma
   v) Pericytic tumors
      (1) Glomus
   vi) Skeletal-muscle tumors
      (1) Rhabdomyosarcoma
   vii) Vascular tumors
      (1) Hemangioma
      (2) Lymphangioma
   viii) Nerve sheath tumors
      (1) Schwannoma
6) Trauma and Overuse
   a) General principles of osseous trauma and overuse
      i) Types
         (1) Closed vs open
         (2) Pathologic
         (3) Fatigue
         (4) Insufficiency
            (a) Subchondral insufficiency fracture
         (5) Pediatric
            (a) Nonaccidental
            (b) Salter-Harris
            (c) Greenstick, bowing, and torus
            (d) Slipped capital femoral epiphysis
      ii) Relationship of force and deformation to fracture
      iii) Mechanisms of injury
      iv) Fracture patterns, bone contusions, and associated injuries
      v) Fracture description
      vi) Fracture healing
      vii) Complications of fracture healing
      viii) Fracture eponyms and overuse syndromes
   b) Dislocations
   c) General principles of soft-tissue trauma and overuse
      i) Tendinosis, tendon tears, and tenosynovitis
      ii) Muscle injuries and grading
      iii) Ligamentous injuries and grading
      iv) Bursitis
      v) Hematomas
      vi) Degloving injuries and Morel-Lavallee lesions
      vii) Myositis ossificans
      viii) Compartment syndrome
      ix) Myonecrosis
d) Site-specific entities (should know important fractures and dislocations for all sites)
   i) Shoulder
      (1) Labral and ligamentous tears
         (a) Bankart and Bankart variants
         (b) Superior labrum anterior posterior (SLAP; not including subtypes)
         (c) Paralabral cysts
         (d) Humeral avulsion glenohumeral ligament (HAGL)
      (2) Rotator cuff
         (a) Partial vs full-thickness
         (b) Acute vs chronic
         (c) Tendinopathy (including hydroxyapatite deposition disease/calcific tendinosis)
      (3) Acromial-clavicular injuries
      (4) Biceps tears and dislocations
      (5) Pectoralis major injuries
      (6) Adhesive capsulitis
      (7) Impingement disorders
      (8) Little leaguer shoulder
   ii) Elbow
      (1) Biceps and triceps tears
      (2) Epicondylitis and tears of the common flexor and extensor tendons
      (3) Tears of the medial and lateral collateral ligamentous complexes
      (4) Osteochondral lesions
      (5) Little leaguer elbow
   iii) Wrist and hand
      (1) Ulnar abutment
      (2) Triangular fibrocartilage, scapholunate, and lunatotriquetral ligament tears
      (3) De Quervain tenosynovitis
      (4) Intersection syndrome
      (5) Tendon tears and dislocations
      (6) Scapholunate advanced collapse
      (7) DISI, VISI, and perilunate wrist instability
      (8) Gamekeeper and Stener lesions
   iv) Spine (see neuroradiology section)
   v) Hip
      (1) Labral tears and paralabral cysts
      (2) Femoroacetabular impingement
      (3) Tears of the gluteal and hamstring tendons
      (4) Apophyseal injuries
      (5) Psoas tendon abnormalities
   vi) Knee and leg
      (1) Meniscus
         (a) Normal variants and pitfalls
         (b) Types of tears
         (c) Parameniscal and Intrameniscal cysts
      (2) Tears and abnormalities of the cruciate and collateral ligaments
      (3) Posterolateral corner injury
      (4) Iliotibial band syndrome
(5) Osteochondral lesions
(6) Patellar tracking disorder
(7) Tennis leg
(8) Tendon tears
(9) Jumper’s knee, Sinding-Larsen-Johansson, and Osgood-Schlatter disease

vii) Ankle and foot
(1) Plantar fasciitis
(2) Sinus tarsi syndrome
(3) Tendon tears and dislocations
(4) Impingement disorders
(5) Haglund deformity
(6) Ligamentous tears
(7) Osteochondral defect

7) Nerve Entrapment and Associated Disorders
   a) General principles of nerve entrapment
   b) Specific disorders
      i) Suprascapular nerve entrapment
      ii) Acute brachial neuritis (Parsonage-Turner)
      iii) Quadrilateral space syndrome
      iv) Carpal, cubital, and tarsal tunnel syndromes
      v) Sciatic and peroneal nerve entrapment
      vi) Radial, median, posterior interosseous, and ulnar nerve entrapment
      vii) Obturator and femoral nerve entrapment

8) Metabolic Disorders
   a) Osteoporosis and osteopenia
   b) Hyperparathyroidism
   c) Thyroid acropachy
   d) Hypothyroidism
   e) Scurvy
   f) Rickets and osteomalacia
   g) Renal osteodystrophy
   h) Tumoral calcinosis
   i) Calciphylaxis
   j) Acromegaly
   k) Bisphosphonate-related fractures
   l) Intoxication/poisoning
      i) Heavy metal/lead
      ii) Hypervitaminosis A and D
      iii) Fluorosis

9) Hematologic and Marrow Disorders
   a) Sickle cell and thalassemia
   b) Hemophilia
   c) Myelofibrosis
d) Extramedullary hematopoiesis
e) Marrow reconversion
f) Leukemia and myelodysplasia
g) Radiation-induced marrow changes
h) Mastocytosis
i) Gaucher disease

10) Osteonecrosis and Related Disorders
   a) Osteonecrosis
      i) Etiology
      ii) Imaging characteristics
   b) Osteochondritis dissecans
   c) Bone marrow edema syndromes (transient osteoporosis of the hip)
   d) Osteochondroses
      i) Legg-Calve-Perthes
      ii) Kienböck
      iii) Kohler
      iv) Panner
      v) Freiberg
      vi) Sever
      vii) Scheuermann
      viii) Tibia vara (Blount disease)

11) Miscellaneous
    a) Paget disease
    b) Sarcoidosis
    c) Hypertrophic osteoarthropathy (primary and secondary)
    d) Periosteal changes from venous stasis
    e) Infantile cortical hyperostosis/Caffey disease
    f) Complex regional pain syndrome (reflex sympathetic dystrophy)
    g) Muscle infarction

12) Arthropathy
    a) General features
       i) Distribution and demographics
       ii) Imaging findings
    b) Osteoarthritis (including erosive osteoarthritis)
    c) Inflammatory
       i) Rheumatoid arthritis
       ii) Psoriatic arthritis
       iii) Reactive arthritis
       iv) Ankylosing spondylitis
       v) Enteropathic arthritis
       vi) Juvenile idiopathic arthritis
d) Connective tissue diseases
   i) Systemic lupus erythematosus (SLE)
   ii) Scleroderma
   iii) Dermatomyositis
   iv) Polymyositis

e) Crystal-associated
   i) Gout
   ii) Calcium pyrophosphate deposition disease (CPPD)
   iii) Hydroxyapatite deposition disease (HADD)

f) Neuropathic

g) Miscellaneous
   i) Hemochromatosis
   ii) Pigmented villonodular synovitis
   iii) Synovial chondromatosis
   iv) Osteitis condensans illii
   v) Osteitis pubis and pubic instability
   vi) Degenerative disk disease
   vii) Diffuse idiopathic sclerosing hyperostosis (DISH)
   viii) Ossification of the posterior longitudinal ligament
   ix) Alkaptonuria/ochronosis
   x) Lipoma arborescens
   xi) Post-traumatic osteolysis
   xii) Scheuermann disease

13) Postoperative Imaging
   a) Internal and external fixation (including spine)
      i) Important types of hardware
      ii) Appropriate positioning of hardware
      iii) Complications
         (1) Infection
         (2) Loosening
         (3) Component fracture
   b) Arthroplasty
      i) Important types
      ii) Appropriate positioning
      iii) Complications
         (1) Infection
         (2) Loosening, cement fractures, component shift, and subsidence
         (3) Osteolysis (particle disease)
         (4) Component (polyethylene liner or prosthesis) wear, breakage, and dislocation
         (5) Periprosthetic fracture
         (6) Heterotopic ossification
         (7) Metallosis
   c) Other postoperative imaging
      i) Normal vs abnormal appearance of the following surgeries:
(1) Anterior cruciate ligament
(2) Meniscus
(3) Vertebral augmentation
(4) Sarcoma resection
(5) Rotator cuff
(6) Glenoid labrum
(7) Osteochondral lesions

14) ACR Appropriateness Criteria specific to Musculoskeletal Imaging
Neuroradiology

1) Technique and Indications: Understand the Basic Principles Behind and Indications for Use of Methods of Examination
   a) Radiography
   b) CT
   c) MR
   d) Ultrasound
   e) Angiography
   f) Advanced imaging techniques
      i) MR angiography
      ii) CT angiography
      iii) CT perfusion
      iv) MR perfusion
      v) Diffusion-weighted imaging
      vi) MR spectroscopy
      vii) Functional MRI
      viii) Diffusion tensor imaging
      ix) Myelography
      x) Cisternography
     xi) PET CT and other nuclear medicine imaging techniques

Be able to appropriately choose study types for a variety of clinical situations, and recognize the strengths and weaknesses of each type of imaging exam.

2) Brain
   a) Normal anatomy
      i) Brain parenchyma
      ii) Ventricular system
      iii) Extra-axial spaces
      iv) Pial and dural coverings
      v) Cranial nerves
      vi) Arterial and venous structures
      vii) Skull and surrounding soft tissues
      viii) Intracranial arterial and venous structures on imaging studies
(1) CT angiography
(2) MR angiography
(3) Catheter angiography

Understand the function of the anatomic structures and how they are affected by various pathologies.

b) White matter disease (inherited)
   i) Adrenoleukodystrophy
   ii) Metachromatic leukodystrophy
   iii) Alexander disease
   iv) Canavan disease
   v) Krabbe disease
   vi) Pelizaeus-Merzbacher disease
   vii) Phenylketonuria and other amino acid disorders

c) Neurodegenerative disorders
   i) Aging brain
   ii) Alzheimer disease
   iii) Other cortical dementias
   iv) Parkinson disease
   v) Cerebellar degeneration
   vi) Amyotrophic lateral sclerosis
   vii) Wallerian degeneration
   viii) Huntington disease
   ix) Fahr disease
   x) Wilson disease
   xi) Hallervorden-Spatz disease
   xii) Leigh disease
   xiii) Tay-Sachs disease
   xiv) Hurler syndrome
   xv) MELAS syndrome

d) Infection/inflammation/demyelinating
   i) Viral
   ii) Bacterial
   iii) Mycobacterial
   iv) Fungal
   v) Parasitic
   vi) Prion infections
   vii) Congenital and neonatal infections
       (1) Cytomegalovirus (CMV)
       (2) Toxoplasmosis
       (3) Herpesvirus (HSV)
       (4) HIV
       (5) Varicella
(6) Rubella
(7) Enterovirus
viii) Non-infectious inflammatory processes
   (1) Chemical meningitis
   (2) Limbic encephalitis
   (3) Lymphocytic hypophysitis
   (4) Granulomatous processes
      (a) Sarcoidosis
      (b) Histiocytosis
ix) White matter inflammatory conditions
   (1) Multiple sclerosis
   (2) Viral and post-viral demyelination
e) Congenital/developmental
   i) Chiari malformations
   ii) Cephaloceles
   iii) Corpus callosum anomalies
   iv) Holoprosencephalies
   v) Septo-optic dysplasia
   vi) Sulcation and migrational disorders
   vii) Posterior fossa malformations
   viii) Cysts
ix) Neurocutaneous syndromes
   (1) Neurofibromatosis (NF) I and II
   (2) Tuberous sclerosis
   (3) von Hippel-Lindau disease
   (4) Sturge-Weber syndrome
   (5) Basal cell nevus syndrome
   (6) Klippel-Trenaunay-Weber syndrome
   (7) Wyburn-Mason syndrome
   (8) Rendu-Osler-Weber syndrome
   (9) Ataxia- telangiectasia
   (10) Neurocutaneous melanosis
x) Normal patterns of cortical and white matter development, and deviations from normal
   (1) Cortical dysplasias
   (2) Hemimegalencephaly

Recognize and be familiar with the imaging appearance and clinical presentation of mesial temporal sclerosis and other seizure-associated conditions.
f) Cyst and hydrocephalus
   i) Communicating and obstructive hydrocephalus
   ii) Arachnoid cyst
   iii) Colloid cyst
iv) Rathke cleft cyst
v) Neuroepithelial cyst
vi) Disorders of cerebrospinal fluid hydrodynamics
   (1) Increased intracranial pressure from hydrocephalus and shunt malfunction
   (2) Intracranial hypotension
   (3) Complications of cerebrospinal fluid diversion procedures

  g) Tumors and tumorlike conditions
     i) Locations
        (1) Parenchymal
        (2) Meningeal
        (3) Pineal region
        (4) Intraventricular
        (5) Sellar/suprasellar
        (6) Cerebellopontine angle
        (7) Skull base
        (8) Cavernous sinus
        (9) Foramen magnum
     ii) Tumor types
        (1) Low-grade and malignant astrocytomas
        (2) Glioblastoma multiforme
        (3) Gliosarcoma
        (4) Gliomatosis cerebri
        (5) Pleomorphic xanthoastrocytoma
        (6) Pilocytic astrocytoma
        (7) Subependymal giant cell astrocytoma
        (8) Oligodendroglioma
        (9) Ependymoma
        (10) Subependymoma
        (11) Choroid plexus tumors
        (12) Meningioma
        (13) Hemangiopericytoma
        (14) Hemangioblastoma
        (15) Ganglioglioma
        (16) Gangliocytoma
        (17) Central neurocytoma
        (18) Dysembryoplastic neuroepithelial tumor (DNET)
        (19) Lhermitte-Duclos syndrome
        (20) Germ cell tumors
        (21) Primitive neuroectodermal tumor (PNET)
        (22) Lymphoma
        (23) Leukemia
        (24) Myeloma
        (25) Schwannoma
        (26) Neurofibroma
        (27) Malignant peripheral nerve sheath tumor
(28) Craniopharyngioma
(29) Pituitary adenoma
(30) Chordoma
(31) Chondrosarcoma
(32) Dermoid
(33) Epidermoid
(34) Lipoma

In the case of primary brain tumors, be familiar with differentiating imaging findings for various tumor grades. Recognize imaging appearance in postoperative and post-treatment changes.

h) Trauma
   i) Subarachnoid hemorrhage
   ii) Epidural and subdural hematoma
   iii) Contusion
   iv) Axonal injury
   v) Diffuse cerebral edema
   vi) Herniation patterns
   vii) Complications and sequelae of head trauma
      (1) Ischemia
      (2) Infarction
      (3) Secondary hemorrhage
      (4) Pneumocephalus
      (5) Cerebrospinal fluid leak
      (6) Encephalomalacia
   viii) Non-accidental trauma

i) Vascular pathology: Clinical presentation of, complications from, and treatment options for:
   i) Aneurysm (1)
      Saccular (2)
      Mycotic (3)
      Traumatic (4)
      Oncotic
      (5) Flow-related
      (6) Drug-related
      (7) Vasculopathic
      (8) Fusiform
      (9) Dissecting
      (10) Pseudoaneurysm
   ii) Vascular malformations
      (1) Pial (2)
      Dural (3)
      Mixed
      (4) Arteriovenous-fistulae
(5) Cavernous angiomas
(6) Capillary telangiectasias
(7) Developmental venous anomalies
(8) Vein of Galen malformations
(9) Venous varix

iii) Stroke
   (1) Arterial
   (2) Venous
   (3) Vasculitic, including specific patterns
   (4) Hypoxic-anoxic encephalopathy
   (5) Vasculitis
   (6) Posterior reversible encephalopathy syndrome
   (7) Vascular occlusive disease

iv) Intracranial hemorrhage
   (1) Age of blood products on CT and MRI
   (2) Patterns of hemorrhage with regard to causative factors
      (a) Trauma
      (b) Neoplasm
      (c) Aneurysm
      (d) Vascular malformation
      (e) Vasculitis
      (f) Non-aneurysmal subarachnoid hemorrhage
      (g) Hypertension
      (h) Hemorrhagic infarct (arterial and venous)
      (i) Amyloid angiopathy

3) Spine
   a) Normal anatomy
      i) Bony vertebral anatomy
      ii) Intervertebral discs
      iii) Facet joints
      iv) Ligaments
      v) Spinal cord
      vi) Nerve roots and plexuses
      vii) Meninges
      viii) Intradural and extradural spaces
      ix) Surrounding soft tissues

   b) Congenital/developmental
      i) Chiari malformations
      ii) Spinal dysraphism (open and occult)
      iii) Tethered cord
      iv) Caudal regression syndrome
      v) Spinal lipomas
      vi) Sacral meningocele
vii) Sacrococcygeal teratoma
viii) Split notochord syndromes
ix) Enterogenous cyst
x) Scoliosis
xi) Fusion anomalies
xii) Segmentation anomalies
xiii) Neurofibromatosis type I
xiv) Neurofibromatosis type II
xv) von Hippel-Lindau disease
c) Degenerative disease
  i) Normal aging
  ii) Disc degeneration
  iii) Disc bulges and herniations (including appropriate descriptive terminology)
  iv) Spondylosis
  v) Arthrosis
  vi) Synovial cyst
  vii) Spondylolisthesis
  viii) Spondylolysis
  ix) Spinal stenosis
  x) Ossification of the posterior longitudinal ligament (OPLL)
  xi) Diffuse idiopathic sclerosing hyperostosis (DISH)
  xii) Scheuermann disease
  xiii) Arthritides
  xiv) Postoperative spine
d) Infection/inflammatory/demyelinating in specific anatomic sites
  i) Arachnoiditis
  ii) Diskitis
  iii) Osteomyelitis
  iv) Epidural infection
  v) Subdural infection
  vi) Subarachnoid infection
  vii) Meningitis
  viii) Myelitis
  ix) Spinal cord abscess
e) Infection/inflammatory/demyelinating-specific pathologies
  i) Bacterial
  ii) Mycobacterial
  iii) Fungal
  iv) Viral
  v) Parasitic
  vi) Granulomatous
vii) Transverse myelitis  
viii) HIV myelopathy  
ix) Radiation-induced myelitis  
x) Acute disseminated encephalomyelitis (ADEM)  
xi) Multiple sclerosis

f) Trauma  
i) Cervical, thoracic, and lumbosacral fracture  
ii) Osteoporotic compression fracture  
iii) Subluxation  
iv) Dislocation  
v) Spinal cord injury and its sequelae  
vi) Epidural and subdural hematoma  
vii) Plexus injuries

g) Vascular  
i) Spinal cord ischemia and infarction (arterial & venous)  
ii) Arteriovenous malformations  
   (1) Dural arteriovenous fistula (AVF)  
   (2) Glomus malformations  
   (3) Juvenile type malformations  
   (4) Intradural extramedullary AVF  
   (5) Cavernous angiomas

h) Tumors and tumorlike masses: benign and malignant neoplasms of the vertebral column, spinal cord, and nerves  
i) Schwannoma  
ii) Neurofibroma  
iii) Malignant peripheral nerve sheath tumor  
iv) Meningioma  
v) Dermoid  
vi) Epidermoid  
vii) Paragangioma  
viii) Astrocytoma  
ix) Ependymoma  
x) Hemangioblastoma  
xii) Lymphoma  
xiii) Leukemia  
xiv) Myeloma  
ixv) Plasmacytoma  
xvi) Chordoma  
xvii) Chondrosarcoma  
xviii) Osteosarcoma  
xviii) Fibrosarcoma
xix) Ewing sarcoma
xx) Hemangiomas
xxi) Osteoblastoma
xxii) Osteoid osteoma
xxiii) Osteochondroma
xxiv) Giant cell tumor
xxv) Aneurysmal bone cyst
xxvi) Angiolipoma
xxvii) Eosinophilic granuloma
xxviii) Pathologic fractures
xxix) Metastatic disease

i) Miscellaneous
   i) Arachnoid cyst
   ii) Parameningeal cyst
   iii) Spinal cord herniation

4) Extracranial Head and Neck
   a) Normal anatomy—bone and soft tissues
      i) Orbits
      ii) Paranasal sinuses
      iii) Facial bones
      iv) Skull base
      v) Temporal bone, including temporomandibular joint (TMJ)
      vi) Nasal cavity
      vii) Oral cavity
      viii) Oropharynx
      ix) Nasopharynx
      x) Hypopharynx
      xi) Larynx
      xii) Neck spaces (suprahyoid and infrahyoid)
      xiii) Classification of lymph node level

   b) Normal anatomy—vascular: normal extracranial arterial and venous structures on vascular imaging modalities
      i) CT angiography
      ii) MR angiography
      iii) Ultrasound
      iv) Catheter angiography

   c) Infectious/inflammatory/granulomatous
      i) Orbit
         (1) Preseptal cellulitis
         (2) Orbital cellulitis
(3) Subperiosteal phlegmon and abscess
(4) Extension of fungal sinus disease
(5) Pseudotumor
(6) Thyroid orbitopathy
(7) Sarcoid
(8) Lacrimal adenitis
(9) Wegener granulomatosis
(10) Tolosa-Hunt syndrome
(11) Optic neuritis

ii) Sinonasal cavity/facial bones
(1) Osteomyelitis (2)
Acute sinusitis (3)
Chronic sinusitis
(4) Complications of sinusitis
(5) Fungal infection
   (a) Immunocompromised and immunocompetent patients
   (b) Allergic fungal sinusitis
(6) Polyps
(7) Polyposis
(8) Mucocele
(9) Retention cyst
(10) Antrochoanal polyp
(11) Sarcoid
(12) Wegener granulomatosis

iii) Skull base and temporal bone
(1) Osteomyelitis
(2) Necrotizing otitis externa
(3) Petrous apicitis
(4) Otitis externa
(5) Otitis media
(6) Mastoiditis
(7) Cholesteatoma
(8) Ramsey-Hunt syndrome
(9) Labyrinthitis
(10) Labyrinthitis ossificans
(11) Bell palsy
(12) Otosclerosis

iv) Oral cavity, pharynx, supra- and infrahyoid neck
(1) Odontogenic infections
(2) Infections of salivary gland origin
(3) Tonsillitis
(4) Adenoiditis
(5) Cellulitis, phlegmon, and abscess involving neck spaces
(6) Sjögren disease
(7) Non-neoplastic lymphadenopathy  
   (a) Viral  
   (b) Bacterial  
   (c) Mycobacterial  
   (d) Granulomatous  
(8) Thyroiditis (acute and chronic, e.g., Hashimoto)

d) Tumors and tumor-like conditions  
i) Orbit  
   (1) Optic nerve sheath meningioma  
   (2) Optic glioma  
   (3) Lacrimal gland tumors  
   (4) Rhabdomyosarcoma  
   (5) Retinoblastoma  
   (6) Ocular hamartoma  
   (7) Uveal melanoma  
   (8) Metastases  
   (9) Cavernous hemangiomas  
   (10) Vasoformative lesions  
      (a) Infantile hemangiomas  
      (b) Lymphatic/venous malformations  
   (11) Lymphoma/leukemia  

ii) Sinonasal cavity and facial bones  
   (1) Squamous cell carcinoma  
   (2) Undifferentiated carcinoma  
   (3) Lymphoma  
   (4) Melanoma  
   (5) Esthesioneuroblastoma  
   (6) Inverted papilloma  
   (7) Minor salivary gland neoplasms  
   (8) Schwannoma and meningioma  
   (9) Juvenile nasal angiofibroma  
   (10) Vasoformative lesions  
      (a) Infantile hemangiomas  
      (b) Lymphatic/venous malformations  
      (c) Arteriovenous malformations  
   (11) Hemangiopericytoma  
   (12) Rhabdomyosarcoma  
   (13) Osteoma  
   (14) Osteoblastoma  
   (15) Giant cell tumor  
   (16) Rhabdomyosarcoma  
   (17) Malignant fibrous histiocytoma  
   (18) Plasmacytoma
(19) Paget disease
(20) Fibrous dysplasia
(21) Ossifying fibroma and other fibroosseous lesions
(22) Myxoma
(23) Chondroma
(24) Chondrosarcoma
(25) Osteosarcoma
(26) Ewing sarcoma
(27) Ameloblastoma
(28) Aneurysmal bone cyst
(29) Odontogenic cysts and tumors
(30) Langerhans cell histiocytosis
(31) Metastases

iii) Skull base and temporal bone
(1) Hemangiomas
(2) Angiofibroma
(3) Schwannoma
(4) Neurofibroma
(5) Teratoma
(6) Dermoid
(7) Pituitary adenoma
(8) Germinoma
(9) Lymphoma
(10) Nasopharyngeal carcinoma
(11) Salivary gland tumors
(12) Chloroma
(13) Plasmacytoma
(14) Metastases
(15) Myeloma
(16) Chondrosarcoma
(17) Chordoma
(18) Endolymphatic sac tumor
(19) Paraganglioma
(20) Adenoma
(21) Neuroma
(22) Langerhans cell histiocytosis/eosinophilic granuloma
(23) Osteoblastoma
(24) Giant cell tumor
(25) Pigmented villonodular synovitis
(26) Rhabdomyosarcoma
(27) Paget disease (28)
Fibrous dysplasia (29)
Osteoma/exostosis (30)
Meningioma
iv) Oral cavity, pharynx, supra, and infrahyoid neck
   (1) Malignant adenopathy
   (2) Lymphoma
   (3) Squamous cell carcinoma
   (4) Schwannoma
   (5) Neuroma
   (6) Neurofibroma
   (7) Goiter
   (8) Thyroid neoplasms
   (9) Parathyroid neoplasms
   (10) Salivary gland neoplasms
   (11) Vasoformative lesions
        (a) Infantile hemangiomas
        (b) Lymphatic/venous malformations
        (c) Arteriovenous malformations
   (12) Paraganglioma
   (13) Lipoma/liposarcoma

e) Cystic lesions of the head and neck
   i) Branchial cleft cysts (types I-IV)
   ii) Thyroglossal duct cyst
   iii) Ranula
   iv) Dermoid/epidermoid
   v) Thymic cyst
   vi) Cystic hygroma (lymphangioma)
   vii) Laryngocele
   viii) Cystic lymph nodes

f) Trauma
   i) Orbital fractures
   ii) Soft tissue injuries of the globe and orbit
   iii) Maxillofacial fracture
   iv) Mandibular fractures
   v) Temporomandibular joint (TMJ) fracture/dislocation
   vi) Skull base fractures
   vii) Temporal bone fractures (including classification systems)
        (1) Longitudinal/transverse
        (2) Otic capsule spared/involved
   viii) Laryngeal fractures

g) Vascular
   i) Orbit
      (1) Venous varix
      (2) Hemangiomas
3) Lymphangioma
4) Superior ophthalmic vein thrombosis
5) Carotid-cavernous fistula
ii) Sinonasal cavity/facial bones
iii) Skull base/temporal bone
   1) Dissection
   2) Aneurysm
   3) Pseudoaneurysm
   4) Aberrant internal carotid artery
   5) Persistent stapedial artery
   6) Jugular dehiscence
   7) Jugular diverticulum
   8) High-riding jugular bulb
iv) Oral cavity, pharynx, supra- and infrahyoid neck
   1) Medial course of internal carotid artery
   2) Dissection
   3) Thrombosis
   4) Occlusion
   5) Pseudoaneurysm
   6) Fibromuscular dysplasia
   7) Aneurysm

h) Congenital
   i) Orbit
      1) Sphenoid wing dysplasia
      2) Septooptic dysplasia
      3) Coloboma
      4) Congenital glaucoma
      5) Persistent hyperplastic primary vitreous (PHPV)
      6) Coats disease
      7) Toxocariasis
      8) Infantile hemangiomas
      9) Lymphatic malformation
     10) Dermoid
   ii) Sinonasal cavity/facial bones
      1) Hypoplasia
      2) Aplasia
      3) Down syndrome
      4) Kartagener syndrome
      5) Cephaloceles/nasal glioma
      6) Choanal atresia
   iii) Skull base/temporal bone
      1) Cephaloceles
      2) Arachnoid cyst
(3) External auditory canal atresia
(4) Aberrant facial nerve course
(5) Congenital cholesteatoma
(6) Ossicular deformities
(7) Large vestibular aqueduct syndrome
(8) Mondini defect
(9) Michel aplasia

iv) Oral cavity, pharynx, and supra- and infrahyoid neck

i) Branchial cleft cysts (types I-IV)
   i) Thyroglossal duct cyst
   ii) Lingual thyroid
   iii) Dermoid/epidermoid
   iv) Thymic cyst
v) Vasoformative lesions
   (1) Infantile hemangiomas
   (2) Lymphatic/venous malformations
   (3) Arteriovenous malformations
Nuclear Radiology

1) Breast
   a) Benign neoplasm
      i) Radiopharmaceuticals: $^{18}$F FDG
      ii) Imaging techniques: PET and PET-CT
      iii) Typical indications: breast lesion
   b) Malignant neoplasm, primary
      i) Radiopharmaceuticals: $^{18}$F FDG
      ii) Imaging techniques: PET and PET-CT
      iii) Typical indications: breast lesion
   c) Malignant neoplasm, metastatic
      i) Radiopharmaceuticals: $^{99m}$Tc HDP/MDP; $^{18}$F FDG, and $^{18}$F NaF
      ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
      iii) Typical indications: staging disease and treatment strategy
   d) Lymphatic mapping/sentinel lymph node (SLN)
      i) Radiopharmaceuticals: $^{99m}$Tc sulfur colloid
      ii) Injection techniques: intradermal, peritumoral, and periareolar
      iii) Imaging and localization techniques: planar, SPECT and/or SPECT-CT, and intraoperative gamma probe
      iv) Typical indications: identification and localization of SLN for intraoperative gamma probe-directed sampling
   e) Infection and inflammation
      i) Radiopharmaceuticals: $^{67}$Ga citrate, $^{111}$In/$^{99m}$Tc WBCs; $^{18}$F FDG
      ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
      iii) Typical indications: breast abscess and inflammation
   f) Normal and other
      i) Radiopharmaceuticals: all of above
      ii) Imaging techniques: all of above
      iii) Typical indications: all of above
   g) Artifacts and quality control
      i) Patient Issues: preparation, motion, positioning, and contamination
      ii) Radiopharmaceutical issues: preparation, administration technique, and altered biodistribution
      iii) Technical issues: instrumentation, acquisition and processing, transmission imaging, and quantification (SUV)

2) Cardiac
   a) Perfusion imaging, coronary artery disease
      i) Radiopharmaceuticals: $^{99m}$Tc sestamibi/tetrofosmin, $^{201}$Tl chloride; $^{13}$N NH$_3$ (ammonia), and $^{82}$Rb chloride
      ii) Stress protocols: exercise, pharmacologic (regadenoson [Lexiscan] and dobutamine)
      iii) Imaging techniques: SPECT, ECG-gated SPECT and/or SPECT-CT; PET and PET-CT
iv) Quantitative analysis: left ventricular ejection fraction (LVEF), systolic function, diastolic function, summed stress score (SSS), and transient ischemic dilatation (TID)

v) Typical indications: perfusion, function, and wall motion; ischemia vs infarction and risk stratification

b) Perfusion imaging, non-coronary artery disease
i) Radiopharmaceuticals: $^{99m}$Tc sestamibi/tetrofosmin, $^{201}$Tl chloride; $^{13}$N NH3 (ammonia), $^{82}$Rb chloride
ii) Stress protocols: exercise, pharmacologic (regadenoson [Lexiscan] and dobutamine)
iii) Imaging techniques: SPECT, ECG-gated SPECT and/or SPECT-CT; PET and PET-CT
iv) Quantitative analysis: left ventricular ejection fraction (LVEF), systolic function, diastolic function, summed stress score (SSS), transient ischemic dilatation (TID)

v) Typical indications: perfusion, function, and wall motion; cardiomyopathy

c) Metabolism and viability
i) Radiopharmaceuticals: $^{201}$Tl chloride; $^{18}$F FDG
ii) Imaging techniques: SPECT, ECG-gated SPECT and/or SPECT/CT; PET and PET/CT
iii) Typical Indications: hibernating/viable myocardium; pre-operative evaluation

d) Function: multigated acquisition (MUGA) and first-pass studies
i) Radiopharmaceuticals: $^{99m}$Tc RBCs and $^{99m}$Tc DTPA
ii) Imaging techniques: ECG-gated planar; ECG-gated SPECT
iii) Quantitative analysis: left ventricular ejection fraction (LVEF), right ventricular ejection fraction (RVEF)

iv) Typical indications: baseline function, cardiotoxicity after chemotherapy

e) Shunts
i) Radiopharmaceuticals: $^{99m}$Tc MAA
ii) Imaging techniques: planar, SPECT
iii) Quantitative analysis: quantification of shunt

iv) Typical indications: right-to-left shunt

f) Infection and inflammation
i) Radiopharmaceuticals: $^{67}$Ga citrate, $^{111}$In/$^{99m}$Tc WBCs; $^{18}$F FDG
ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
iii) Typical indications: pericarditis/myocarditis, myocardial/valvular abscess, and sarcoidosis

g) Normal and other
i) Radiopharmaceuticals: all of above
ii) Imaging techniques: all of above

iii) Typical indications: all of above

h) Artifacts and quality control
i) Patient issues: preparation, motion, positioning, and contamination; arrhythmia
ii) Radiopharmaceutical issues: preparation, administration technique and timing, and altered biodistribution

iii) Technical issues: instrumentation, acquisition and processing, attenuation-correction, ECG-gating, and quantification (LVEF, RVEF, ED and ES function, SSS, and TID)
3) **Gastrointestinal (GI)**
   a) Liver and spleen
      i) Radiopharmaceuticals: $^{99m}$Tc sulfur colloid, $^{99m}$Tc MAA, $^{99m}$Tc RBCs, damaged $^{99m}$Tc RBCs
      ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
      iii) Typical indications: cirrhosis, hepatic arterial perfusion/systemic shunting before radioembolization, cavernous hemangioma, and accessory spleen/splenosis
   b) Biliary
      i) Radiopharmaceuticals: $^{99m}$Tc IDA analogs
      ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
      iii) Pharmacologic protocols: morphine sulfate and sinalide (CCK)
      iv) Quantitative analysis: gallbladder ejection fraction (GBEF)
      v) Typical indications: acute cholecystitis, chronic acalculous cholecystitis, common bile duct obstruction, biliary ectasia, bile leak, and postoperative complications
   c) Bowel: GI bleeding
      i) Radiopharmaceuticals: $^{99m}$Tc RBCs and $^{99m}$Tc pertechnetate
      ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
      iii) Typical indications: active GI bleeding site and varices; Meckel diverticulum
   d) Bowel: GI motility
      i) Radiopharmaceuticals: $^{99m}$Tc sulfur colloid as solid meal (e.g., eggs)/as liquid meal
      ii) Imaging techniques: planar
      iii) Quantitative analysis: T ½, 4-hour retained activity, and geometric mean methodology
      iv) Typical indications: gastroparesis, gastroesophageal reflux, and aspiration
   e) Benign neoplasm
      i) Radiopharmaceuticals: $^{99m}$Tc sulfur colloid, $^{99m}$Tc IDA; $^{18}$F FDG
      ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
      iii) Typical indications: liver mass (e.g., fibronodular hyperplasia)
   f) Malignant neoplasm, primary
      i) Radiopharmaceuticals: $^{67}$Ga citrate, $^{18}$F FDG
      ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
      iii) Typical indications: hepatocellular cancer (HCC), GI stromal tumor, lymphoma, and esophageal/gastric/biliary/pancreatic/colorectal/peritoneal cancer
   g) Malignant neoplasm, metastatic
      i) Radiopharmaceuticals: $^{18}$F FDG
      ii) Imaging techniques: PET and PET-CT
      iii) Typical indications: staging disease and treatment strategy
   h) Infection and inflammation
      i) Radiopharmaceuticals: $^{67}$Ga citrate, $^{111}$In/$^{99m}$Tc WBCs; $^{18}$F FDG
      ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
      iii) Typical indications: abscess and inflammatory bowel disease
   i) Normal and other
4) **Musculoskeletal**
   a) Benign neoplasm
      i) Radiopharmaceuticals: $^{99m}$Tc HDP/MDP; $^{18}$F NaF, $^{18}$F FDG
      ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
      iii) Typical indications: radiographically visible or occult lesions, e.g., osteoid osteoma
   b) Malignant neoplasm, primary
      i) Radiopharmaceuticals: $^{99m}$Tc HDP/MDP; $^{18}$F NaF, $^{18}$F FDG
      ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
      iii) Typical indications: osteosarcoma, Ewing sarcoma, multiple myeloma, and lymphoma
   c) Malignant neoplasm, metastatic
      i) Radiopharmaceuticals: $^{99m}$Tc HDP/MDP; $^{18}$F NaF, $^{18}$F FDG
      ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
      iii) Typical indications: staging disease, treatment strategies
   d) Therapy
      i) Radiopharmaceuticals: $^{153}$Sm lexidronam pentasodium, $^{89}$Sr chloride
      ii) Patient issues: selection, preparation, informed consent, understanding and calculation of administered activity, counseling of patients and families on radiation safety issues, release criteria, and follow-up
      iii) Typical indications: painful skeletal metastases
   e) Tumor-like conditions
      i) Radiopharmaceuticals: $^{99m}$Tc HDP/MDP; F-18 NaF, F-18 FDG
      ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
      iii) Typical indications: fibrous dysplasia, Paget disease
   f) Metabolic & vascular abnormalities
      i) Radiopharmaceuticals: $^{99m}$Tc HDP/MDP, $^{99m}$Tc sulfur colloid; $^{18}$F NaF, $^{18}$F FDG
      ii) Imaging techniques: three-phase, planar, SPECT and/or SPECT-CT; PET and PET-CT
      iii) Typical indications: hyperparathyroidism, “Superscan” (renal osteodystrophy, myelofibrosis), avascular necrosis, complex regional pain syndrome, and hypertrophic arthropathy
   g) Trauma
      i) Radiopharmaceuticals: $^{99m}$Tc HDP/MDP
      ii) Imaging techniques: planar, SPECT and/or SPECT-CT
iii) Typical indications: stress/insufficiency fracture, occult fracture, nonaccidental trauma, and heterotopic bone formation

h) Infection & Inflammation
i) Radiopharmaceuticals: $^{67}$Ga citrate, $^{111}$In/$^{99m}$Tc WBCs, $^{99m}$Tc sulfur colloid; $^{18}$F FDG
ii) Imaging techniques: three-phase, dual-tracer; planar, SPECT and/or SPECT/CT; PET and PET/CT
iii) Typical indications: osteomyelitis, cellulitis, synovitis/arthritis, septic joint, hardware infection

i) Extraskeletal processes
   i) Radiopharmaceuticals: $^{99m}$Tc HDP/MDP
   ii) Imaging techniques: planar, SPECT and/or SPECT-CT
   iii) Typical findings: benign (e.g., lung in hypercalcemia, myocardial infarction/myocarditis/pericarditis, and cardiac amyloidosis) vs malignant (e.g., breast carcinoma primary, liver metastases from colon cancer, pleural effusion in lung cancer, and peritoneal ovarian carcinomatosis); and renal anomalies

j) Bone mineral density (BMD) (dual-energy x-ray absorptiometry, DEXA)
   i) Imaging techniques: DEXA
   ii) Quantitative analysis and pitfalls: T-score, Z-score, region-of-interest (ROI) selection, artifacts
   iii) Typical indications: osteoporosis vs osteopenia, fracture risk assessment, and serial evaluations to evaluate effects of medication

k) Normal and other
   i) Radiopharmaceuticals: all of above
   ii) Imaging techniques: all of above
   iii) Typical indications: all of above

l) Artifacts and quality control
   i) Patient issues: preparation, motion, positioning, and contamination
   ii) Radiopharmaceutical issues: preparation, administration technique, and altered biodistribution
   iii) Technical issues: instrumentation, acquisition and processing, quantification (SUV; T-score, Z-score)

5) Neurology
   a) Brain death
      i) Radiopharmaceuticals: $^{99m}$Tc ECD/HMPAO, and $^{99m}$Tc DTPA
      ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
      iii) Typical indications: confirmation of clinical brain death
   b) Stroke, cerebrovascular disease and vascular reserve
      i) Radiopharmaceuticals: $^{99m}$Tc ECD/HMPAO, $^{18}$F FDG
      ii) Imaging techniques: SPECT and/or SPECT-CT; PET and PET-CT
      iii) Stress protocols: Wada test, acetazolamide (Diamox) challenge, and balloon occlusion
      iv) Typical indications: ischemia vs infarct, and vascular reserve
   c) Cerebrospinal fluid (CSF)
i) Radiopharmaceuticals: $^{111}\text{In}/^{99m}\text{Tc}$ DTPA

ii) Imaging techniques: planar, SPECT and/or SPECT-CT

iii) Typical indications: normal pressure hydrocephalus, leak, and V-P shunt patency

d) Dementias, behavioral disorders, and movement disorders

i) Radiopharmaceuticals: $^{99m}\text{Tc}$ ECD/HMPAO; $^{123}\text{I}$ DaTscan; $^{18}$F FDG, $^{18}$F amyloid agents

ii) Imaging techniques: SPECT and/or SPECT-CT; PET and PET-CT

iii) Typical indications: Alzheimer disease, Lewy body-associated, frontotemporal, multi-infarct, senile, depression, Parkinson disease

e) Seizure

i) Radiopharmaceuticals: $^{99m}\text{Tc}$ ECD/HMPAO; $^{18}$F FDG

ii) Imaging techniques: SPECT and/or SPECT-CT; PET and PET-CT

iii) Stress protocols: injection during active seizure, and interictal setting

iv) Typical indications: localization of seizure focus, and interictal vs ictal protocols

f) Benign neoplasm

i) Radiopharmaceuticals: $^{99m}\text{Tc}$ HDP/MDP, $^{111}\text{In}$ pentetreotide (OctreoScan), and $^{18}$F FDG

ii) Imaging techniques: Planar, SPECT and/or SPECT-CT; PET and PET-CT)

iii) Typical indications: meningioma

g) Malignant neoplasm, primary

i) Radiopharmaceuticals: $^{18}$F FDG

ii) Imaging techniques: PET and PET-CT

iii) Typical indications: glioblastoma, astrocytoma, and lymphoma

h) Malignant neoplasm, metastatic

i) Radiopharmaceuticals: $^{18}$F FDG

ii) Imaging techniques: PET and PET-CT

iii) Indications: staging disease, treatment strategy, and tumor viability

i) Infection and inflammation

i) Radiopharmaceuticals: $^{67}\text{Ga}$ citrate, $^{111}\text{In}/^{99m}\text{Tc}$ WBCs; $^{18}$F FDG

ii) Imaging techniques: SPECT and/or SPECT-CT; PET and PET-CT

iii) Typical indications: abscess, encephalitis, toxoplasmosis, and radionecrosis

j) Normal and other

i) Radiopharmaceuticals: all of above

ii) Imaging techniques: all of above

iii) Typical indications: all of above

k) Artifacts and quality control

i) Patient issues: preparation, motion, positioning, and contamination

ii) Radiopharmaceutical issues: preparation, administration technique, and altered biodistribution

iii) Technical issues: instrumentation, acquisition and processing, and quantification (SUV)

6) Pediatrics

a) Brain and cerebrospinal fluid (CSF)
i) Radiopharmaceuticals: $^{99m}$Tc ECD/HMPAO, $^{18}$F FDG; $^{111}$In/$^{99m}$Tc DTPA)
ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
iii) Typical indications: seizure, neoplasm; V-P shunt patency, and hydrocephalus

b) Cardiac
i) Radiopharmaceuticals: $^{99m}$Tc RBCs, $^{19}$mTc sestamibi/tetrofosmin
ii) Imaging techniques: ECG-gated planar, SPECT, ECG-gated SPECT, and/or SPECT-CT
iii) Quantitative analysis: left ventricular ejection fraction (LVEF)
iv) Typical indications: congenital heart disease, Kawasaki disease

c) Thoracic
i) Radiopharmaceuticals: $^{99m}$Tc MAA, $^{133}$Xe gas, $^{99m}$Tc DTPA aerosol
ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
iii) Typical indications: pulmonary artery atresia, right-to-left shunt, cystic fibrosis, and Swyer-James syndrome

d) GI and hepatobiliary system
i) Radiopharmaceuticals: $^{99m}$Tc sulfur colloid, $^{99m}$Tc IDA analog, $^{99m}$Tc pertechnetate
ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
iii) Pharmacologic protocols: phenobarbital, H2 blockers (e.g., cimetidine)
iv) Quantitative analysis: gastric emptying T ½, and gallbladder ejection fraction (GBEF)
v) Typical indications: aspiration, gastroesophageal reflux, gastric emptying, biliary atresia, and Meckel diverticulum

e) Musculoskeletal
i) Radiopharmaceuticals: $^{99m}$Tc HDP/MDP, $^{18}$F NaF, and $^{18}$F FDG
ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
iii) Typical indications: osteoid osteoma, fracture, avascular necrosis, osteomyelitis, nonaccidental trauma, and metastases

f) Endocrine
i) Radiopharmaceuticals: $^{123}$I NaI, $^{99m}$Tc pertechnetate, $^{131}$I NaI
ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
iii) Typical indications: hypothyroidism (lingual thyroid, agenesis, organification defect), hyperthyroidism, thyroid cancer, and radioiodine therapy

g) Infection and inflammation
i) Radiopharmaceuticals: $^{67}$Ga citrate, $^{111}$In/$^{99m}$Tc WBCs; $^{18}$F FDG
ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
iii) Typical indications: osteomyelitis/septic joint, lung inflammation, inflammatory bowel disease, and abscess

h) Neoplasm
i) Radiopharmaceuticals: $^{99m}$Tc HDP/MDP, $^{123}$I MIBG, $^{111}$In pentetreotide (Octreoscan); $^{18}$F FDG
ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
iii) Typical Indications: Osteosarcoma/Ewing sarcoma, histiocytosis/eosinophilic granuloma, neuroblastoma, lymphoma, and hepatic tumors

i) Urinary Tract
i) Radiopharmaceuticals: $^{99m}$Tc DMSA, $^{99m}$Tc DTPA, $^{99m}$Tc MAG3, and $^{99m}$Tc sulfur colloid
ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
iii) Pharmacologic protocols: diuretics (e.g., furosemide)
iv) Quantitative analysis: relative renal function, response to diuretic challenge
v) Typical indications: congenital anomalies, ectopia, multicystic dysplastic kidney, horseshoe kidney, pyelonephritis, hypertension, hydronephrosis, and vesicoureteral reflux
j) Normal and other
   i) Radiopharmaceuticals: all of above
   ii) Imaging Techniques: all of above
   iii) Typical Indications: all of above
k) Artifacts and quality control
   i) Patient issues: preparation, motion, positioning, and contamination; dosimetry
   ii) Radiopharmaceutical issues: preparation, administration technique, and altered biodistribution
   iii) Technical issues: instrumentation, acquisition and processing, and quantification (T/², GBEF, and SUV)

7) Reproductive/Endocrine
   a) Thyroid gland
      i) Radiopharmaceuticals: ¹²³I NaI, ⁹⁹mTc pertechnetate
      ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
      iii) Quantitative techniques: uptake probe (24-hour radioiodine uptake)
      iv) Typical indications: goiter (in situ, substernal), benign thyroid nodules, multinodular gland, and hyperthyroidism (Graves disease, thyroiditis, and toxic nodules)
   b) Thyroid cancer
      i) Radiopharmaceuticals: ¹²³I/¹³¹I NaI, ¹¹¹In pentetreotide (OctreScan), and; ¹⁸F FDG
      ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
      iii) Typical indications: thyroid bed remnant, and staging locoregional disease/distant metastases for papillary and follicular and medullary cancers
   c) Therapy
      i) Radiopharmaceuticals: ¹³¹I NaI, calculation of administered activity (benign vs malignant conditions)
      ii) Patient issues: selection, preparation, informed consent, understanding and calculation of administered activity, counseling of patients and families on radiation safety issues, release criteria, and follow-up; pregnancy
      iii) Typical indications: benign (hyperthyroidism), malignant (thyroid cancer remnant vs metastases)
   d) Adrenal
      i) Radiopharmaceuticals: ¹²³I MIBG, ¹¹¹In pentetreotide (OctreoScan)
      ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
      iii) Typical indications: pheochromocytoma, cortical adenoma
   e) Neuroendocrine
      i) Radiopharmaceuticals: ¹¹¹In pentetreotide (OctreoScan)
      ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
iii) Typical indications: carcinoid, islet cell tumors, medullary thyroid cancer, and pheochromocytoma/paraganglioma/neuroblastoma

f) Parathyroid gland
i) Radiopharmaceuticals: $^{99m}$Tc sestamibi, $^{99m}$Tc pertechnetate, and $^{123}$I NaI
ii) Imaging techniques: dual-phase, dual-tracer, planar, SPECT, and/or SPECT-CT
iii) Typical Indications: hyperparathyroidism (adenoma, hyperplasia, and ectopic)

g) Female reproductive system neoplasms
i) Radiopharmaceuticals: $^{99m}$Tc HDP/MDP; $^{18}$F NaF, and $^{18}$F FDG
ii) Imaging techniques: Planar, SPECT and/or SPECT-CT; PET and PET-CT
iii) Typical indications: Staging disease, treatment strategy

h) Male reproductive system neoplasms
i) Radiopharmaceuticals: $^{99m}$Tc HDP/MDP; $^{18}$F NaF, $^{18}$F FDG
ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
iii) Typical indications: staging disease, treatment strategy

i) Normal and other
i) Radiopharmaceuticals: all of above
ii) Imaging techniques: all of above
iii) Typical indications: all of above

j) Artifacts and quality control
i) Patient issues: preparation, motion, positioning, and contamination
ii) Radiopharmaceutical issues: preparation, administration technique, and altered biodistribution
iii) Technical issues: instrumentation, acquisition and processing, and quantification (24-hour uptake, SUV)

8) THORACIC

a) Ventilation/perfusion, thromboembolic disease
i) Radiopharmaceuticals: $^{99m}$Tc MAA, $^{133}$Xe gas, and $^{99m}$Tc DTPA aerosol
ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
iii) Typical indications: acute or chronic pulmonary embolism and pulmonary hypertension

b) Ventilation/perfusion, nonthromboembolic disease
i) Radiopharmaceuticals: $^{99m}$Tc MAA, $^{133}$Xe gas, and $^{99m}$Tc DTPA aerosol
ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
iii) Quantitative techniques: regional/split (differential) lung function
iv) Typical indications: fat emboli, hilar mass, vasculitis, prepulmonaryectomy and pulmonary transplant evaluation, and pulmonary hypertension

c) Ventilation/perfusion, chronic obstructive airways disease (COPD) and airways disease
i) Radiopharmaceuticals: $^{99m}$Tc MAA, $^{133}$Xe gas, and $^{99m}$Tc DTPA aerosol
ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
iii) Quantitative techniques: Regional/split (differential) lung function
iv) Typical indications: COPD, asthma, cystic fibrosis, mucus plug, and preb partiallymphectomy evaluation

d) Benign neoplasm/mass/solitary pulmonary nodule
i) Radiopharmaceuticals: $^{18}$F FDG
ii) Imaging techniques: PET and PET-CT
iii) Typical indications: hamartoma, granuloma, and excluding malignancy
e) Malignant neoplasm, primary
i) Radiopharmaceuticals: $^{111}$In pentetreotide (Octreoscan) and $^{18}$F FDG
ii) Imaging techniques: SPECT and/or SPECT-CT; PET and PET-CT
iii) Typical indications: carcinoid, esophageal cancer, mediastinal tumor, lung cancer, pleural neoplasm, and lymphoma
f) Malignant neoplasm, metastatic
i) Radiopharmaceuticals: $^{99m}$Tc HDP/MDP, $^{18}$F NaF, and $^{18}$F FDG
ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
iii) Typical indications: staging disease, treatment strategy
g) Trauma
i) Radiopharmaceuticals: $^{99m}$Tc HDP/MDP, $^{99m}$Tc MAA, $^{133}$Xe, and $^{99m}$Tc DTPA aerosol
ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
iii) Typical indications: rib fractures, pneumothorax, hemothorax, and bronchopleural fistula
h) Infection and inflammation
i) Radiopharmaceuticals: $^{67}$Ga citrate, $^{111}$In/$^{99m}$Tc WBCs, and $^{18}$F FDG
ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
iii) Typical indications: sarcoidosis, occupational lung disease, pneumonia, abscess, tuberculosis, MAL, pneumocystis pneumonia (PCP), histoplasmosis, and talc pleuritis
i) Normal and other
i) Radiopharmaceuticals: all of above
ii) Imaging techniques: all of above
iii) Typical indications: all of above
j) Artifacts and quality control
i) Patient issues: preparation, motion, positioning, and contamination
ii) Radiopharmaceutical issues: preparation, administration technique, and altered biodistribution
iii) Technical issues: instrumentation, acquisition and processing, and quantification (split (differential) lung and SUV)

9) URINARY
a) Perfusion and function
i) Radiopharmaceuticals: $^{99m}$Tc MAG-3, $^{99m}$Tc DTPA
ii) Imaging techniques: planar
iii) Quantitative analysis: relative renal function, renogram, and glomerular filtration rate (GFR)
iv) Typical indications: renal dysfunction/failure, renal artery occlusion, and renal vein thrombosis
b) Diuretic challenge
i) Radiopharmaceuticals: $^{99m}$Tc MAG-3, $^{99m}$Tc DTPA
ii) Imaging techniques: planar
iii) Pharmacologic protocols: diuretics (e.g., furosemide)
iv) Quantitative analysis: relative renal function, and response to diuretic challenge
v) Typical indications: obstructive vs nonobstructive hydronephrosis, and stent function
c) Cortical
i) Radiopharmaceuticals: $^{99m}$Tc DMSA
ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
iii) Quantitative analysis: relative renal function
iv) Typical indications: relative function, scarring, and prenephrectomy assessment
d) Leak
i) Radiopharmaceuticals: $^{99m}$Tc MAG-3 and $^{99m}$Tc DTPA
ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
iii) Typical indications: urinoma, and leak after transplant/other surgery/instrumentation, trauma
e) Transplant
i) Radiopharmaceuticals: $^{99m}$Tc MAG-3 and $^{99m}$Tc DTPA
ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
iii) Quantitative analysis: renogram
iv) Typical indications: acute tubular necrosis, rejection, drug toxicity (cyclosporine), and late complications (obstruction, infection, infarction, and lymphocele/urinoma)
f) Benign neoplasm
i) Radiopharmaceuticals: $^{18}$F FDG
ii) Imaging techniques: PET and PET-CT
iii) Typical indications: angiomyolipoma and complex cystic mass
g) Malignant neoplasm, primary
i) Radiopharmaceuticals: $^{18}$FFDG
ii) Imaging techniques: PET and PET-CT
iii) Typical indications: lymphoma and renal cell cancer
h) Malignant neoplasm, metastatic
i) Radiopharmaceuticals: $^{99m}$Tc HDP/MDP; $^{18}$FNaF, and $^{18}$FFDG
ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
iii) Typical indications: staging disease and treatment strategy
i) Infection and inflammation
i) Radiopharmaceuticals: $^{99m}$Tc DMSA, $^{67}$Ga citrate, $^{111}$In/$^{99m}$Tc WBCs, and $^{18}$FFDG
ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
iii) Typical indications: pyelonephritis and abscess
j) Normal and other
i) Radiopharmaceuticals: all of above
ii) Imaging techniques: all of above
iii) Typical indications: all of above
k) Artifacts and quality control
i) Patient issues: preparation, motion, positioning, and contamination
ii) Radiopharmaceutical issues: preparation, administration technique, and altered biodistribution
iii) Technical issues: instrumentation, acquisition and processing, and quantification (relative renal function, GFR, and SUV)

10) VASCULAR

a) Patency
   i) Radiopharmaceuticals: $^{99m}$Tc pertechnetate, $^{99m}$Tc RBCs
   ii) Imaging techniques: planar
   iii) Typical indications: preoperative evaluation, postoperative evaluation, and deep venous thrombosis

b) Malignant neoplasm, primary
   i) Radiopharmaceuticals: $^{18}$F FDG
   ii) Imaging techniques: PET and PET-CT
   iii) Typical indications: sarcoma

c) Malignant neoplasm, metastatic
   i) Radiopharmaceuticals: $^{99m}$Tc sulfur colloid and $^{18}$F FDG
   ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
   iii) Typical indications: lymphatic mapping/sentinel lymph node (SLN) in melanoma, staging disease, and treatment strategy

d) Infection and inflammation
   i) Radiopharmaceuticals: $^{67}$Ga citrate, $^{111}$In/$^{99m}$Tc WBCs, and $^{18}$F FDG
   ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
   iii) Typical indications: vascular graft infection, catheter infection, vasculitis, and atherosclerosis

e) Normal and other
   i) Radiopharmaceuticals: all of above
   ii) Imaging techniques: all of above
   iii) Typical indications: all of above

f) Artifacts and quality control
   i) Patient Issues: preparation, motion, positioning, and contamination
   ii) Radiopharmaceutical issues: preparation, administration technique, and altered biodistribution
   iii) Technical Issues: instrumentation, acquisition and processing, and quantification (SUV)
Pediatric Radiology

1) General Pediatric Imaging: Basic Knowledge/Competency with:
   a) National patient safety goals as they apply to pediatric imaging
   b) Contrast reactions in children (features, prevention, and treatment)
   c) General knowledge of practice-based imaging guidelines and appropriateness criteria
      (ACR Appropriateness Criteria and Practice Guidelines and Technical Standards)
   d) ALARA principles (e.g., Image Gently Campaign) for modalities using ionizing radiation
   e) Age-related development and normal anatomy
   f) Appropriate appearance of surgical devices and support apparatus
   g) Communication of urgent/emergent findings
      i) List of urgent/emergent findings in children
   h) Unique considerations for modalities:
      i) Indications
         (1) General for each
         (2) Ultrasound
            (a) Hips (effusion, congenital hip dysplasia)
            (b) Spine
            (c) Brain
            (d) Chest/mediastinum
            (e) Neck
            (f) Imperforate anus (level of pouch)
            (g) Intussusceptions
            (h) Appendicitis
            (i) Pyloric stenosis
            (j) Diaphragm motion (infant)
            (k) Interventional guidance
         (3) CT urography
         (4) MR urography, MR cholangiopancreatography (MRCP)
      ii) Limitations
      iii) General techniques
         (1) Radiography
            (a) Collimation
            (b) Settings
            (c) Numbers of views
         (2) Fluoroscopy/angiography
            (a) Pulsed fluoroscopy
            (b) Other fluoroscopy settings
            (c) Shielding
            (d) Dose reduction techniques
            (e) Special contrast use/considerations
         (3) CT: dose reduction techniques and contrast doses
         (4) MRI: coil optimization; contrast types and dose
(5) RNI: see nuclear medicine study guide

iv) Risks

2) Brain, Head and Neck, and Spine
   a) Skull
      i) Congenital
         (1) Synostoses
         (2) Congenital dermal sinus
         (3) Dermoid/epidermoid
      ii) Inflammatory
         (1) Osteomyelitis
      iii) Trauma
         (1) Caput succedaneum
         (2) Subgaleal hemorrhage
         (3) Cephalohematoma
         (4) Fractures (especially non-accidental injury/abuse)
   iv) Basic temporal bone anatomy
      (1) Congenital
         (a) Mondini malformation
         (b) Michele malformation
   v) Inflammatory disorders
      (1) Cholesteatoma
      (2) Mastoiditis
   vi) Variants
      (1) Lückenschädel (2)
      Wormian bones (3)
      Parietal foramina

b) Vertebral column
   i) Congenital
      (1) Absence or hypoplasia of odontoid
      (2) Os odontoideum
      (3) Segmentation anomalies
      (4) Klippel-Feil anatomy
      (5) Sprengel deformity
      (6) Butterfly vertebra
      (7) Spinal dysraphism
      (8) Diastematomyelia
      (9) Sacral agenesis (including caudal regression syndrome)
      (10) Partial absence (including Currarino triad/ASP)
   ii) Inflammatory
      (1) Discitis
      (2) Infectious spondylitis (tuberculosis)
   iii) Neoplasms
      (1) Ewing sarcoma
(2) Aneurysmal bone cyst
(3) Osteoblastoma
(4) Osteoid osteoma
(5) Langerhans cell histiocytosis
(6) Metastases (including leukemia and lymphoma)

iv) Trauma
(1) Fractures/dislocations
(2) Atlanto-dens and atlanto-occipital injuries
(3) Spondylolysis/spondylolisthesis
(4) Insufficiency fracture (and etiologies)

v) Miscellaneous

vi) Dysplasia/syndromes
(1) Mucopolysaccharidoses
(2) Spondylometaphyseal dysplasia

vii) Scheuermann disease

viii) Scoliosis (repair and hardware complications)

c) Brain

i) Congenital
(1) Migrational disorders
(2) Lissencephaly
(3) Pachygyria
(4) Schizencephaly
(5) Heterotopic gray matter
(6) Polymicrogyria
(7) Holoprosencephaly
(8) Anomalies of corpus callosum
(9) Hydranencephaly
(10) Dandy-Walker malformations
(11) Chiari malformation types I and II
(12) Cephalocele
(13) Neurocutaneous syndromes
(14) Vein of Galen malformation
(15) Causes of hydrocephalus
   (a) Aqueductal stenosis
   (b) Syndromic
   (c) Masses

ii) Inflammatory
(1) Bacterial infections
   (a) Meningitis
   (b) Cerebritis
   (c) Abscess
(2) Tuberculosis infections
(3) Viral infections (encephalitis)
   (a) TORCH infections
iii) Neoplasms
iv) Posterior fossa
   (1) Medulloblastoma
   (2) Ependymoma
   (3) Brainstem glioma
   (4) Astrocytoma
v) Supratentorial
   (1) Pineal region tumors
   (2) Craniopharyngioma
   (3) Astrocytoma
   (4) Oligodendroglioma
   (5) Primitive neuroectodermal tumor (PNET)
   (6) Choroid plexus tumors
vi) Cerebral infarction/ischemia
   (1) Childhood infarcts
   (2) Arteritis
   (3) Sickle cell (including moyamoya)
   (4) Carotid occlusion
   (5) Venous sinus thrombosis
   (6) Intracranial hemorrhage
   (7) Neonatal hypoxic ischemic injury
      (a) Vascular borderzone infarctions
      (b) Multicystic encephalomalacia
vii) Trauma (including nonaccidental injuries)
   (1) Cerebral injury (including shearing injuries and concussion)
   (2) Subdural hematoma
   (3) Epidural hematoma
   (4) Subarachnoid hemorrhage
viii) Syndromic/systemic
   (1) Neurocutaneous syndromes
   (2) Chiari malformation types I and II
ix) Vascular
   (1) Arteriovenous malformations, congenital “aneurysms” (vein of Galen)
x) Metabolic brain disorders
   (1) Leukodystrophies
d) Spinal cord
i) Congenital
   (1) Myelomeningocele/meningocele
   (2) Lipomyelomeningocele
   (3) Diastematomyelia
   (4) Tethered cord
   (5) Dermal sinus
   (6) Intradural lipoma
   (7) Hydrosyringomyelia
(8) Neurenteric cysts

ii) Tumors
(1) Neurofibroma
(2) Astrocytoma
(3) Ependymoma
(4) Metastases
(5) Neuroblastoma, ganglioneuroblastoma, ganglioglioma

iii) Sacrococcygeal masses
(1) Germ cell tumors (i.e., teratoma)
(2) Neuroblastoma
(3) Lymphoma
(4) Rhabdomyosarcoma

iv) Other
(1) Infections
(2) Demyelinating disorders
(3) Trauma
(4) Vascular malformations

e) Neck
i) Congenital
(1) Fibromatosis colli
(2) Lymphatic malformations
(3) Branchial cleft cysts
(4) Thyroglossal duct cysts

ii) Neoplasms
(1) Lymphoma
(2) Neuroblastoma
(3) Rhabdomyosarcoma
(4) Nasopharyngeal carcinoma
(5) Hemangiomas

iii) Infectious/inflammatory
(1) Adenitis
(2) Retropharyngeal abscess

iv) Thyroid disorders
(1) Absence/hypoplasia/ectopic
(2) Thyroiditis
(3) Thyroid masses
(4) Goiter

f) Head/face
i) Congenital
(1) Vascular malformations
(2) Persistent hyperplastic primary vitreous (PHPV)
(3) Coloboma

ii) Inflammatory
(1) Orbital masses
(2) Ocular masses  
(3) Orbital cellulitis  
(4) Sinusitis  

iii) Neoplastic/mass like  
(1) Retinoblastoma  
(2) Nasopharyngeal masses  
(3) Carcinoma  
(4) Juvenile angiofibroma  
(5) Sinus masses  

iv) Trauma  
(1) Facial fracture (Le Fort classification)  

3) Chest and Airway  

a) Upper airway  
  i) Congenital  
    (1) Tracheomalacia/bronchomalacia/laryngomalacia  
    (2) Laryngeal stenosis, web, cleft  
    (3) Choanal atresia  
    (4) Masses: hemangioma  
  
  ii) Inflammatory  
    (1) Tonsillar enlargement/adenoidal hypertrophy  
    (2) Croup  
    (3) Epiglottitis  
    (4) Tracheitis  
    (5) Retropharyngeal abscess  

  iii) Neoplasm  
    (1) Juvenile angiofibroma  
    (2) Subglottic hemangioma  
    (3) Laryngeal papilloma  

  iv) Trauma  
    (1) Foreign body  
    (2) Acquired subglottic stenosis  

b) Chest  
  i) Congenital  
    (1) Agenesis/hypoplasia  
    (2) Venolobar syndrome  
    (3) Bronchial atresia  
    (4) Bronchopulmonary foregut malformations  
      (a) Sequestration  
      (b) Bronchogenic cyst  
      (c) Congenital pulmonary airway malformation (CPAM)/cystic adenomatoid malformation (CCAM)  
      (d) Congenital lobar emphysema  
      (e) Hybrid lesions
(5) Tracheal bronchus
(6) Tracheoesophageal fistula
(7) Lymphangiectasia

ii) Inflammatory
(1) Infections
   (a) Bacterial pneumonia
       (i) Streptococcus
       (ii) Staphylococcus
       (iii) Pertussis
       (iv) Chlamydia
       (v) Mycoplasma
       (vi) H. influenza
       (vii) Round pneumonia
       (viii) Abscess
   (ix) Complications
       1. Necrosis
       2. Abscess
       3. Fistulae
       4. Empyema
       5. Pneumatocele
   (b) Viral pneumonia
       (i) Respiratory syncytial virus (RSV)
       (ii) Varicella
       (iii) Measles
   (c) Tuberculosis
   (d) Fungal infections
   (e) Other opportunistic infections
   (f) Plasma cell granuloma/inflammatory pseudotumor and myofibroblastic inflammatory tumor
(2) Small airways disease
   (a) Reactive airways disease
   (b) Viral pneumonia (3)

Bronchiectasis: causes (a)
   Cystic fibrosis
   (b) Immotile cilia syndrome
   (c) Chronic infection (primary immune disorders)
   (d) Foreign body
   (e) Aspiration

iii) Neoplasms/mass-like lesions
(1) Mediastinal masses
   (a) Anterior
       (i) Lymphoma/leukemia
       (ii) Germ cell tumors
       (iii) Thymoma/carcinoma
(iv) Other masses: thymic cysts and bronchogenic cysts
(v) Normal prominent thymus and thymic rebound
(b) Middle
(i) Adenopathy (lymphoma/mets)
(ii) Congenital masses: bronchogenic cysts, esophageal duplication cyst and neureneric cyst
(iii) Neurogenic tumors
(c) Posterior
(i) Neurogenic tumors
(ii) Other masses: bronchogenic cyst, infection, hematoma and adenopathy

(2) Primary lung tumors
(a) Adenoma/carcinoid tumor
(b) Hamartoma
(c) Hemangioma
(d) Mesenchymal sarcoma (and its association with developmental cystic lesions of the lung)
(e) Metastatic lung lesions

(3) Chest wall neoplasms/masses
(a) Ewing sarcoma family (including Askin tumor)
(b) Benign rib and spine neoplasms
(c) Vascular malformations
(d) Infections

iv) Trauma
(1) Contusion
(2) Air leak
(a) Pneumothorax
(b) Pneumomediastinum
(c) Bronchopleural fistula
(3) Fracture of tracheobronchial tree
(4) Airway foreign body
(5) Post-traumatic bronchial stenosis
(6) Post-traumatic diaphragmatic hernia

v) Vascular
(1) Pulmonary thromboembolic disease
(2) Other venous thrombosis or occlusion, anomalous vessels
(3) Arteriovenous malformations

vi) Unique chest problems in neonate
(1) Hyaline membrane disease
(2) Transient tachypnea of newborn
(3) Neonatal pneumonia
(4) Congenital diaphragmatic hernia
(5) Chronic lung disease of infancy (bronchopulmonary dysplasia)
(6) Meconium aspiration syndrome
(7) Persistent fetal circulation
(8) Extracorporeal membrane oxygenation (ECMO) therapy and its complications
(9) Air leak in the neonate
   (a) Including pulmonary interstitial emphysema
vii) Miscellaneous: includes chest manifestations of systemic disorders
   (1) Idiopathic pulmonary hemosiderosis
   (2) Alveolar proteinosis
   (3) Collagen vascular diseases
   (4) Spontaneous pneumothorax and pneumomediastinum
   (5) Cardiogenic and noncardiogenic pulmonary edema
   (6) Histiocytosis
   (7) Vasculitis (Wegener disease)

4) Cardiovascular: Cardiac
a) Congenital heart disease
   i) Segmental approach to imaging of congenital heart disease
      (1) Normal segmental anatomy
      (2) Anomalies of visceroatrial situs
         (a) Asplenia
         (b) Polysplenia
         (c) Situs inversus
   ii) Left-to-right shunts
      (1) Ventricular septal defect
      (2) Patent ductus arteriosus
      (3) Atrial septal defect
      (4) Endocardial cushion defect
      (5) Aortopulmonary window
      (6) Partial anomalous pulmonary venous return
   iii) Intermixing (admixture) states with increased pulmonary blood flow
      (1) Total anomalous pulmonary venous connection (TAPVC) without obstruction
      (2) D-transposition of the great arteries
      (3) Truncus arteriosus
      (4) Single ventricle
   iv) Intermixing (admixture) states with decreased pulmonary blood flow
      (1) Tetralogy of Fallot
      (2) Pulmonary atresia with ventricular septal defect (VSDV
      (3) Single ventricle with right ventricular outflow tract (RVOT) obstruction
   v) Left-sided obstruction
      (1) Coarctation
      (2) Hypoplastic left heart syndrome
      (3) Cor triatriatum
      (4) Obstructed TAPVC
   vi) Other congenital heart disease
      (1) Pulmonary valve stenosis
      (2) L-transposition of great arteries
(3) Pulmonary atresia with intact ventricular septum
(4) Ebstein anomaly
(5) Congenital absence of the pericardium

vii) Vascular rings and slings
   (1) Right aortic arch with aberrant left subclavian artery
   (2) Double aortic arch and variants
   (3) Circumflex aortic arch
   (4) Pulmonary sling

viii) Anomalous coronary artery origins
   (1) Anomalous right coronary artery from the left sinus of Valsalva
   (2) Anomalous left coronary artery from the right sinus of Valsalva
   (3) Anomalous left coronary artery from the pulmonary artery

ix) Systemic venous variants
   (1) Left superior vena cava (SVC)
   (2) Interrupted inferior vena cava (IVC) with azygos continuation

x) Late or adult presentations of coronary heart disease (CHD)
   (1) Bicuspid aortic valve, aortic valve stenosis and aortic root dilatation

b) Cardiac masses
   i) Rhabdomyoma, fibroma
   ii) Thrombus

c) Trauma
   i) Hemopericardium
   ii) Hemopericardium

d) Syndromes with congenital heart disease or vascular disease
   i) Marfan syndrome
   ii) Loeys-Dietz syndrome
   iii) Ehlers-Danlos syndrome
   iv) Williams syndrome
   v) Alagille syndrome
   vi) Neurofibromatosis type 1
   vii) Down syndrome
   viii) Holt Oram syndrome
   ix) Turner syndrome
   x) PHACE syndrome

e) Acquired cardiac disease
   i) Infectious/inflammatory
      (1) Pericarditis
      (2) Myocarditis
      (3) Kawasaki disease
   ii) Cardiomyopathies
      (1) Hypertrophic
      (2) Dilated
      (3) Restrictive
      (4) Arrhythmogenic right ventricular dysplasia (ARVD)
f) Cardiac operations
   i) Postoperative cross-sectional imaging assessment of the following procedures:
      (1) Atrial switch for transposition of great arteries (Senning and Mustard procedures)
      (2) Arterial switch for transposition of great arteries (Lateene arterial switch and Lecompte maneuver)
      (3) Single ventricle repair: Norwood 1 and Dames-Kaye Stansel anastomosis
      (4) Superior cavopulmonary connection, including the bidirectional Glenn procedure
      (5) Total cavopulmonary connection: Fontan procedure
      (6) Pulmonary blood flow augmentation as initial palliation for coronary heart disease (CHD), including Blalock-Taussig, Waterston, and Pott shunts

5) Cardiovascular: Vascular
   a) Congenital
      i) Vascular malformations
   b) Variants: Caval anomalies (e.g., left superior vena cava, absent hepatic inferior vena cava)
   c) Trauma
      i) Acute traumatic aortic injury
      ii) Arterial contrast extravasation
      iii) Pseudoaneurysm
      iv) Arteriovenous fistulae
      v) Hypoperfusion complex
   d) Inflammatory/infectious
      i) Aortitis
      ii) Vasculitides
         (1) Takayasu disease and Kawasaki disease
   e) Syndromic/systemic vascular diseases
      i) Syndromes
         (1) Ehlers-Danlos
         (2) Marfan
         (3) Neurofibromatosis and other causes of mid-aortic syndrome
         (4) Williams
   f) Idiopathic
      i) Fibromuscular dysplasia
      ii) Mid-aortic syndrome
   g) Thrombotic
      i) Deep venous thrombosis
      ii) Catheter-related thrombosis and evaluation

6) Gastrointestinal (GI) tract
   a) Biliary system
      i) Congenital
ii) Biliary atresia
iii) Neonatal hepatitis
iv) Choledochal cyst (classification)
v) Acquired miscellaneous
   1) Cholelithiasis
   2) Hydrops of gallbladder
   3) Cholangitis
vi) Cholecystitis

b) Liver
i) Infection
   1) Abscess
   2) Hepatitis

ii) Tumors and tumor-like conditions
   1) Benign
      (a) Mesenchymal hamartoma
      (b) Hemangioendothelioma
   2) Malignant
      (a) Hepatoblastoma
      (b) Hepatoma
      (c) Metastases

iii) Trauma
   1) Lacerations
   2) Subcapsular hematoma
   3) Contusion

iv) Vascular
   1) Portal vein thrombosis
      (a) Cavernous transformation
   2) Portal hypertension
   3) Budd-Chiari syndrome

v) Transplant complications

vi) Other: systemic conditions involving liver
   1) Glycogen storage disease
   2) Beckwith-Wiedemann syndrome

c) Spleen
i) Congenital
   1) Abnormal visceroatrial situs
   2) Wandering spleen

ii) Neoplasms
   1) Infection
      (a) Fungal abscesses
   2) Benign
      (a) Lymphangioma
   3) Malignant
      (a) Lymphoma/leukemia
(4) Trauma
   (a) Laceration
   (b) Contusion
   (c) Subcapsular hematoma
(5) Splenic infarction
   (a) Sickle cell disease
(6) Etiologies for splenomegaly
d) Pancreas
   i) Congenital
      (1) Pancreas divisum
      (2) Cystic fibrosis
   ii) Pancreatitis (and pseudocyst)
      (1) Trauma
         (a) Non-accidental trauma
      (2) Choledochal cyst
      (3) Familial pancreatitis
      (4) Iatrogenic
   iii) Fatty replacement
      (1) Cystic fibrosis
e) Aerodigestive track
   i) Pharynx and esophagus
      (1) Congenital and developmental anomalies
         (a) Esophageal atresia and tracheoesophageal fistula (classification)
      (2) Inflammatory lesions
         (a) Retropharyngeal abscess cellulitis
         (b) Infectious esophagitis
      (3) Trauma
         (a) Foreign bodies
         (b) Iatrogenic perforation
      (4) Esophageal stricture (etiologies)
      (5) Gastroesophageal reflux
   ii) Stomach
      (1) Congenital
         (a) Duplications
         (b) Antral webs
         (c) Volvulus
      (2) Gastric outlet obstruction
         (a) Acquired
            (i) Hypertrophic pyloric stenosis
            (ii) Inflammatory
            (iii) Corrosive ingestion
            (iv) Chronic granulomatous disease
      (3) Inflammatory
         (a) Eosinophilic enteritis
(b) Peptic diseases
(c) Chronic granulomatous disease

(4) Miscellaneous
(a) Bezoars
(b) Foreign bodies
(c) Spontaneous rupture of stomach

iii) Small Bowel
(1) Congenital
   (a) Duodenal webs, stenosis, and other obstructions
   (b) Malrotation with/without midgut volvulus
   (c) Duodenal, jejunal, and ileal stenosis and/or atresia
   (d) Post-inflamatory/infectious or iatrogenic strictures
   (e) Meconium ileus
   (f) Meconium peritonitis
   (g) Mesenteric and omental cysts
   (h) Duplication cysts
   (i) Meckel diverticula (including other omphalomesenteric anomalies)
   (j) Abdominal wall defects
       (i) Omphalocele and gastroschisis
       (ii) Hernias

(2) Neoplasms
   (a) Benign
       (i) Polyps and leiomyomas
   (b) Malignant
       (i) Lymphoma

(3) Malabsorption
   (a) Cystic fibrosis

(4) Trauma
   (a) Blunt abdominal trauma
   (b) Transplant

(5) Miscellaneous
   (a) Necrotizing enterocolitis
   (b) Ischemic bowel
   (c) Intussusception
   (d) Henoch-Schölein purpura
   (e) Graft vs host disease

(6) Cause of small bowel obstruction

iv) Colon
(1) Congenital
   (a) Imperforate anus /anorectal malformation
   (b) Duplications
   (c) Colonic atresia
   (d) Hirschsprung disease
   (e) Meconium plug/neonatal small left colon syndrome
(2) Infectious/inflammatory
   (a) Appendicitis
   (b) Infectious colitis/typhilitis
(3) Neoplasms
   (a) Benign: polyps, leiomyoma
   (b) Malignant
      (i) Lymphoma
(4) Trauma
v) Other
(1) Mesenteric adenitis

7) Genitourinary system
   a) Growth and development/normal variants: kidney (echogenic pyramids, lobulation)
   b) Kidneys
      i) Congenital anomalies
         (1) Ureteropelvic junction (UPJ)
         (2) Duplication
         (3) Multicystic dysplasia
         (4) Agenesis
         (5) Hypoplastic kidney
         (6) Horseshoe kidney
         (7) Ectopia
            (a) Ptosis
            (b) Pelvic
            (c) Crossed ectopia
         (8) Relationship of congenital renal anomalies with other congenital anomalies
            (VATER association, spinal dysraphism, etc.)
      ii) Cystic renal disease
         (1) Autosomal recessive
         (2) Autosomal dominant
         (3) Cysts associated with syndromes
         (4) Associated liver disease (fibrosis)
      iii) Inflammatory
         (1) Acute pyelonephritis
         (2) Abscess
         (3) Reflux nephropathy
      iv) Neoplasms
         (1) Wilms tumor and variants
         (2) Nephrogenic rests
         (3) Mesoblastic nephroma
         (4) Multilocular cystic nephroma
         (5) Leukemia/lymphoma
      v) Trauma
         (1) Subcapsular hematoma
(2) Laceration (including those communicating with collecting system)
(3) Contusion
(4) Avulsion of vascular pedicle
(5) UPJ avulsion or laceration
vi) Vascular
(1) Arterial stenosis
(2) Renal vein thrombosis
(3) Tumor thrombus
vii) Involvement by systemic disorders
(1) Tuberous sclerosis
(2) Von Hippel-Lindau disease
viii) Miscellaneous
(1) Urolithiasis/nephrocalcinosis
(2) Renal transplantation
c) Adrenal gland
i) Neoplasms
(1) Neuroblastoma
(2) Adrenocortical carcinoma
ii) Congenital adrenal hyperplasia
iii) Trauma
(1) Hemorrhage (neonatal) and adrenal calcification
d) Bladder, ureters, and urethra
i) Congenital
(1) Posterior urethral valves
(2) Ureterovesical junction obstruction
(3) Primary megaureter
(4) Bladder diverticula
(5) Ureteral duplication
(6) Ureterocele
(7) Urachal abnormalities
(8) Hypospadias
(9) Epispadias/exstrophy
(10) Prune belly syndrome
(11) Urologic sequela of anorectal anomalies
ii) Infectious/inflammatory
(1) Urinary tract infection
(2) Viral cystitis
(3) Hemorrhagic cystitis
iii) Trauma
(1) Extravasation
iv) Neoplasms
(1) Rhabdomyosarcoma
v) Miscellaneous
(1) Vesicoureteral reflux
(2) Neurogenic bladder
(3) Dysfunctional voiding

e) Male genital tract: scrotal
i) Testicular torsion
ii) Infectious/inflammatory
   (1) Epididymitis/orchitis
iii) Differential for scrotal fluid collections
iv) Hernia
v) Undescended testis
vi) Microlithiasis
vii) Neoplasms
   (1) Germ cell tumors
   (2) Stroma cell tumors
   (3) Metastases
   (4) Leukemia

f) Female genital tract
i) Congenital
   (1) Cloacal anomalies
ii) Ovaries
   (1) Torsion
   (2) Ovarian cysts (including neonatal physiologic)
   (3) Germ cell tumors
   (4) Cystic neoplasms
   (5) Polycystic ovarian disease
iii) Uterus and vagina
   (1) Congenital anomalies: vaginal occlusion (hydrometrocolpos, etc.)
   (2) Fusion anomalies of the müllerian duct (uterus didelphys, etc.)
   (3) Masses
      (a) Rhabdomyosarcoma
      (b) Clear cell adenocarcinoma
iv) Intersex states
   (1) Differential diagnosis
   (2) Work-up
v) Other
   (1) Prune belly syndrome

8) Musculoskeletal imaging

   a) Normal growth and development/variants

   b) Congenital
      i) Osteochondrodysplasias affecting growth of tubular bones and spine (identifiable at birth)
         (1) Thanatophoric dysplasia
         (2) Chondrodysplasia punctata
         (3) Achondroplasia
(4) Asphyxiating thoracic dystrophy
ii) Osteochondrodysplasias affecting growth of tubular bones and spine (identifiable in later life)
   (1) Metaphyseal chondrodysplasia
   (2) Multiple epiphyseal dysplasia
iii) Osteochondrodysplasias with disorganized development of cartilage and fibrous components of the skeleton
   (1) Multiple cartilaginous exostoses
   (2) Enchondromatosis
   (3) Polyostotic fibrous dysplasia
   (4) Neurofibromatosis
iv) Abnormalities of density of cortical diaphyseal structure and metaphyseal modeling
   (1) Osteogenesis imperfecta
   (2) Osteopetrosis
   (3) Pycnodysostosis
   (4) Diaphyseal dysplasia
   (5) Metaphyseal dysplasia
v) Limb reduction anomalies (including proximal focal femoral deficiency and radial ray anomalies)
vii) Amniotic band syndrome
vii) Congenital bowing deformities and pseudoarthroses
viii) Congenital foot deformities
   (1) Tarsal coalition
   (2) Pes planus
   (3) Talipes equinovarus
   (4) Pes cavus
   (5) Metatarsus adductus
ix) Skeletal abnormalities associated with syndromes
   (1) Trisomy 21 syndrome, Marfan syndrome and neurofibromatosis
x) Skeletal abnormalities associated with metabolic disorders
   (1) Mucopolysaccharidoses and mucolipidoses
xi) Developmental dysplasia of hip
xii) Skeletal abnormalities associated with neuromuscular diseases
   (1) Meningomyelocele
   (2) Cerebral palsy
   (3) Muscular dystrophy
c) Infectious inflammatory
   i) Pyogenic osteomyelitis
   ii) Septic arthritis
   iii) Toxic synovitis of the hip
   iv) Tuberculosis
   v) Caffey disease
   vi) Multifocal osteomyelitis
   vii) Dermatomyositis/polymyositis and other inflammatory myopathies
viii) Arthropathies
   1) Juvenile rheumatoid arthritis (juvenile idiopathic arthritis)

d) Hemophilic arthropathy
e) Neoplasm
   i) Benign
      1) Osteochondroma
      2) Unicameral bone cyst
      3) Aneurysmal bone cyst
      4) Nonossifying fibroma/fibrous cortical defect
      5) Fibrous dysplasia
      6) Langerhans cell histiocytosis
      7) Osteoid osteoma
      8) Osteoblastoma
      9) Chondroblastoma
     10) Chondromyxoid fibroma
   ii) Malignant
      1) Ewing sarcoma
      2) Osteogenic sarcoma
      3) Metastases (including leukemia/lymphoma)
   iii) Vascular
      1) Vascular malformations
   iv) Trauma
      1) Fractures
         a) Accidental trauma (including Salter-Harris, greenstick-bowing, and buckle fractures)
         b) Nonaccidental trauma (battered child syndrome)
v) Growth arrest/bone bar and non union
vi) Toddler’s fracture
vii) Slipped capital femoral epiphysis
f) Endocrine/Metabolic
   i) Rickets
   ii) Renal osteodystrophy
   iii) Hyperparathyroidism
   iv) Hypoparathyroidism
   v) Hypophosphatasia
   vi) Scurvy
   vii) Bone age determination
g) Osteochondroses
   i) Legg-Perthes disease
   ii) Kohler disease
   iii) Freiberg disease
   iv) Osteochondritis dissecans
   v) Blount disease and physiologic bowing
9) Select general/multiorgan system syndromes with salient imaging findings
   a) Neurocutaneous syndrome
   b) Sturge-Weber syndrome
   c) Trisomy 21 syndrome
   d) CHARGE syndrome
   e) Marfan syndrome
   f) Beckwith-Wiedemann syndrome
   g) Turner syndrome
   h) Ehlers-Danlos syndrome
   i) DiGeorge syndrome
   j) Klippel-Trenaunay-Weber syndrome

10) Multisystemic disorders/processes
    a) Systemic lupus erythematosus and other systemic vasculitides
    b) Juvenile idiopathic arthritis
    c) Wegener disease
    d) Primary immune deficiencies (severe combined immunodeficiency (SCIDS), chronic granulomatous disease, and DiGeorge syndrome)
    e) Sickle cell anemia
    f) Child abuse
    g) Immunocompromised host (transplant immune suppression, antibiotics, steroids, and chemotherapy)
       i) Includes post-transplant lymphoproliferative syndrome
    h) VATER/VACTERL
    i) Retained surgical material
    j) Venticuloperitoneal (VP) shunt complications

11) Interventional
    a) Abscess drainage/aspiration
    b) Solid organ soft tissue mass biopsy
       i) Thyroid, liver, kidney, bone, lymph node and nodule
    c) Thoracentesis/thoracostomy tube placement
    d) Paracentesis
    e) Hip aspirations
    f) Arthrography (diagnostic and therapeutic)
Physics

1) Atomic Structure: Composition of the Atom
   a) Electrons
      i) Electron orbits
      ii) Naming of orbits
      iii) Binding energy
      iv) Transitions of electrons
      v) Characteristic radiation
      vi) Auger electrons
   b) Nucleus
      i) Composition
      ii) Nuclear force
      iii) Mass defect
      iv) Binding energy
      v) Instability of the nucleus

2) Electromagnetic Radiation
   a) Wave-particle duality
      i) Characteristics of waves
      ii) Characteristics of particles
   b) Electromagnetic spectrum
      i) Non-ionizing
      ii) Ionizing

3) Particulate Radiation
   a) Light particles
   b) Heavy charged particles
   c) Uncharged particles
      i) Neutrons
      ii) Neutrinos

4) Ionizing Radiation Interactions with Matter
   a) Charged particles
      i) Ionization and excitation
      ii) Bremsstrahlung
      iii) Secondary ionization
         (1) Specific ionization
         (2) Linear energy transfer (LET)
      iv) Positron annihilation
   b) Photons
      i) Coherent scattering
      ii) Compton scattering
iii) Photoelectric effect
iv) Tissue interactions
v) Contrast media
c) Attenuation of photons
   i) Linear attenuation coefficient
   ii) Attenuation equation
   iii) Mono- and polyenergetic x-ray beams
iv) Half-value layer (HVL)
   (1) Effective energy
   (2) Beam hardening

5) Radiation Units
   a) Unit systems
      i) SI
      ii) Classical
   b) Exposure
      i) Coulomb/kilogram
      ii) Roentgen (R)
c) Kerma - kinetic energy released in matter
   i) Gray (Gy)
   ii) Rad
d) Absorbed dose
   i) Gray (Gy)
   ii) Rad
e) Equivalent dose
   i) Radiation weighting factors
   ii) Sievert (Sv)
   iii) Rem
f) Effective dose
   i) Tissue weighting factors
   ii) Sievert (Sv)
   iii) Rem
   iv) Reference levels
   v) Use in radiation protection
g) Peak skin dose

6) X-ray Production
   a) Properties of x-rays
      i) Bremsstrahlung
         (1) Importance in imaging
         (2) Influence of electron energy
         (3) Influence of target material
         (4) Influence of filtration
      ii) Characteristic radiation
(1) Importance in imaging  
(2) Influence of electron energy  
(3) Influence of target material  
(4) Influence of filtration  

b) X-ray tube  
i) Cathode  
   (1) Filament  
   (2) Focusing cup  
   (3) Filament current and tube current  
ii) Anode  
   (1) Composition  
   (2) Focal spot  
   (3) Line-focus principle  
   (4) Heel effect  
iii) Application-specific tubes  
   (1) Mammography  
   (2) CT  
   (3) Interventional  
c) Generators  
i) Frequency  
ii) Technique factors  
   (1) kVp  
   (2) mA  
   (3) Time  
   (4) Automatic exposure control (AEC)  
d) X-ray beam  
e) Beam filtration  
   (1) Inherent  
   (2) Added (Al, Cu, Mo, Rh, other)  
   (3) Minimum HVL  
   (4) Shaped filters  
ii) Spectrum  
iii) Collimators  
   (1) Field size limitation  
   (2) Light/x-ray alignment  
   (3) Effect on image quality  

7) Imaging Science  
a) Statistics  
i) Precision and accuracy  
ii) Systematic and random errors  
iii) Metrics  
iv) Confidence intervals  
v) Error propagation
b) Properties of images
   i) Imaging information domains
      (1) Spatial
      (2) Frequency
      (3) Temporal
   ii) Image characteristics
      (1) Contrast
      (2) Spatial resolution and modulation transfer function (MTF)
      (3) Quantum noise and other noise sources
      (4) Dynamic range
      (5) Contrast-to-noise ratio (CNR), signal-to-noise ratio (SNR), and detective quantum efficiency (DQE)
      (6) Temporal resolution
   iii) Analog and digital image representation
      (1) Conversion process (analog-to-digital converter [ADC] and digital-to-analog converter [DAC])
      (2) Sampling, quantization, and the Nyquist limit
   iv) Image processing
      (1) Preprocessing for uniformity and defect corrections
      (2) Segmentation and region of interest selection
      (3) Grayscale manipulation and lookup tables
      (4) Filtering
      (5) Reconstruction approaches
      (6) 3D presentation methods
      (7) Image fusion and image registration
      (8) Computer-aided detection and diagnosis (CAD)

c) Display of images
   i) Display systems: hard copy and soft copy
   ii) Display characteristics and quality control
   iii) Viewing conditions for image review

d) Human perception of medical images
   i) Human vision characteristics
   ii) Measures of observer performance and receiver operating characteristic (ROC) analysis

 8) Biological Effects of Ionizing Radiation: Radiation Biology
  a) Principles
i) Linear energy transfer (LET)
ii) Relative biologic effectiveness (RBE)
iii) Weighting factors
b) Molecular effects of radiation
   i) Direct and indirect effects
   ii) Effects of radiation on DNA
c) Cellular effects of radiation
   i) Law of Bergonié and Tribondeau
   ii) Radiosensitivity of different cell types
   iii) Radiosensitivity of the cell cycle
   iv) Cellular damage and apoptosis
   v) Cell survival curves and cell repair
d) System effects of radiation
   i) Tissues and organs
   ii) Whole body
   iii) Population
e) Deterministic (nonstochastic) effects
   i) Radiation syndromes
   ii) Specific effects
      (1) Erythema
      (2) Epilation
      (3) Cataracts
      (4) Sterility
f) Probabilistic (stochastic) radiation effects
g) Radiation epidemiology
   i) Carcinogenesis
      (1) Radiation-induced cancers
      (2) Latency
   ii) Mutagenesis
   iii) Teratogenesis
h) Radiation risk
   i) Risk-benefit in radiology
   i) Risk models
      (1) Relative
      (2) Absolute
   ii) Information sources
      (1) Biological Effects of Ionizing Radiation (BEIR VII) reports
      (2) International Council on Radiation Protection (ICRP) reports
      (3) National Council on Radiation Protection and Measurements (NCRP 116) reports
      (4) United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reports
   iii) Perception of risk
j) Dose-response models
9) Radiation Protection and Associated Regulations
   a) Background radiation sources
   b) Non-medical radiation sources
   c) Medical sources: occupational and patient doses
      i) Projection radiography
      ii) Mammography
      iii) Fluoroscopy
      iv) Interventional radiology and diagnostic angiography
      v) CT
      vi) Sealed source radioactive material
      vii) Unsealed radioactive material
      viii) Therapeutic external radiation
     ix) Non-ionizing
   d) Factors affecting patient dose from medical sources
      i) Regulatory dose limits and “trigger” levels
      ii) Joint Commission on Accreditation of Healthcare Organizations (JCAHO) reviewable and nonreviewable events
   e) Persons at risk
      i) Occupational
      ii) Nonoccupational staff
      iii) Members of the public
      iv) Fetus
      v) Patient
   f) Dose limits
      i) Occupational dose limits
      ii) Members of the public
   g) Radiation detectors
      i) Personal dosimeters
         (1) Available technologies
         (2) Appropriate use and limitations
      ii) Area monitors
         (1) Dosimeters
         (2) Ion chambers
         (3) Geiger-Müller (G-M)
         (4) Scintillators
   h) Principles of radiation protection
      i) Time
      ii) Distance
      iii) Shielding for facilities, workers, and others
      iv) Shielding materials
      v) Contamination control
      vi) As low as reasonably achievable (ALARA)
      vii) Procedure appropriateness
     i) Advisory bodies
i) International Commission on Radiological Protection (ICRP)
ii) National Council on Radiation Protection and Measurements (NCRP)
iii) Conference of Radiation Control Program Directors (CRCPD)
iv) International Atomic Energy Agency (IAEA)
v) Joint Commission on Accreditation of Healthcare Organizations (JCAHO)
vi) American College of Radiology (ACR)
vii) National Electrical Manufacturers Association (NEMA) (Medical Imaging and Technology Alliance or MITA)

j) Regulatory agencies
i) U.S. Nuclear Regulatory Commission and Agreement States
   (1) 10 CFR Parts 19, 20, 30, 32, 35, 110
   (2) Guidance documents (NUREG 1556, Vols. 9 and 11)
   (3) Regulatory guides
ii) State regulations for machine-produced sources
iii) U.S. Food and Drug Administration (FDA)
   (1) Center for Devices and Radiological Health (CDRH)
   (2) Center for Drug Evaluation and Research (CDER)
iv) U.S. Office of Human Research Protections
v) U.S. Department of Transportation
vi) U.S. Department of Labor Occupational Safety and Health Administration (OSHA)

j) International Electrotechnical Commission (IEC)

k) Radiation safety with radioactive materials
i) Surveys
ii) Ordering, receiving, and unpacking radioactive materials
iii) Contamination control
iv) Radioactive waste management
v) Qualifications for using radioactive materials
   (1) Diagnostic (10 CFR 35.200 and 35.100, or equivalent Agreement State regulations)
   (2) Therapeutic (10 CFR 35.300 and 35.1000, or equivalent Agreement State regulations)

vi) Medical events: reportable and nonreportable

l) Estimating effective fetal dose (procedure-specific doses)

m) Shielding
i) Occupancy and workload
ii) Controlled verses uncontrolled areas

n) Radiological emergencies
i) Incidents
ii) Purposeful exposures
iii) Treatment of radiological casualties

10) X-ray Projection Imaging: Concepts and Detectors
a) Radiography concepts
   i) Geometry
(1) Magnification  
(2) Inverse-square law

ii) Radiographic contrast  
(1) Subject  
(2) Detector

iii) Scatter and scatter reduction  
(1) Scatter-to-primary ratio  
(2) Grids  
(3) Air gap

iv) Artifacts and image degradation  
(1) Distortion  
(2) Geometric unsharpness  
(3) Grid  
(4) Detector

b) Radiographic detectors  
   i) Screen-film systems  
      (1) Intensifying screens  
      (2) Film and film processing
   ii) Computed radiography (CR)  
       (1) Storage phosphors  
       (2) CR readers
   iii) Flat panel detectors  
       (1) Direct detectors  
       (2) Indirect detectors

11) General Radiography  
   a) X-ray system components  
      i) Tube and filtration  
      ii) Collimation  
      iii) Automatic exposure control (AEC)  
      iv) Grids and Bucky factor
   b) Geometrical effects and requirements  
      i) Focal spot size  
      ii) Collimation  
      iii) Heel effect
   c) Acquisition systems  
      i) Screen/film  
      ii) Digital  
         (1) CR systems  
         (2) Flat-panel systems
      iii) Dual-energy  
      iv) Linear tomography  
      v) Tomosynthesis
   d) Image characteristics
i) Spatial resolution
ii) Contrast sensitivity
iii) Noise
iv) Temporal resolution
v) Artifacts
e) Application requirements
   i) Chest
   ii) Abdomen
   iii) Spine
   iv) Extremities
   v) Pediatrics and neonatal
   vi) Portable/mobile
f) Dosimetry
   i) Entrance skin exposure
   ii) Effective dose
   iii) Appropriate organ doses
   iv) Doses for different procedures
   v) Technique optimization
g) Factors affecting patient dose
   i) Technique (e.g., kVp, mA, time)
   ii) Imaging geometry
   iii) Beam filtration and grid
   iv) Field size
   v) Exposure class
h) Quality control (QC) tests and frequencies

12) Mammography
   a) Clinical importance
   b) Mammography equipment
      i) Dedicated x-ray tube
         1) Anode materials
         2) kVp
         3) Focal spot size and characteristics
         4) Target-filter combinations
         5) X-ray spectra
         6) Low peak kilovoltage (kVp)
         7) Half-value layer (HVL)
      ii) Breast compression paddle
      iii) Collimation
      iv) Grids
      v) Automatic exposure control (AEC)
c) Geometry
   i) Source-to-image receptor distance (SID)
   ii) Source-to-object distance (SOD)
iii) Object-to-image receptor distance (OID)
iv) Chest-wall coverage
v) Heel effect
vi) Magnification
vii) Advantages of magnification
d) Acquisition systems
i) Screen/film and film processing
ii) Full-field digital mammography
iii) Tomosynthesis systems
iv) Stereotactic biopsy systems
e) Artifacts
f) Radiation dose
i) Entrance skin exposure
ii) Average glandular dose
iii) Dose limits
iv) Factors affecting patient radiation dose
v) Radiation risk versus benefits of screening
g) Viewing images
i) Lighting requirements: luminance and illuminance
ii) Dedicated view boxes and displays
iii) Dedicated PACS
h) Quality control
i) Mammography Quality Standards Act (MQSA)
   (1) Personnel requirements
   (2) Dose limits
   (3) Image quality and accreditation phantom
ii) American College of Radiology (ACR) accreditation

13) Fluoroscopy and Interventional Imaging
a) System components
i) Tube
ii) Filtration
iii) Collimation
iv) Grids
v) Automatic brightness control (ABC)
vi) Automatic brightness stabilization (ABS)
vii) Compensation filters
b) Configurations and geometry
i) Focal spot size
ii) Magnification
iii) Under-table versus over-table x-ray tube
iv) C-arms
c) Image intensifier (II) acquisition systems
i) II structure
ii) Gain
iii) Field of view (FOV), magnification, and resolution
iv) Cameras and video systems
v) Image distortions
   (1) Lag
   (2) Veiling glare
   (3) Vignetting
   (4) Other: pincushion, barrel, “S”-distortion
d) Flat-panel acquisition systems
   i) Detectors
   ii) Magnification
   iii) Binning
   iv) Comparison to II
   v) Image distortions
      (1) Correlated noise
      (2) Lag
      (3) Ghosting
e) Real-time imaging
   i) Continuous fluoroscopy
   ii) High-dose rate fluoroscopy
   iii) Variable frame-rate pulsed fluoroscopy
   iv) Spot images
   v) Operating mode variables
      (1) Effective mA
      (2) Pulse width
      (3) Variable beam filtration
      (4) Software processing
f) Image quality
   i) Low-contrast sensitivity
   ii) High-contrast (spatial) resolution
   iii) Temporal resolution
   iv) Noise
g) Image processing
   i) Frame averaging
   ii) Last-image hold and last-series hold
   iii) Digital subtraction angiography (DSA)
   iv) Road mapping
   v) Cone beam CT
h) Applications
   i) Dose and dosimetry
      i) Federal and state regulations
         (1) Dose rates and limits
         (2) Audible alarms
         (3) Recording of “beam-on” time
(4) Minimum source-to-patient distance
(5) Sentinel event
   ii) Dose-area-product (DAP) and Kerma-area-product (KAP) meters
   iii) Entrance skin exposure
   iv) Peak skin dose
   v) Cumulative dose
   vi) Patient dose for various acquisition modes
   vii) Operator and staff dose considerations and protection
j) Technique optimization and factors affecting patient dose

14) CT
   a) System components
   b) System geometry
   c) Parameters for image acquisition
      i) kVp
      ii) mA
      iii) Rotation time
      iv) Table speed
      v) Pitch
      vi) Image thickness versus beam width
   d) Image formation
      i) Attenuation coefficient
      ii) Hounsfield unit (HU) definition
      iii) Axial filtered back-projection
      iv) Helical reconstruction
      v) Iterative reconstruction
   e) Modes of operation
   f) Image contrast, detail and noise
   g) Artifacts
   h) Image processing and display
   i) Clinical application and protocols
   j) Dose and dosimetry
      i) Dose profile
      ii) CT dose index and CTDI_{vol}
      iii) Multiple scan average dose (MSAD)
      iv) Dose-length product (DLP)
      v) Organ dose and effective dose
      vi) Size-specific estimated dose
      vii) Adult and pediatric technique optimization
      viii) Beam width and pitch
      ix) Over-beam and over-ranging
   k) Technique optimization and factors affecting patient dose
      i) kVp, mA, and rotation time
      ii) Patient size
iii) Table increment, table speed, and pitch
iv) Scan length
v) Number of phases (e.g., pre- and post-contrast)
vi) Technique selection
vii) Dose modulation schemes
viii) Dual source
ix) Patient shielding (pros and cons)

15) Ultrasound (Please see Ultrasound Section of the Core Exam Study Guide for a more detailed physics outline.)
   a) Properties of ultrasound waves
   b) Interaction of sound waves and tissue
      i) Acoustic properties of tissues
   c) Transducer components and design
      i) Transducer selection for clinical applications
   d) Ultrasound beam characteristics and beam formation
   e) Grayscale ultrasound image formation and scanning modes
      i) Grayscale image optimization
   f) Doppler phenomenon and scanning modes
      i) Optimization of Doppler parameters
   g) Gray-scale and Doppler artifacts
   h) Advanced imaging methods
      i) 3D/4D volumetric imaging
      ii) Harmonic imaging
      iii) Spatial compounding
      iv) Ultrasound contrast agents
      v) Elastography
      i) Thermal and non-thermal effects on tissue, and ultrasound safety
   j) Equipment quality assurance

16) MRI
   a) Magnetism and magnetic fields
      i) Magnetic susceptibility
      ii) Types of magnetic materials
      iii) Magnetic fields (B)
      iv) Magnetic moment interaction with an external field (B0): the Larmor equation and precessional frequency
      v) Net magnetization due to B0 and field strength
   b) Nuclear MR and excitation
   c) MR signal properties
      i) Spin density (proton)
      ii) T2 (transverse) relaxation
      iii) T2* relaxation
      iv) T1 (longitudinal) relaxation
v) T1-weighting, T2-weighting, proton density-weighting

d) Pulse sequences and contrast mechanisms
   i) Echo time (TE), repetition time (TR), and inversion time (TI)
   ii) Spin-echo (SE) pulse sequences
   iii) Inversion-recovery spin-echo pulse sequences
   iv) Gradient-echo (GE or GRE) pulse sequences
   v) Echo-planar (EPI) pulse sequences
   vi) Fast- or turbo-spin-echo (FSE) pulse sequences
   vii) Manipulation of pulse sequence characteristics

e) MR instrumentation
   i) Static magnetic field (B0) systems
   ii) Gradient fields and the gradient subsystem
   iii) Shimming and shim coils
   iv) Radiofrequency transmitter (B1) subsystem
   v) Radiofrequency receiver subsystem
   vi) Radiofrequency coils

f) Spatial localization
   i) Slice-selection
   ii) Phase-encoding
   iii) Frequency-encoding

g) Two-dimensional Fourier transform (2DFT) image reconstruction
   i) k-space description
   ii) Methods of filling k-space

h) Image characteristics
   i) Factors affecting spatial resolution
   ii) Factors affecting signal-to-noise ratio (SNR)
   iii) Tradeoffs among spatial resolution, SNR, and acquisition time
   iv) Factors affecting image contrast

i) Contrast agents

j) Spatial saturation and fat suppression

k) Special acquisition techniques
   i) Angiography
   ii) Diffusion, perfusion and neuro imaging
   iii) Functional MRI (fMRI)
   iv) Magnetization transfer contrast (MTC)

l) Artifacts

m) Safety, bioeffects, and FDA limits
   i) Static magnetic field (ferromagnetic materials)
   ii) Radiofrequency field (heating)
   iii) Gradient field (nerve stimulation)
   iv) Contrast agent safety issues

n) Accreditation, quality control (QC) and quality improvement
   i) Components of an ACR MRI accreditation program
   ii) Quality control phantoms and measurements
iii) Quality improvement program considerations

17) Nuclear Medicine Physics and Instrumentation

a) Physics of the nucleus
   i) Nuclear nomenclature (isotope, isobar, isotone, isomer)
   ii) Nuclear stability
   iii) Radioactivity
b) Radioactive decay modes
   i) Gamma emission
   ii) Alpha decay
   iii) Beta decay
     (a) Beta minus
     (b) Beta plus (positron)
     (c) Electron capture
   iv) Isomeric transition: $^{99m}_T$C

c) Radioactivity
   i) Definition of terms
     (a) Radioactivity
     (b) Decay constant, half life
   ii) Tracer principle
   iii) Exponential decay equation
   iv) Radionuclide equilibrium
     (a) Secular and transient equilibrium
     (b) Radionuclide generators: $^{99}$Mo/$^{99m}$Tc, $^{82}$Sr/$^{82}$Rb
d) Radionuclide production
   i) Neutron activation
   ii) Fission byproducts
   iii) Charged particle accelerators
e) Radiation detectors
   i) Detection parameters
     (a) Efficiency
     (b) Energy resolution
     (c) Count rate capability
     (d) Spatial resolution
   ii) Counting statistics
f) Ionization detectors
   i) Ionization versus voltage curve: recombination, saturation, proportional, and Geiger–Müller regions
   ii) Instruments
     (a) Dose calibrator
     (b) Survey meters: cutie-pie, G-M detector
g) Solid state (semi-conductor) detectors
   i) General principles
   ii) Cadmium telluride and cadmium zinc telluride
h) Scintillation detectors
   i) Scintillators
      (a) Conventional nuclear medicine: sodium iodide, cesium iodide
      (b) PET: lutetium oxyorthosilicate (LSO), lutetium yttrium orthosilicate (LYSO)
   ii) Thyroid probe and well counters
   iii) Coincidence detection
i) Gamma cameras
   i) Scintillation camera
   ii) Collimation
   iii) Quality control
      (a) Uniformity
      (b) Spatial resolution
iv) Performance parameters
   (a) Uniformity
   (b) Spatial resolution
   (c) Energy resolution
   (d) Count sensitivity
v) Image quality
   (a) Count density requirements
   (b) Contrast improvement: choice of radiopharmaceutical, delayed imaging, collimation and view choice
j) Emission tomography
   i) Fundamentals
      (a) Projections, uniformity, stationary object, center of rotation
      (b) Filtered backprojection and iterative reconstruction
   ii) Degrading factors leading to artifacts
      (a) Attenuation
      (b) Scattered radiation
      (c) Spatial resolution
      (d) Noise
      (e) Uniformity
      (f) Motion
k) SPECT
   i) Instrumentation
      (a) Scintillation camera systems
      (b) Cardiac systems
      (c) SPECT/CT
   ii) Quality control
      (a) Planar tests
      (b) Center of rotation
      (c) SPECT phantom
   iii) Corrections
      (a) Motion
      (b) Attenuation
(c) Scatter
(d) Spatial resolution

iv) Accreditation
(a) ACR (b) ICANL (c) JCAHO

l) PET
i) Instrumentation
(a) Coincidence detection
(b) Time of flight
(c) PET/CT

ii) Quality control
(a) Normalization
(b) Blank scan
(c) Uniformity: artifacts
(d) PET phantom
(e) Standardized uptake value (SUV) calibration

iii) Corrections
(a) Random coincidences
(b) Scatter
(c) Attenuation
(d) Spatial resolution

iv) Accreditation
(a) ACR (b) ICANL (c) The Joint Commission

m) Internal dosimetry
i) Radiation dose parameters
(a) Total decays: cumulated activity and residence time
(b) Emitted energy: dose equilibrium constant
(c) Absorbed fraction
(d) Distribution mass: effective of body size
(e) S factor

ii) Effective half life
(a) Physical decay
(b) Biological clearance

iii) Critical organ
(a) Renal clearance
(b) GL clearance
Radioisotope Safety Examination (RISE)

General:

(A) 700 hours of training and experience, including a minimum of 80 hours of classroom and laboratory training, in basic radionuclide handling techniques applicable to the medical use of unsealed byproduct material for imaging and localization studies; and (B) work experience, under the supervision of an authorized user who meets the requirements in §§ 35.57, 35.290, or 35.390 and 35.290(c)(1)(ii)(G), or equivalent Agreement State requirements.

Specifics:

1) Radiation Physics and Instrumentation
   a) Radiation monitoring instruments
   b) Dose calibrators
      i) Calibration
      ii) Quality control (QC)
      iii) Operation and use
   c) Counting systems and monitoring equipment
      i) Calibration
      ii) Quality control (QC)
      iii) Operation and use

2) Radiation Protection
   a) ALARA concept
   b) Radiation protection program
   c) Audit program
   d) Operating and emergency procedures
   e) Radiation area designations and safety instructions
      i) Restricted area
      ii) Public area
      iii) Caution signs
      iv) Engineering controls

3) Mathematics Pertaining to the Use and Measurement of Radioactivity
   a) Radioactive decay
   b) Radioactive equilibrium
   c) Units and conversions

4) Radiation Biology
   a) Radiation dose: absorbed dose, dose equivalent, effective dose
   b) Deterministic effects
   c) Stochastic effects
   d) Risks of radiation-induced cancer

5) Management of Radioactive Sources
   a) Ordering, receiving and opening of packages
   b) Sealed source regulations
c) Exempt quantities
d) Use records: unit dose, multi-dose vials
e) Radiation area surveys
f) Waste management/disposal
   i) Cold trash surveys
   ii) Waste decay-in-storage surveys and logs
6) Regulatory Exposure Limits
   a) Occupational dose limits
   b) Pregnant workers
c) Public dose
d) Safe use of unsealed licensed material
e) Respiratory protection and controls
f) Conditions requiring individual monitoring of external and internal occupational dose
7) Radiopharmaceutical Administration
   a) Verifying patient identity
   b) Recording
c) Administering/confirming prescribed dose
d) Pregnancy considerations
e) Fetal radiation dose issues
f) Breast feeding recommendations
8) Administrative/Practice Controls and Responsibilities
   a) NRC authority/Agreement States
   b) Personnel
      i) Technologists
      ii) Radiation safety officer (RSO)
      iii) Authorized users (AU)
      iv) Authorized nuclear pharmacists
      v) Authorized medical physicists (AMP)
c) Licenses
d) Written directive (WD) procedures and safety
   i) Studies requiring WD
   ii) Replacement of WD with an oral directive
   iii) Information required in the WD
   iv) Procedures for administrations requiring a WD
e) Patient issues: selection, preparation, informed consent, understanding and calculation of administered activity, counseling of patients and families on radiation safety issues, release criteria, follow-up; pregnancy, breast-feeding recommendations
f) Safety during ¹³¹I sodium iodide therapy greater than 33 mCi
   i) Inpatient
   ii) Outpatient: release criteria
   iii) Patient issues: selection, preparation, informed consent, understanding and calculation of administered activity, counseling of patients and families on radiation safety issues, release criteria, follow-up; pregnancy, breast-feeding recommendations
g) Radiopharmacy (“hot lab”) procedures and safety
   i) Safe procedures for personnel and patients
   ii) Thyroid bioassays
   iii) Radionuclide generator operation
       (1) Measuring and testing the eluate for radionuclidic purity
       (2) Processing the eluate with reagent kits to prepare labeled radioactive drugs
       (3) Record keeping
9) Radiation Accidents/Incidents
   a) Medical events/reportable events
      i) Events requiring reporting
      ii) Information required in the report
      iii) Notifying the NRC
      iv) Notifying referring physician/patient
   b) Radiation spills
      i) Major spill
      ii) Minor spill
Reproductive/Endocrine Imaging and Therapy

1) Adrenal
   a) Congenital abnormalities
   b) Benign masses
   c) Malignant primary and secondary neoplasms
   d) Endocrine disorders
   e) Acquired diseases and conditions
      i) Infection
      ii) Inflammatory conditions
      iii) Hemorrhage

2) Thyroid
   a) Benign masses
      i) Goiter
   b) Malignant masses
   c) Endocrine disorders
      i) Hypothyroidism
      ii) Hyperthyroidism

3) Parathyroid
   a) Benign masses
   b) Malignant primary and secondary neoplasms
   c) Endocrine disorders
      i) Hypoparathyroidism
      ii) Hyperparathyroidism

4) Female genitourinary tract
   a) Congenital abnormalities
   b) Infertility
   c) Menopause
   d) Uterus and cervix
      i) Benign and malignant masses
      ii) Acquired conditions (infection, hemorrhage)
   e) Ovaries and fallopian tubes
      i) Benign and malignant masses
         1) Cysts and cystic lesions
      ii) Acquired conditions (infection, hemorrhage)
         1) Infections
            a) Pelvic inflammatory disease
         2) Torsion
         3) Ovarian failure
   f) Vulva and vagina
i) Benign and malignant masses
   (1) Cysts and cystic lesions

5) Obstetrical and Fetal Imaging
   a) Early pregnancy and placentation
   b) Ectopic pregnancy
   c) Fetal biometry and fetal growth
   d) Congenital fetal anomalies
   e) Maternal disorders in pregnancy
   f) Multiple gestations

6) Male Genitourinary Tract
   a) Scrotum, testes, penis, seminal vesicles, vas deferens, ejaculatory ducts
      i) Congenital abnormalities
      ii) Benign and malignant masses
      iii) Trauma
      iv) Torsion
   b) Infertility

7) Modalities and Techniques
   a) Fluoroscopy
   b) Radiography
   c) Hysterosalpingography
   d) Ultrasound
      i) Transabdominal
      ii) Endovaginal
      iii) 3D ultrasonography
      iv) Color, power, and spectral Doppler
   v) Scrotal and endorectal ultrasound of the male lower genitourinary tract
   vi) Saline infusion sonohysterography
   vii) Thyroid and parathyroid ultrasound
   e) CT
   f) MRI
   g) Image-guided biopsy and drainage
      i) Thyroid uptake and/or scan - Radioiodine ($^{131}$I and $^{123}$I)
   h) Thyroid scan - technetium pertechnetate
   i) Parathyroid scan – $^{99m}$Tc sestamibi
   j) Radionuclide studies: diagnosis and treatment of endocrine disorders (includes octreotide and MIBG imaging)
   k) FDG-PET/CT
Noninterpretive Skills

The Noninterpretive Skills portion of the ABR examinations is intended to focus on established knowledge in the areas of radiology quality and safety, professionalism and ethics, compliance, and regulatory and legal issues, as well as basic research and screening concepts. Since the range of content relevant to these topics is broad, a separate Study Guide has been produced to serve as a syllabus of the “core” knowledge that residents eligible to take the Core Exam and Certifying Exam are expected to know. The Study Guide should be considered a major resource to identify topics and content for the examination, but it is not the “last word” on these topics, nor does it take the place of textbooks, other definitive source material, education you should have received during your residency or fellowship training, or continuing education. We also draw your attention to the Bibliography and Suggested Reading List at the end of the Study Guide and to web links to key public documents, which are available on the websites of the major voluntary organizations in radiology, such as ACR, ARRS, and RSNA. We highly recommend these “deeper” resources to provide perspective and depth of understanding of the concepts that are only superficially outlined here. CLICK HERE to access the NIS Study Guide.

Noninterpretive Skills Study Guide Outline:

1. General Quality Improvement
   a) Traditional Definition of Quality in Healthcare
   b) The New Paradigmatic Approach to Quality Science
   c) Six Core Competencies of MOC
   d) Best Practices
   e) Methodologies

2. Patient Safety
   a) Findings of IOM Report: “To Err is Human: Building a Safer Health System”
   b) Human Factors
   c) High Reliability Organization (HRO)
   d) Culture of Safety

3. Professionalism and Ethics
   a) Medical Professionalism in the New Millennium: A Physician Charter

4. Compliance, Regulatory, and Legal Issues
   a) Confidentiality: HIPAA Privacy Rule
   b) Risk Management and Legal Issues
   c) Centers for Medicare and Medicaid Services (CMS) Definitions

5. Research and Screening
   a) Basic Statistics for Literature Interpretation in Imaging
   b) Biases
Thoracic Imaging

1. Basics of Imaging, including Chest Radiography (CXR), CT and MRI, Ultrasound (US), and Percutaneous Intervention
   a) Indications and limitations of the modalities
   b) Physics behind image creation, including artifacts on CXR, CT, MRI and US
      i. X-ray physics
      ii) CT physics
         (1) CT artifacts relevant to thoracic imaging
         (2) Tradeoffs between noise, dose, and image quality
         (3) Spatial resolution, contrast resolution, and imaging reconstruction algorithms
         (4) Contrast injection—principles, protocols, bolus geometry, iodine flux
      iii) MRI physics
         (1) MR artifacts relevant to thoracic imaging
         (2) Trade-off between spatial resolution, temporal resolution, contrast resolution, and acquisition time
         (3) Principles of black blood, edema, and scar imaging
         (4) Steady-state free precession cine imaging
         (5) Velocity-encoded cine (phase contrast) imaging—principles, applications, and limitations
   c) 3D imaging and post-processing
      i) Multiplanar reconstruction (MPR)
      ii) Maximum intensity projection (MIP) and minimum intensity projection (minIP)
      iii) Volume rendering (VR)
   d) Patient safety
      i) Radiation exposure and how technical modifications may modify dose
      ii) Contrast agents used for thoracic imaging

2) Normal Anatomy, including Variants, Encountered on CXR, CT, MRI and US
   a) Lungs, including tracheobronchial and pulmonary lobar anatomy, and fissures
   b) Mediastinal and thoracic inlet anatomy
   c) Chest wall anatomy

3) Physiology Relevant to Thoracic Imaging, including Pulmonary Function Tests, Restrictive and Obstructive Patterns

4) Definition, Identification, and Significance of Signs and Finding Nomenclature in Thoracic Radiology. Knowledge should include diseases for which these signs are classic, potential alternative diagnoses, or pitfalls [Hansell et al. Fleischner Society: Glossary of Terms for Thoracic Imaging. Radiology 2008;246:697-722]
   a) Air bronchogram
   b) Air crescent sign
   c) Deep sulcus sign on a supine radiograph
d) Continuous diaphragm sign
e) Ring around the artery sign
f) Fallen lung sign
g) Flat waist sign
h) Gloved finger sign
i) Golden S sign
j) Luftsichel sign
k) Hampton hump
l) Silhouette sign
m) Cervicothoracic sign, tapered margins sign
n) Figure 3 sign
o) Fat pad sign or sandwich sign
p) Scimitar
q) Hilum overlay sign and hilum convergence sign
r) Beaded septum sign
s) Tree-in-bud
t) Centrilobular nodules
u) Perilymphatic nodules
v) Random or miliary nodules
w) Crazy paving
x) Ground glass halo
y) Mosaic attenuation
z) Consolidation
aa) Ground glass opacity
bb) Honeycombing
c) Interlobular and intralobular septal thickening and reticulation
d) Juxtaphrenic peak
e) Secondary pulmonary lobule
f) Mass and nodule
g) Parenchymal and subpleural bands
hh) Pleural plaques or pseudoplaques
ii) Reverse halo sign
jj) Signet ring sign (also known as pearl ring sign)
k) Split pleura sign
ll) Headcheese sign
mm) Thoracoabdominal sign
nn) Westermark sign
oo) CT angiogram sign
pp) Bulging fissure sign
qq) Fleischner sign
rr) Comet tail sign
ss) Thymic sail sign
tt) Split pleura sign
uu) Positive bronchus sign
5) Infectious Pneumonia - CXR and CT Findings
   a) Mycobacterial and fungal
   b) Viral
   c) Community- and hospital-acquired bacterial pneumonia
   d) Pneumonia in the immunocompromised, including patients:
      i) with HIV/AIDS
      ii) with post-transplantation status
      iii) on chemotherapy, receiving corticosteroids, or with immune conditions
   e) Septic emboli

6) Lung Cancer and other Parenchymal Neoplasms
   a) Solitary pulmonary nodule (SPN)
      i) Approach to diagnosis (contrast-enhancement, imaging features)
      ii) Management (PET, biopsy, follow-up/comparison)
      iii) Perception and errors in perception
   b) Screening for lung cancer – current status
   c) Chronic alveolar disease as a manifestation of neoplasm
   d) Lung cancer staging
   e) Manifestations of small cell and non small cell carcinoma, and bronchoalveolar cell carcinoma, including common locations for metastases
   f) Other tumors
      i) Metastases
      ii) Carcinoid
      iii) Hamartoma
      iv) Lymphoma
      v) Chondrosarcoma

7) The Intensive Care Unit CXR - The Expected Location of the Support Devices and the Ability to Recognize Misplaced Lines and Complications (Pneumothorax, Hemothorax, Hematoma, Pneumoperitoneum)
   a) Central lines (including wrong vein and intra-arterial)
   b) Esophageal tubes/probes (including esophageal, nasogastric, and feeding tubes, endobronchial or intrapleural misplacement
   c) Endotracheal and tracheostomy tubes
   d) Pulmonary artery (Swan-Ganz) catheters (including peripheral placement and pseudoaneurysm formation)
   e) Chest tubes (including intraparenchymal and intrafissural placement)
   f) Assist devices
8) Trauma, including Blunt and Penetrating Trauma
   a) Acute traumatic aortic injury
   b) Esophageal injury
   c) Tracheobronchial injury
   d) Lung injuries (contusion, shear injury, aspiration, laceration)
   e) Diaphragm injury, both acute and delayed presentations
   f) Tension hemopneumothorax, pneumothorax, pneumomediastinum
   g) Flail chest, skeletal fractures, and dislocations
   h) Fat emboli

9) Congenital Lung and Mediastinal Disease Manifesting in the Adult
   a) Foregut duplication cysts, including bronchogenic cysts and esophageal duplication cysts
   b) Bronchial atresia
   c) Arteriovenous malformations
   d) Partial anomalous pulmonary venous return
   e) Left superior vena cava (SVC) and duplicated SVC
   f) Swyer-James syndrome (unilateral bronchiolitis obliterans)
   g) Poland syndrome
   h) Sequestration (intralobar and extralobar)
   i) Congenital cystic adenomatoid malformation
   j) Aortic arch anomalies

10) Diffuse Lung Disease
    a) Cystic disease
        i) Langerhans cell histiocytosis
        ii) Lymphangioleiomyomatosis
        iii) Tracheobronchial papillomatosis
        iv) Lymphocytic interstitial pneumonia
        v) Cystic metastases
        vi) Chronic pneumocystis
    b) Pneumoconioses
        i) Silicosis/coal workers pneumoconiosis
        ii) Asbestosis
        iii) Berylliosis
    c) Idiopathic/fibrotic
        i) Usual interstitial pneumonia (UIP)
        ii) Nonspecific interstitial pneumonia (NSIP)
        iii) Desquamative interstitial pneumonia (DIP)
        iv) Acute interstitial pneumonia (AIP)
    d) Pulmonary edema
        i) Cardiogenic
        ii) Noncardiogenic
    e) Drug toxicity, including chemotherapy agents such as bleomycin and medications such as Amiodarone
f) Sarcoidosis, including CXR staging  
g) Lymphangitic carcinomatosis  
h) Differential diagnoses for chronic upper lobe predominant disease and chronic lower lobe predominant disease

11) Diffuse Alveolar Disease and Inflammatory Conditions  
a) Pulmonary alveolar proteinosis  
b) Lipoid pneumonia  
c) Organizing pneumonia, including cryptogenic  
d) Eosinophilic pneumonia  
e) Hypersensitivity pneumonia/extrinsic allergic alveolitis  
f) Differential diagnosis of peripheral alveolar opacities

12) Central Airways Diseases, Bronchiectasis, and Obstructive Lung Disease  
a) Tracheal/bronchial tumors or masses  
   i) Squamous cell cancer and papillomas  
   ii) Adenocarcinoma  
   iii) Mucoepidermoid  
   iv) Adenoid cystic carcinoma  
   v) Carcinoid  
   vi) Metastases  
b) Cystic fibrosis  
c) Tracheal stenosis  
   i) Inhalation and iatrogenic (such as tracheostomy or endotracheal tube)  
   ii) Granulomatous disease (Sarcoid, Wegener, tuberculosis)  
   iii) Amyloidosis  
   iv) Conditions that spare the posterior membrane (relapsing polychondritis; tracheopathia osteochondroplastica)  
d) Tracheobronchomalacia  
e) Bronchiectasis, including upper versus lower lobe predominant bronchiectasis  
   i) Immotile cilia syndrome (Kartagener)  
   ii) Recurrent aspiration  
   iii) Tracheobronchomegaly (Mounier-Kuhn)  
   iv) Tuberculosis  
f) Small airway disease  
   i) Asthma  
   ii) Bronchiolitis obliterans  
   iii) Graft-versus-host disease  
g) Small airway infection, including Mycobacterium avium-intracellulare (MAI)  
h) Broncholithiasis  
   i) Allergic bronchopulmonary aspergillosis (ABPA)  
j) Aspiration and foreign bodies  
k) Emphysema, including centrilobular, paraseptal, panacinar, and paracatricial  
l) Giant bulla
13) Thoracic Manifestations of Systemic Disease
   a) Rheumatoid arthritis
   b) Scleroderma and mixed connective tissue disease
   c) Systemic lupus erythematosus
   d) Hepatopulmonary syndrome
   e) Vasculitis (Wegener, Goodpasture)
   f) Tuberous sclerosis
   g) Neurofibromatosis
   h) Sickle cell disease
   i) Polymyositis/dermatomyositis
   j) Sjögren syndrome
   k) Metastatic pulmonary calcification

14) Diseases of the Pleura, Chest Wall, and Diaphragm
   a) Mesothelioma
   b) Pleural metastases
   c) Fibrous tumor of the pleura
   d) Lipoma
   e) Empyema
   f) Chylothorax
   g) Pleural plaques, including asbestos exposure, hemothorax, prior infection
   h) Unilateral pleural calcification
   i) Pleural effusions, including differential diagnosis for unilateral and bilateral effusions
   j) Diaphragmatic hernias, including post-traumatic, Bochdalek, Morgagni, sliding hiatal
   k) Disorders of diaphragm motion, including role of sniff test
   l) Neurofibromatosis
   m) Chest wall tumors, including metastases, sarcomas, and desmoid tumors

15) Mediastinal Masses (Including Cardiac and Vascular-related Masses)
   a) Anterior mediastinum
      i) Thymic origin, including thymoma, carcinoma, carcinoid, and cyst
      ii) Germ cell tumors, including seminoma and teratoma
      iii) Lymphoma
      iv) Goiter
   b) Middle mediastinum
      i) Duplication cysts
      ii) Lymph node enlargement
      iii) Esophageal origin, including cancer, diverticulum, achalasia, varices
      iv) Airway masses
      v) Vascular masses
   c) Posterior mediastinum
      i) Nerve sheath tumors (neurofibromas, schwannomas)
      ii) Paragangliomas (ganglioneuroma and ganglioneuroblastoma)
iii) Spine and paraspinal processes, including extramedullary hematopoiesis, metastases, diskitis
d) Superior mediastinal / thoracic inlet masses
   i. Goiter
   ii. Lymphangioma
e) Differential diagnoses of mediastinal masses based on location and CT attenuation (fat, fluid, calcified, enhancing)/MR signal characteristics
f) Vascular masses (aneurysms and pseudoaneurysms)
g) Diffuse mediastinal disease
   i) Mediastinitis
   ii) Fibrosing mediastinitis
h) Differential diagnosis for egg-shell calcifications
i) Mediastinal lymph node enlargement

16) Atelectasis and Collapse, including CXR/CT Findings and Differential Diagnosis
   a) Lobar collapse (right upper, middle, right lower, left upper, lingual, left lower, and combined right middle/lower)
   b) Unilateral lung collapse
   c) Collapse from an obstructing mass
d) Round atelectasis

17) Pulmonary Arteries
   a. Acute pulmonary embolism
   b. Chronic pulmonary embolism
   c. Pulmonary infarct
d. Pulmonary embolism mimics, including pulmonary artery sarcoma
e. Pseudoaneurysm
f. Vasculitis (Takayasu)

18) Postoperative and Post-treatment Thorax
   a) Lung resection, including post-lobectomy, post-wedge resection, pneumonectomy, and post-pneumonectomy syndrome
   b) Lobar torsion
c) Radiation fibrosis and pneumonitis
d) Post lung transplantation, including acute, subacute, and chronic complications, single and bilateral transplantation
e) Post-esophagectomy
f) Post-lung volume reduction surgery
g) Airway and esophageal stents
h) Eloesser flap

19) Percutaneous Thoracic Interventions
   a. Aspiration, biopsy and drainage
   b. Clinical indications and contraindications
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>c.</td>
<td>Techniques</td>
</tr>
<tr>
<td>d.</td>
<td>Accuracy</td>
</tr>
<tr>
<td>e.</td>
<td>Complications</td>
</tr>
<tr>
<td>f.</td>
<td>Post-procedure care</td>
</tr>
</tbody>
</table>
Ultrasound

1) Medical and Comprehensive knowledge
   a) “Hands-on” scanning: recognize the normal appearance as well as the most common pathology of the following:
      i) Pleural space (effusion)
      ii) Peritoneal space
         (1) Ascites
         (2) Hemorrhage
      iii) Gallbladder
         (1) Gallstones
         (2) Acute cholecystitis
      iv) Biliary
         (1) Common bile duct
         (2) Biliary ductal dilatation
      v) Liver
         (1) Masses
         (2) Steatosis
         (3) Cirrhosis
      vi) Kidney
         (1) Hydronephrosis
         (2) Stones
         (3) Mass/cyst
      vii) Pancreas
         (1) Pancreatitis
         (2) Mass/cyst
      viii) Retroperitoneal
         (1) Abdominal mass
         (2) Cyst
         (3) Adenopathy
      ix) Alimentary tract
         (1) Normal gut signature
         (2) Appendicitis
         (3) Intussusception
         (4) Inflammatory bowel disease
      x) Thyroid
         (1) Nodules
         (2) Diffuse disease
      xi) Parathyroid
         (1) Adenoma
         (2) Hyperplasia
         (3) Testis/Epididymis/Scrotum
         (4) Mass/cyst
(5) Torsion
(6) Trauma
(7) Infection
xii) Transabdominal/transvaginal pelvis
   (1) Uterus – measurement
   (2) Fibroids
   (3) Adenomyosis
   (4) Endometrial stripe
   (5) Adnexal mass/cyst
   (6) Free fluid
xiii) First Trimester Pregnancy
   (1) Normal
   (2) Failed early intrauterine pregnancy
   (3) Ectopic pregnancy
xiv) Obstetrics
   (1) Basic fetal biometry
   (2) Basic second/third trimester fetal anatomy
   (3) Placental localization
   (4) Amniotic fluid volume
   (5) Comprehensive second/third trimester
xv) Pediatrics
   (1) Abdomen
   (2) Spine
   (3) Hips
   (4) Neonatal brain
   (5) GI tract
xvi) Breast
   (1) Solid mass/cyst
   (2) Lymph nodes
   (3) Breast cancer staging
xvii) Vascular
   (1) Lower and upper extremity venous (deep vein thrombosis)
   (2) Lower and upper extremity arterial
   (3) Carotid and vertebral arteries
   (4) Abdominal aorta (aneurysm, including how to measure)
   (5) Abdominal Doppler
   (6) Inferior vena cava (IVC)
   (7) Hepatic and renal transplants
xviii) Musculoskeletal (MSK)
   (1) Tendons
   (2) Mass/cyst
   (3) Muscle
xix) US guided procedures
   (1) Aspiration
(2) Fine-needle aspiration (FNA)
(3) Biopsy
(4) Line placement

b) Physics/instrumentation: The resident should understand the basic principles of physics that form the foundation of clinical ultrasound.
   i) Range of US frequencies used in generating diagnostic images
   ii) Transducer type: curvilinear, linear, sector, vector, endoluminal
   iii) Transducer selection for various clinical applications
   iv) Transducer components and beam characteristics
   v) Beam formation/focusing
   vi) Frequency, sound speed, wavelength, intensity, decibels, beam width
   vii) Trade-off of frequency in terms of depth versus resolution
   viii) Mode: grayscale, M-mode, A-mode, B-mode, pulsed wave Doppler, color and power Doppler, B-flow
   ix) Image orientation
   x) Frame rate
   xi) Grayscale image optimization
      1) Focal zone
      2) Power output
      3) Gain
      4) Time gain compensation
      5) Line density
      6) Transmit frequency
      7) Dynamic range
   xii) Acoustic properties of matter
      1) Fluid
      2) Cyst
      3) Calcification
      4) Complex fluid and solid structures, gas, metal, fat
   xiii) Interaction of sound waves with tissues
      1) Reflection
      2) Attenuation
      3) Scattering
      4) Refraction
      5) Absorption
      6) Acoustic impedance
      7) Pulse-echo principles
   xiv) Thermal and nonthermal effects on tissue
      1) Biological health risks
      2) Mechanical index
      3) Cavitation
      4) Relative risks for different scan modes
      5) Thermal and mechanical indices
   xv) Doppler phenomenon, Doppler equation
xvi) Grayscale vs Doppler (trade-off of penetration and resolution)

xvii) Optimization of Doppler parameters

1) Color box – size, shape, and angle
2) Transmit frequency
3) Doppler angle
4) Wall filter
5) Pulse repetition frequency
6) Scale, gain
7) Color write priority
8) Sample volume size

xviii) Artifacts

1) Beam width
2) Side lobe
3) Slice thickness

xix) Multiple reflection artifacts - mirror image/reverberation

xx) Refractive artifacts, misregistration

1) Ring down
2) Acoustic shadowing and enhancement
3) Speed propagation artifact
4) Anisotropy

xxi) Doppler artifacts

1) Pulse wave
2) Color imaging, including aliasing
3) Color blooming
4) Soft tissue vibration
5) Flash
6) Motion

xxii) 3D/4D volumetric imaging

xxiii) Harmonic imaging

xxiv) Spatial compounding

xxv) Panoramic imaging

xxvi) Fusion imaging (transducer tracking)

xxvii) Ultrasound contrast agents

xxviii) Elastography

xxix) Equipment quality assurance

1) Phantoms
2) Spatial/contrast resolution
3) Care of probes
4) Cleaning/disinfection
5) Infection control

2) Clinical applications

a) General

i) Understand the importance of clinical ultrasound protocols. Published guidelines from the American College of Radiology (ACR) with or without local modification are
acceptable frames of reference. Residents should also be familiar with ACR appropriateness criteria as a guide for appropriate clinical use of ultrasound and other imaging modalities.

ii) Understand the clinical uses and limitations of ultrasound, as well as the appropriate integration of other complementary cross-sectional imaging studies, particularly CT and MRI.

iii) Understand the importance of documentation, reporting, communication and reporting of critical findings.

iv) Understand the importance of clinical quality assurance, including radiologic-pathologic correlation, as well as sonographer-physician discrepancies.

b) Abdomen

i) Liver

(1) Normal echotexture/echogenicity/size/shape
(2) Normal variants
(3) Diffuse disease
   (a) Steatosis, including focal steatosis and focal sparing
   (b) Acute and chronic hepatitis
   (c) Cirrhosis
   (d) Edema

(4) Masses
   (a) Cyst
   (b) Cavernous hemangioma
   (c) Focal nodular hyperplasia
   (d) Adenoma
   (e) Metastasis
   (f) Hepatocellular carcinoma
   (g) Lymphoma
   (h) Cholangiocarcinoma
   (i) Granuloma
   (j) Hematoma
   (k) Biloma
   (l) Abscess
      (i) Pyogenic/Echinococcal/Amebic

   (m) Post-liver transplantation collections
      (i) Hematoma/ Biloma/Abscess

(5) Trauma

ii) Gallbladder

(1) Normal size/shape/wall
(2) Gallstones
(3) Sludge
(4) Acute cholecystitis
   (a) Calculous/acalculous/gangrenous/perforated/emphysematous
(5) Other etiologies of wall thickening
(a) Polyp  
(b) Hyperplastic cholecystosis  
(c) Carcinoma  
(d) Porcelain gallbladder

iii) Bile ducts  
(1) Normal intra- and extrahepatic bile duct appearance/size  
(2) Normal variants  
(3) Ductal dilatation  
(4) Bile duct stones  
(5) Cholangitis  
(a) Primary sclerosing/Pyogenic/Recurrent pyogenic/AIDS  
(6) Caroli disease  
(7) Choledochal cysts  
(8) Pneumobilia  
(9) Cholangiocarcinoma

iv) Pancreas  
(1) Normal echotexture/echogenicity/size/shape  
(2) Normal variants  
(3) Pancreatic duct  
(4) Masses  
(a) Cyst  
(b) Pseudocysts  
(c) Cystic neoplasms  
(d) Cancer  
(e) Metastases  
(f) Lymphoma  
(g) Islet cell tumor  
(h) Intraductal papillary mucinous neoplasm (IPMN)  
(5) Pancreatitis  
(a) Abscess  
(b) Pseudocyst  
(c) Pseudoaneurysm  
(d) Chronic pancreatitis

v) Spleen  
(1) Normal echotexture/echogenicity/size/shape  
(2) Normal variants  
(3) Masses  
(a) Cyst  
(b) Lymphoma  
(c) Metastases (d) Abscess  
(e) Infarct  
(f) Granuloma  
(4) Trauma
vi) Peritoneal cavity
   (1) Normal anatomy
   (2) Ascites
   (3) Hemorrhage
   (4) Abscess
   (5) Omental/peritoneal metastasis
   (6) Omental infarct
   (7) Mesothelioma
   (8) Free air

vii) Gastrointestinal tract
   (1) Normal gut ultrasound signature
   (2) Acute appendicitis
   (3) Diverticulitis
   (4) Inflammatory bowel disease (Crohn disease, ulcerative colitis)
   (5) Colitis
   (6) Bowel obstruction (including intussusception, malignancy)
   (7) Cancer
   (8) Lymphoma
   (9) GI stromal tumor (GIST)
   (10) Fistulae, abscess

viii) Abdominal wall
   (1) Normal echogenicity/echotexture
   (2) Hematoma
   (3) Abscess
   (4) Hernia
   (5) Masses
      (a) Primary tumor
      (b) Metastasis
      (c) Lymphoma
      (d) Desmoids tumor
      (e) Lipoma
      (f) Endometriosis

ix) Organ transplants: see vascular section

c) Urinary Tract and Adrenal Glands
   i) Kidney
      (1) Normal echotexture/echogenicity/size/shape
      (2) Normal variants/congenital anomalies
      (3) Calculi
      (4) Hydronephrosis
      (5) Glomerular & interstitial renal disease
      (6) Cysts
         (a) Simple (b)
         Complex (c)
         Peripelvic
(d) Adult polycystic disease
(e) Acquired renal cystic disease
(7) Perinephric fluid/collections
(8) Masses
   (a) Angiomyolipoma
   (b) Oncocytoma
   (c) Multilocular cystic nephroma
   (d) Renal cell carcinoma
   (e) Transitional cell carcinoma
   (f) Lymphoma
   (g) Metastasis
(9) Infection
   (a) Pyelonephritis
   (b) Xanthogranulomatous pyelonephritis
   (c) Emphysematous pyelonephritis
   (d) Abscess
   (e) Perinephric abscess
(10) Medullary nephrocalcinosis
(11) Infiltrative disease
(12) Renal transplant (see vascular section)

ii) Ureters
   (1) Dilatation of the collecting system
   (2) Megaureter
   (3) Ureterocele (including ectopic ureterocele)
   (4) Ureteral stone
   (5) Pyonephrosis
   (6) Clot in collecting system
   (7) Transitional cell cancer
   (8) Stents

iii) Urinary bladder
   (1) Normal size/shape/wall
   (2) Calculi
   (3) Wall thickening
   (4) Ureteral jets
   (5) Bladder volume, including post-void residual
   (6) Masses
      (a) Transitional cell carcinoma
      (b) Pheochromocytoma
      (c) Endometriosis
   (7) Cystitis, including emphysematous cystitis
   (8) Hemorrhage
   (9) Wall thickening
   (10) Bladder outlet obstruction
   (11) Diverticula
(12) Ureterocele, including ectopic ureterocele
(13) Ureterovesical junction (UVJ) stone
(14) Fungus balls
iv) Adrenal glands
   (1) Normal echotexture/echogenicity/size/shape
   (2) Masses
      (a) Adenoma
      (b) Pheochromocytoma
      (c) Myelolipoma
      (d) Metastasis
      (e) Lymphoma
      (f) Cancer
      (g) Hemorrhage
v) Transabdominal and transrectal prostate
   (1) Normal echotexture/echogenicity/size/shape
   (2) Benign prostatic hypertrophy
   (3) Cancer
   (4) Prostatitis
   (5) Abscess
vi) Retroperitoneum
   (1) Adenopathy
   (2) Primary sarcoma
   (3) Hemorrhage
   (4) Abscess
d) Gynecology
i) Uterus
   (1) Normal echotexture/echogenicity/size/shape
   (2) Endometrium
      (a) Normal appearance during phases of menstrual cycle
      (b) Thickness measurement
         (i) Premenopausal
         (ii) Postmenopausal
         (iii) Effects of hormone replacement
      (c) Normal variants/congenital anomalies
      (d) Intrauterine device
         (i) Normal location
         (ii) Displaced/extruded
      (e) Endometrial fluid
      (f) Endometrial polyp
      (g) Endometrial hyperplasia
      (h) Endometrial carcinoma
      (i) Endometritis
   (3) Myometrium
      (a) Fibroids
(b) Leiomyosarcoma  
(c) Adenomyosis  

ii) Ovary  
(1) Normal echotexture/echogenicity/size/shape, including physiologic variation during phases of menstrual cycle  
(a) Follicles  
(b) Corpus luteum  
(c) Hemorrhagic ovarian cyst  
(2) Polycystic ovarian disease  
(3) Ovarian hyperstimulation syndrome  
(4) Masses/Cysts  
(a) Simple/hemorrhagic/ruptured ovarian cyst  
(b) Endometrioma  
(c) Cystadenoma/carcinoma  
(d) Dermoid  
(e) Fibroma and other stromal tumors  
(f) Germ cell tumor  
(g) Metastasis  
(5) Ovarian torsion  
(6) Pelvic inflammatory disease  
(a) Tubo-ovarian abscess  
(7) Ovarian cancer, including staging  

iii) Cervix  
(1) Normal echotexture/echogenicity  
(2) Stenosis  
(3) Polyp  
(4) Cancer  
(5) Fibroid  

iv) Fallopian tube  
(1) Hydrosalpinx  
(2) Pyosalpinx  
(3) Postoperative changes  
(4) Essure devices  

v) Post-hysterectomy appearance of pelvis  

vi) Free pelvic fluid  

vii) Peritoneal inclusion cyst  

viii) Saline hysterosonography  

e) Obstetrics  

i) First trimester  
(1) Normal findings of intrauterine gestational sac  
(a) Size  
(b) Gestational sac growth  
(c) Yolk sac  
(d) Embryo
(e) Cardiac activity, including normal embryonic heart rate
(f) Amnion
(g) Chorion
(h) Chorionic villus sampling (CVS)/Amniocentesis
(i) Normal early fetal anatomy/growth
(j) Crown-rump length measurement
(k) Correlation with β-hCG levels and menstrual dates

(2) Multiple gestations (chorionicity and amnionicity)

(3) Failed early pregnancy
   (a) Spontaneous complete/incomplete abortion
   (b) Anembryonic gestation
   (c) Embryonic demise
   (d) Subchorionic hematoma

(4) Ectopic pregnancy, including unusual ectopic pregnancy
   (a) Interstitial
   (b) Cervical
   (c) Ovarian
   (d) Scar (Caesarean delivery)
   (e) Abdominal
   (f) Rudimentary horn

(5) Gestational trophoblastic disease

(6) Nuchal translucency

(7) Embryonic structural abnormalities, anencephaly

   ii) Second and third trimester
      (1) Normal findings
         (a) Normal fetal anatomy/situs/development
         (b) Placenta
         (c) Biometry
         (d) Amniotic fluid volume
      (2) Multiple gestations
      (3) Common congenital anomalies
      (4) Recognition of fetal abnormalities that require high-risk obstetrics referral
         (a) Intrauterine growth retardation
         (b) Hydrops
         (c) Holoprosencephaly
         (d) Hydrocephalus
         (e) Neural tube defects
         (f) Multicystic dysplastic kidney
         (g) Hydronephrosis
         (h) Anencephaly
         (i) Chromosomal abnormalities and syndromes
            (i) Down syndrome
            (ii) Turner syndrome
         (j) Hydrops
(k) Congenital infections  
(l) Chest masses  
(m) Cardiac malformations and arrhythmias  
(n) Diaphragmatic hernia  
(o) Abdominal wall defects  
(p) Abdominal masses  
(q) Gastrointestinal tract obstruction/abnormalities  
(r) Ascites  
(s) Skeletal dysplasias  
(t) Cleft lip/palate  
(u) Complications of twin pregnancy  
(v) Hydranencephaly  
(5) Borderline findings  
(a) Nuchal thickening  
(b) Choroid plexus cyst  
(c) Echogenic cardiac focus  
(d) Echogenic bowel  
(e) Borderline hydrocephalus  
(6) Oligohydramnios  
(a) Spontaneous premature rupture of membranes  
(b) Renal disease  
(c) Fetal death  
(d) Intrauterine growth retardation  
(e) Infection  
(7) Polyhydramnios  
(8) Placenta  
(a) Placenta previa  
(b) Vasa previa  
(c) Abruption  
(d) Percreta-, increta- and accreta  
(e) Placental masses  
(f) Succenturiate placenta  
(9) Cervical appearance and length, cervical incompetence  
(10) Umbilical cord  
(a) Two-vessel umbilical cord  
(b) Cord masses  
(c) Placental cord insertion site  
(d) Velamentous cord insertion  
(e) Cord prolapse  
(f) Umbilical cord Doppler  
(g) Fetal cranial Doppler  
(h) Biophysical profile  
(i) Guidance for amniocentesis  
(j) Retained products of conception
f) Thyroid/neck
   i) Thyroid
      (1) Normal echotexture/echogenicity/size/shape
      (2) Hashimoto thyroiditis
      (3) Graves disease
      (4) Subacute thyroiditis
      (5) Characterization of thyroid nodules
         a) Benign nodules
            i) Colloid cysts
            (ii) Cysts
         b) Malignant nodules
            i) Papillary carcinoma
            (ii) Follicular neoplasm
            (iii) Medullary carcinoma
            (iv) Anaplastic carcinoma
            (v) Lymphoma
            (vi) Metastasis
         c) Non-specific nodules
         d) Multinodular goiter
      (6) National consensus guidelines for performing fine-needle aspiration (FNA)
      (7) Post-thyroidectomy neck surveillance for recurrence of papillary thyroid cancer – role of ultrasound
         a) Central versus lateral neck, levels
   ii) Parathyroid
      (1) Normal
      (2) Adenoma
      (3) Carcinoma
      (4) Hyperplasia
   iii) Congenital cysts
      (1) Branchial cleft cyst
      (2) Thyroglossal duct cyst
   iv) Lymph nodes
      (1) Normal echotexture/echogenicity/size/shape
      (2) Benign reactive
      (3) Metastasis (including surveillance for papillary thyroid cancer)
      (4) Lymphoma
   v) Salivary glands
      (1) Normal echotexture/echogenicity/size/shape
      (2) Benign and malignant neoplasms
         a) Pleomorphic adenoma
         (b) Warthin tumor
         (c) Adenoid cystic carcinoma
         (d) Mucoepidermoid carcinoma
      (3) Infection
(4) Inflammation
(5) Stones
g) Chest
   i) Normal anatomy
   ii) Pleural effusion
   iii) Atelectasis
   iv) Pneumonia
   v) Lung cancer
   vi) Lung metastasis
   vii) Pleural metastasis
   viii) Adenopathy
       (1) Mediastinal and axillary
       (2) Metastasis
       (3) Lymphoma (4) Reactive
ix) Mediastinal tumors
x) Chest wall
   (1) Hematoma
   (2) Abscess
   (3) Primary tumor
   (4) Metastasis
   (5) Lymphoma
   (6) Lipoma
h) Vascular/Doppler
   i) Aorta and mesenteric branches
      (1) Normal size/measurement/appearance/Doppler waveform
      (2) Normal variants
      (3) Aneurysm
      (4) Dissection
      (5) Thrombosis
      (6) Status post stent graft placement including endoleak
      (7) Status post surgery
      (8) Coarctation (9)
      Stenosis (10) Mesenteric
      Ischemia (11) Mesenteric
      aneurysms
      (12) Pseudoaneurysms
      (13) Mesenteric venous thrombosis
   ii) Spleen
      (1) Normal artery and vein size/appearance/Doppler waveform
      (2) Normal variants
      (3) Artery
         (a) Thrombosis
         (b) Aneurysm
(4) Vein
   (a) Thrombosis
(5) Infarction

iii) Lower and upper extremity arterial
(1) Normal appearance and Doppler waveforms
(2) Stenosis
(3) Occlusion/thrombosis
(4) Post catheterization complications
   (a) Pseudoaneurysm/Arteriovenous fistula/dissection/hematoma
(5) Arterial bypass graft
   (a) Normal and abnormal
(6) Peripheral vascular aneurysm

iv) Renal artery
(1) Normal appearance and Doppler waveform
(2) Stenosis
(3) Occlusion
(4) Bypass grafts
(5) Stent/Angioplasty
(6) Aneurysm
(7) Arteriovenous fistula/malformation
(8) Fibromuscular dysplasia
(9) Infarction

v) Renal vein
(1) Normal appearance and Doppler waveform
(2) Thrombosis (bland and tumor)
(3) Arteriovenous fistula/malformation

vi) Carotid artery
(1) Normal appearance and Doppler waveforms
(2) Atherosclerotic plaque/Fibrointimal thickening
(3) Stenosis
(4) Occlusion
(5) Waveform analysis
(6) Dissection
(7) Arteriovenous fistula
(8) Aneurysm
(9) Pseudoaneurysm
(10) Status post carotid endarterectomy and stent
    (a) Normal
    (b) Restenosis
    (c) Complications

vii) Vertebral artery
(1) Normal appearance and Doppler waveforms
(2) Normal variants
(3) Stenosis/Occlusion (proximal or distal)
(4) Subclavian steal syndrome
(5) Partial subclavian steal

viii) Hemodialysis graft/fistula
(1) Normal appearance and Doppler waveforms
(2) Stenosis
(3) Occlusion (including outflow)
(4) Lack of maturation
(5) Fluid collections
(6) Pseudoaneurysms
(7) Steal

ix) Inferior vena cava
(1) Normal appearance and Doppler waveform
(2) Thrombosis (bland and tumor)
(3) Filter
(4) Masses

x) Lower and upper extremity venous
(1) Normal appearance and Doppler waveform
(2) Deep vein thrombosis
(3) Arteriovenous fistula
(4) Tricuspid regurgitation, right heart failure
(5) Chronic venous insufficiency
(6) Pre-arterial bypass graft/dialysis access vein mapping
(7) Nonvascular causes of leg pain and swelling

xi) Hepatic vasculature (native)
(1) Normal hepatic artery, portal vein and hepatic vein size/appearance/Doppler waveform
(2) Normal variants
(3) Portal vein
   (a) Bland thrombosis
   (b) Tumor thrombus
   (c) Cavernous transformation
   (d) Para umbilical vein
   (e) Varices
(4) Hepatic artery
   (a) Thrombosis
   (b) Stenosis
   (c) Aneurysm/Pseudoaneurysm
(5) Hepatic vein
   (a) Bland thrombosis
   (b) Tumor thrombus
   (c) Budd-Chiari syndrome
   (d) Stenosis
(6) Infarction

xii) Hemodynamics of cirrhosis, portal hypertension, and varices
xiii) TIPS evaluation
   (1) Normal appearance and Doppler waveforms
   (2) Stenosis
   (3) Occlusion
   (4) Complications
xiv) Renal transplant
   (1) Normal appearance and Doppler arterial and venous waveforms
   (2) Causes of elevation of arterial resistive index
       (a) Rejection
       (b) Acute tubular necrosis
       (c) Page kidney
       (d) Hydronephrosis
       (e) Pyelonephritis
       (f) Renal vein thrombosis
   (3) Renal infarction
   (4) Post-biopsy complications
       (a) Hematoma
       (b) Pseudoaneurysm
       (c) Arteriovenous fistula
   (5) Renal arterial stenosis/thrombosis
   (6) Renal vein stenosis/thrombosis
   (7) Peritransplant fluid collections
   (8) Post-transplant lymphoproliferative disorder/masses
   (9) Pyelonephritis
   (10) Clot/pus in the collecting system
xv) Liver transplants
   (1) Normal appearance and Doppler arterial and venous waveforms
   (2) Hepatic artery stenosis/thrombosis
   (3) Resistive index
   (4) Portal vein thrombosis/stenosis
   (5) Hepatic vein thrombosis/stenosis
   (6) Post-biopsy complications
       (a) Hematoma
       (b) Pseudoaneurysm
       (c) Arteriovenous fistula
   (7) Inferior vena cava stenosis/thrombosis
   (8) Intrahepatic and peri-hepatic fluid collections
   (9) Post-transplant lymphoproliferative disorder
   (10) Abnormalities of the biliary tree
xvi) Pancreas transplant
   (1) Normal appearance
   (2) Arterial and venous thrombosis/stenosis
   (3) Pancreatitis
   (4) Peritransplant fluid collections
(5) Pseudoaneurysm

i) Scrotum
  i) Testes
   (1) Normal echotexture/echogenicity/size/shape
   (2) Orchitis
   (3) Abscess
   (4) Cysts
       (a) Intratesticular
       (b) Tunica cyst
   (5) Cystic ectasia of rete testis
   (6) Torsion/Detorsion
   (7) Microlithiasis
   (8) Masses
       (a) Germ cell tumor
       (b) Lymphoma
       (c) Metastasis
       (d) Stromal tumor
       (e) Epidermoid cyst
       (f) Infarct/hematoma
   (9) Focal atrophy/fibrosis
   (10) Sarcoidosis
   (11) Tuberculosis
   (12) Trauma
   (13) Nondescended testis

ii) Epididymis
   (1) Normal echotexture/echogenicity/size/shape
   (2) Epididymitis
   (3) Spermatocyte/cyst
   (4) Adenomatoid tumor

iii) Other
   (1) Hydrocele
   (2) Pyocele
   (3) Fournier gangrene
   (4) Scrotal edema
   (5) Hematocele
   (6) Varicocele
   (7) Hernia
   (8) Nondescended testis

j) Pediatrics
  i) Normal anatomy
    (1) Abdomen
    (2) Kidney
    (3) Brain
    (4) Neck
ii) Brain
   (1) Intracranial hemorrhage and complications
       (a) Periventricular leukomalacia
       (b) Hydrocephalus
   (2) Shunt evaluation
   (3) Congenital brain malformations
       (a) Agenesis of corpus callosum
       (b) Vein of Galen aneurysm
       (c) Dandy-Walker malformation
       (d) Aqueductal stenosis

iii) Neonatal spine
   (1) Tethered cord
   (2) Intraspinal mass

iv) Kidneys
   (1) Hydronephrosis
   (2) Stones
   (3) Hydroureters
   (4) Anomalies of position and fusion
   (5) Renal scarring
   (6) Masses
   (7) Cystic disease

v) Adrenal
   (1) Hemorrhage
   (2) Masses (neuroblastoma)

vi) Liver
   (1) Cirrhosis
   (2) Choledochal cysts
   (3) Masses
   (4) Hepatitis/biliary atresia

vii) Gallbladder
   (1) Gallstones
   (2) Biliary stones
   (3) Hydrops

viii) Pancreas: acute pancreatitis

ix) Spleen
   (1) Polysplenia
   (2) Asplenia

x) Hip
   (1) Normal
   (2) Congenital dislocation
   (3) Effusion

xi) Alimentary tract
   (1) Intussusception
   (2) Acute appendicitis
(3) Hypertrophic pyloric stenosis

xii) Scrotal
   (1) Torsion
   (2) Epididymitis
   (3) Orchitis
   (4) Masses
   (5) Undescended testis

xiii) Ovary
   (1) Solid and cystic masses
   (2) Ovarian torsion

xiv) Uterus
   (1) Normal appearance and size
   (2) Imperforate hymen
   (3) Uterine anomalies

xv) Neck masses

xvi) Deep vein thrombosis of upper and lower extremities

xvii) Hepatic and renal organ transplants

xviii) Liver and renal Doppler

k) Musculoskeletal
   i) Normal anatomy
      (1) Tendon
      (2) Muscle
      (3) Ligament
      (4) Cartilage
      (5) Bone
      (6) Nerve
   ii) Tendon
      (1) Tear (partial and full thickness)
      (2) Tendinopathy/tendinosis
      (3) Tenosynovitis
   iii) Muscle
      (1) Tear
      (2) Hematoma
      (3) Abscess
      (4) Neoplasm
   iv) Nerve
      (1) Compression syndromes
      (2) Neuroma
      (3) Tumor
   v) Bone
      (1) Fracture
      (2) Tumor
      (3) Osteomyelitis
   vi) Ligaments
(1) Plantar fasciitis
(2) Plantar fibroma
(3) Pulley rupture

vii) Soft tissues/joints
(1) Baker cyst
(2) Ganglion cyst
(3) Lipoma
(4) Foreign body
(5) Hematoma
(6) Cellulitis, abscess
(7) Necrotizing fasciitis (soft tissue gas)
(8) Joint effusion
(9) Synovitis
(10) Primary neoplasm
11) Metastasis
12) Lymphoma

l) Breast
i) Sonomammographic anatomy
ii) Cyst versus solid mass
iii) Mastitis/abscess
iv) Characterization of cysts
v) Lymph node characterization
(1) Axillary
(2) Supraclavicular
(3) Intramammary

vi) Characterization of solid masses
(1) Benign versus malignant
(a) Cyst
(b) Fibroadenoma
(c) Hamartoma
(d) Abscess
(e) Hematoma
(f) Phyllodes tumor
(g) Ductal/lobular carcinoma
(h) Carcinoma in situ
(i) Metastasis
(j) Lymphoma
(k) Inflammatory carcinoma

vii) Architectural distortion
viii) Intraductal masses/abnormalities, galactocele

ix) Screening
x) Multifocal/centric malignancy
xi) Elastography
xii) Role of IV contrast
m) Interventional
   i) Pre-procedural evaluation
      (1) Coagulation laboratory studies
      (2) Anticoagulation medication
      (3) Stratification of risk for percutaneous procedures
   ii) Informed consent
   iii) Sterile technique
   iv) Techniques for ultrasound-guided invasive procedures: understanding important landmarks and pitfalls of percutaneous procedures, including recognition of critical structures to be avoided
   v) Localization of fluid for paracentesis or thoracentesis to be performed by another service
   vi) Ultrasound-guided paracentesis vii)
   Ultrasound-guided thoracentesis viii)
   Aspiration of fluid collections, cysts ix)
   Biopsy of soft tissue masses
   x) Fine needle aspiration versus core biopsy in specific applications
      (1) Focal liver mass
      (2) Renal mass
      (3) Thyroid/parathyroid mass
      (4) Lymphadenopathy
   xi) Random core liver biopsy
   xii) Random core renal biopsy
   xiii) Catheter placement for abscess and fluid drainage (pleural, peritoneal, and other spaces)
   xiv) Postprocedural evaluation
      (1) Radiographic studies
      (2) Patient monitoring
      (3) Management of complications
   xv) Pseudoaneurysm management: contraindications and technique of non-surgical treatment with ultrasound-guided compression repair versus thrombin injection
   xvi) Intraoperative ultrasound guidance
Urinary Imaging

1) **Kidneys**
   a) Malignant tumors
      i) Primary
      ii) Secondary
   b) Benign tumors
   c) Endocrine tumors
   d) Cystic disease
   e) Complicated cysts
   f) Granulomatous diseases
   g) Infection/inflammation
   h) Hemorrhage
   i) Infarction and ischemia
   j) Trauma/iatrogenic
   k) Congenital anomalies
   l) Medical renal disease
   m) Inherited diseases involving the kidneys (including transplantation)

2) **Ureter**
   a) Malignant tumors
   b) Benign tumors
   c) Infection/inflammation
   d) Hemorrhage
   e) Trauma/iatrogenic
   f) Congenital anomalies
   g) Stricture
   h) Filling defects

3) **Bladder and Neobladder**
   a) Malignant tumors
   b) Benign tumors
   c) Infection/inflammation
   d) Hemorrhage
   e) Trauma/iatrogenic
   f) Congenital anomalies

4) **Prostate Gland and Seminal Vesicles**
   a) Malignant tumors
   b) Benign tumors and hyperplasia
   c) Infection/inflammation
   d) Trauma/iatrogenic
   e) Congenital anomalies
5) Urethra and Penis
   a) Malignant tumors
   b) Benign tumors
   c) Infection/inflammation
   d) Trauma/iatrogenic
   e) Congenital anomalies
   f) Stricture

6) Retroperitoneum
   a) Malignant tumors
      i) Primary
      ii) Secondary
   b) Benign tumors
   c) Hemorrhage
   d) Trauma/iatrogenic
   e) Congenital anomalies
   f) Aortic aneurysm
   g) Retroperitoneal fibrosis
   h) Pelvic lipomatosis
   i) Venous anomalies
   j) Fournier gangrene

7) Vascular Diseases Affecting the Genitourinary Tract
   a) Aneurysms
   b) Stenoses
   c) Malformations
   d) Fistulae
   e) Occlusions
   f) Congenital anomalies

8) Intravascular Contrast Media
   a) Extravasation
   b) Physiology
   c) Adverse reactions (idiosyncratic and nonidiosyncratic)
   d) Prevention and treatment of adverse reactions

9) Urolithiasis (Including Kidney, Ureter, Bladder)

10) Techniques
    a) Excretory urography
    b) Cystography
    c) Urethrography (including antegrade and retrograde)
    d) CT (including CT urography, CT angiography)
    e) MRI (including MR urography, MR angiography)
f) Ultrasound (including Doppler and color flow)
g) Hysterosalpingography
Vascular Imaging

1) Normal and Variant Anatomy as Depicted by Various Imaging Modalities (US, MRI, CT, and angiography)
   a) Arterial (excluding heart and CNS since that content will be covered in neurology and cardiac sections)
   b) Venous (again excluding heart and CNS)

2) Vascular Anatomy/Pathology before and after Intervention. Examples include:
   a) Aortic aneurysms before and after stent graft placement
   b) Arterial and venous stenosis/occlusions before and after endovascular procedures, such as angioplasty, stent placement, lysis, or thrombectomy
   c) Anatomy and pathology seen before and after open vascular procedures. Procedures include bypass grafts for tissue perfusion and dialysis access.

3) Vascular Pathology as Depicted by Various Imaging Modalities. Categories include:
   a) Congenital anomalies
   b) Inflammatory conditions such as vasculitis
   c) Neoplasia
   d) Embolic phenomena
   e) Trauma – blunt and penetrating
   f) Atherosclerosis

4) Physics Knowledge Needed to Safely Operate a C-arm Fluoroscopy Unit
   a) Radiation protection
   b) Optimal use of radiation
   c) Digital subtraction angiography (DSA), including its artifacts