



**Diagnostic Radiology**  
CORE Examination Study Guide  
Updated 4/30/2014

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## 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](http://www.theabr.org), for updated study guide materials and questions.

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## **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) Venaee 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 ( $Q = V \times A$ )
  - (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 funduplications
    - (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) Inflammatory 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) Inflammatory 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 mesentery
    - (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

## Musculoskeletal Imaging

### 1) Imaging Techniques—Indications and Limitations

- a) Radiography
- b) CT
- c) MRI
- d) Nuclear scintigraphy/PET
- e) Diagnostic and therapeutic aspiration and injections
- f) Percutaneous biopsy
- g) Ultrasound
- h) Bone mineral density

### 2) Normal/Normal Variants

- a) Primary and secondary ossification centers and sequence of ossification
- b) Physiologic radiolucencies
- c) Vascular channels
- d) Physiologic bowing
- e) Transverse/growth line
- f) Sesamoids and accessory ossicles
- g) Accessory muscles
- h) Tug lesions

### 3) Congenital and Developmental Spine Abnormalities

- a) Scoliosis
- b) Os odontoideum
- c) Klippel-Feil syndrome
- d) Vertebral anomalies
- e) Schmorl node
- f) Scheuermann disease
- g) Limbus vertebra

### 4) Congenital Anomalies and Dysplasias

- a) Lower extremity
  - i) Developmental hip dysplasia
  - ii) Blount disease
  - iii) Discoid meniscus
  - iv) Foot deformities
  - v) Syndactyl
  - vi) Polydactyly
- b) Upper extremity
  - i) Madelung deformity
  - ii) Congenital dislocation of the radial head
  - iii) Carpal coalition

- iv) Syndactyly
- v) Polydactyly
- vi) Sprengel deformity
- c) Diffuse/multifocal
  - i) Achondroplasia
  - ii) Osteogenesis imperfect
  - iii) Sclerosing osseous dysplasias
  - iv) Osteopetrosis
  - v) Cleidocranial dysplasia/dysostosis
  - vi) Amniotic band syndrome
  - vii) Connective tissue disorders
    - (1) Ehlers-Danlos syndrome
    - (2) Marfan syndrome
  - viii) Neurofibromatosis
  - ix) Cerebral palsy
  - x) Muscular dystrophies
  - xi) Congenital insensitivity to pain
- d) Miscellaneous
  - i) Mucopolysaccharidosis
  - ii) Tuberous sclerosis
  - iii) Down syndrome
  - iv) Turner syndrome
  - v) Apert syndrome
  - vi) Fibrodysplasia/myositis ossificans progressive
  - vii) Macrodystrophy lipomatosa
  - viii) Pachydermoperiostosis
  - ix) Nail-patella syndrome

**5) Infections (Including Routes of Spread, Predisposing Factors, and Common and Other Organisms, including Syphilis, Rubella, Leprosy, and Parasitic)**

- a) Osteomyelitis
  - i) Common sites
  - ii) Terminology
    - (1) Sequestrum
    - (2) Involucrum
    - (3) Cloaca
    - (4) Brodie abscess
    - (5) Sclerosing osteomyelitis
    - (6) Multifocal
- b) Septic arthritis
  - i) Bacterial
  - ii) Tuberculosis
  - iii) Lyme disease
- c) Soft tissue

- i) Abscess
- ii) Cellulitis
- iii) Myositis
- iv) Gas gangrene
- v) Necrotizing fasciitis

**6) Tumors and Tumor-Like Conditions**

- a) Imaging features
  - i) Size
  - ii) Location
  - iii) Aggressiveness/growth pattern
  - iv) Internal characteristics
  - v) Involvement of adjacent structures
  - vi) Margin/zone of transition
  - vii) Pattern of osteolysis
  - viii) Periosteal reaction
  - ix) Soft tissue mass
  - x) Matrix/calcification
  - xi) Biopsy techniques
  - xii) Therapy options
- b) Benign bone lesions
  - i) Cartilaginous
  - ii) Fibrous
  - iii) Osteogenic
  - iv) Lipoid
  - v) Vascular
  - vi) Miscellaneous
- c) Miscellaneous lesions
  - i) Ollier disease
  - ii) Maffucci syndrome
  - iii) Osteofibrous dysplasia (ossifying fibroma)
  - iv) Liposclerosing myxofibrous tumor (LSMFT)
  - v) Hemophilic pseudotumor
  - vi) Hemangiopericytoma
  - vii) Gorham disease
  - viii) Giant reparative granuloma
- d) Malignant bone lesions
  - i) Cartilaginous
  - ii) Fibrous
  - iii) Osteogenic
  - iv) Vascular
  - v) Miscellaneous
  - vi) Secondary tumors

- (1) Radiation
- (2) Paget disease
- (3) Metastases
- e) Benign soft tissue lesions
  - i) Fibrous
  - ii) Neural
  - iii) Cartilaginous
  - iv) Vascular
  - v) Lipoid
  - vi) Muscle
  - vii) Miscellaneous
- f) Malignant soft tissue lesions
  - i) Primary
  - ii) Secondary
    - (1) Leukemia
    - (2) Lymphoma
    - (3) Metastases

## 7) Trauma

- a) General principles
  - i) Relationship of force and deformation to fracture
  - ii) Mechanisms of injury
  - iii) Relevant anatomy and terminology
  - iv) Fracture patterns and associated injuries
  - v) Fracture description
  - vi) Bone and soft tissue stress injuries
  - vii) Fracture healing
  - viii) Complications
  - ix) Open fractures
- b) Repetitive trauma
  - i) Tendinopathy
  - ii) Enthesophyte
- c) Soft tissue injuries and myositis ossificans (including grades of muscle and ligament tear)
- d) Thermal trauma (including burns and cold injuries)
- e) Foreign bodies (including gunshot wounds)
- f) Adult trauma
- g) Pediatric trauma (including non-accidental trauma/child abuse)

## 8) Metabolic Disorders

- a) Osteoporosis
- b) Hyperparathyroidism
- c) Thyroid diseases
- d) Rickets and osteomalacia
- e) Renal osteodystrophy

- f) Pituitary disorders
- g) Intoxication/poisoning
  - i) Heavy metal/lead
  - ii) Fluorine
  - iii) Hypervitaminosis A and D

**9) Hematologic Disorders**

- a) Anemia
- b) Sickle cell
- c) Thalassemia
- d) Hemophilia
- e) Myelofibrosis
- f) Extramedullary hematopoiesis
- g) Marrow reconversion

**10) Osteonecrosis (Causes and Site-specific Disease)****11) Periosteal Reaction**

- a) Primary and secondary hypertrophic osteoarthropathy
- b) Infantile cortical hyperostosis/Caffey disease

**12) Miscellaneous**

- a) Paget disease
- b) Sarcoidosis
- c) Radiation-induced marrow changes
- d) Mastocytosis
- e) Amyloidosis
- f) Lipid storage diseases

**13) Arthropathy**

- a) General features
  - i) Distribution
  - ii) Soft tissue changes
  - iii) Joint space width
  - iv) Bone density
  - v) Osteophytes
  - vi) Subchondral cysts
  - vii) Osseous erosions
  - viii) Proliferative new bone
  - ix) Joint deformity
  - x) Calcification
- b) Osteoarthritis
- c) Inflammatory
  - i) Rheumatoid

- ii) Psoriatic
- iii) Reactive arthritis
- iv) Ankylosing spondylitis
- v) Enteropathic
- vi) Spondyloarthropathy
- vii) Juvenile chronic 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)
- f) Joint replacement procedures and complications, postoperative imaging
- g) Miscellaneous
  - i) Hemochromatosis
  - ii) Pigmented villonodular synovitis
  - iii) Synovial chondromatosis
  - iv) Osteitis condensans ilii
  - v) Degenerative disc disease
  - vi) Diffuse idiopathic sclerosing hyperostosis (DISH)
  - vii) Alkaptonuria/ochronosis

## 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) Oligodendrogioma
    - (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) Paraganglioma
  - viii) Astrocytoma
  - ix) Ependymoma
  - x) Hemangioblastoma
  - xi) Lymphoma
  - xii) Leukemia
  - xiii) Myeloma
  - xiv) Plasmacytoma
  - xv) Chordoma
  - xvi) Chondrosarcoma
  - xvii) 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) Orbit
  - 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) Laryngopyocele
  - 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:  $^{18}\text{F}$  FDG
  - ii) Imaging techniques: PET and PET-CT
  - iii) Typical indications: breast lesion
- b) Malignant neoplasm, primary
  - i) Radiopharmaceuticals:  $^{18}\text{F}$  FDG
  - ii) Imaging techniques: PET and PET-CT
  - iii) Typical indications: breast lesion
- c) Malignant neoplasm, metastatic
  - i) Radiopharmaceuticals:  $^{99\text{m}}\text{Tc}$  HDP/MDP;  $^{18}\text{F}$  FDG, and  $^{18}\text{F}$  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:  $^{99\text{m}}\text{Tc}$  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:  $^{67}\text{Ga}$  citrate,  $^{111}\text{In}/^{99\text{m}}\text{Tc}$  WBCs;  $^{18}\text{F}$  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:  $^{99\text{m}}\text{Tc}$  sestamibi/tetrofosmin,  $^{201}\text{Tl}$  chloride;  $^{13}\text{N}$  NH<sub>3</sub> (ammonia), and  $^{82}\text{Rb}$  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:  $^{99m}\text{Tc}$  sestamibi/tetrofosmin,  $^{201}\text{TI}$  chloride;  $^{13}\text{N}$  NH<sub>3</sub> (ammonia),  $^{82}\text{Rb}$  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:  $^{201}\text{TI}$  chloride;  $^{18}\text{F}$  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:  $^{99m}\text{Tc}$  RBCs and  $^{99m}\text{Tc}$  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:  $^{99m}\text{Tc}$  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:  $^{67}\text{Ga}$  citrate,  $^{111}\text{In}/^{99m}\text{Tc}$  WBCs;  $^{18}\text{F}$  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 sincalide (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  $\frac{1}{2}$ , 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

- 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, pharmaceutical infusion protocols, and quantification (GBEF, T ½; SUV)

**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:  $^{67}\text{Ga}$  citrate,  $^{111}\text{In}/^{99m}\text{Tc}$  WBCs,  $^{99m}\text{Tc}$  sulfur colloid;  $^{18}\text{F}$  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:  $^{99m}\text{Tc}$  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:  $^{99m}\text{Tc}$  ECD/HMPAO, and  $^{99m}\text{Tc}$  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:  $^{99m}\text{Tc}$  ECD/HMPAO;  $^{18}\text{F}$  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;  $^{18}\text{F}$  FDG,  $^{18}\text{F}$  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;  $^{18}\text{F}$  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,  $^{111}\text{In}$  pentetretide (OctreoScan), and  $^{18}\text{F}$  FDG
  - ii) Imaging techniques: Planar, SPECT and/or SPECT-CT; PET and PET-CT
  - iii) Typical indications: meningioma
- g) Malignant neoplasm, primary
  - i) Radiopharmaceuticals:  $^{18}\text{F}$  FDG
  - ii) Imaging techniques: PET and/or PET-CT
  - iii) Typical indications: glioblastoma, astrocytoma, and lymphoma
- h) Malignant neoplasm, metastatic
  - i) Radiopharmaceuticals:  $^{18}\text{F}$  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;  $^{18}\text{F}$  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:  $^{99m}\text{Tc}$  ECD/HMPAO;  $^{18}\text{F}$  FDG;  $^{111}\text{In}/^{99m}\text{Tc}$  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:  $^{99m}\text{Tc}$  RBCs,  $^{99m}\text{Tc}$  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:  $^{99m}\text{Tc}$  MAA,  $^{133}\text{Xe}$  gas,  $^{99m}\text{Tc}$  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:  $^{99m}\text{Tc}$  sulfur colloid,  $^{99m}\text{Tc}$  IDA analog,  $^{99m}\text{Tc}$  pertechnetate
  - ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
  - iii) Pharmacologic protocols: phenobarbital, H<sub>2</sub> blockers (e.g., cimetidine)
  - iv) Quantitative analysis: gastric emptying T  $\frac{1}{2}$ , and gallbladder ejection fraction (GBEF)
  - v) Typical indications: aspiration, gastroesophageal reflux, gastric emptying, biliary atresia, and Meckel diverticulum
- e) Musculoskeletal
  - i) Radiopharmaceuticals:  $^{99m}\text{Tc}$  HDP/MDP;  $^{18}\text{F}$  NaF, and  $^{18}\text{F}$  FDG
  - ii) Imaging techniques: planar, SPECT, and/or SPECT-CT; PET and PET-CT
  - iii) Typical indications: osteoid osteoma, fracture, avascular necrosis, osteomyelitis, nonaccidental trauma, and metastases
- f) Endocrine
  - i) Radiopharmaceuticals:  $^{123}\text{I}$  Nal,  $^{99m}\text{Tc}$  pertechnetate;  $^{131}\text{I}$  Nal
  - 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:  $^{67}\text{Ga}$  citrate,  $^{111}\text{In}/^{99m}\text{Tc}$  WBCs;  $^{18}\text{F}$  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:  $^{99m}\text{Tc}$  HDP/MDP,  $^{123}\text{I}$  MIBG,  $^{111}\text{In}$  pentetreotide (OctreoScan);  $^{18}\text{F}$  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:  $^{99m}\text{Tc}$  DMSA,  $^{99m}\text{Tc}$  DTPA,  $^{99m}\text{Tc}$  MAG3, and  $^{99m}\text{Tc}$  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 ( $T_{\frac{1}{2}}$ , GBEF, and SUV)

## 7) Reproductive/Endocrine

- a) Thyroid gland
  - i) Radiopharmaceuticals:  $^{123}\text{I}$  NaI,  $^{99\text{m}}\text{Tc}$  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:  $^{123}\text{I}/^{131}\text{I}$  NaI,  $^{111}\text{In}$  pentetreotide (OctreoScan), and;  $^{18}\text{F}$  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:  $^{131}\text{I}$  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:  $^{123}\text{I}$  MIBG,  $^{111}\text{In}$  pentetreotide (OctreoScan)
  - ii) Imaging techniques: planar, SPECT, and/or SPECT-CT
  - iii) Typical indications: pheochromocytoma, cortical adenoma
- e) Neuroendocrine
  - i) Radiopharmaceuticals:  $^{111}\text{In}$  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:  $^{99m}\text{Tc}$  sestamibi,  $^{99m}\text{Tc}$  pertechnetate, and  $^{123}\text{I}$  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:  $^{99m}\text{Tc}$  HDP/MDP;  $^{18}\text{F}$  NaF, and  $^{18}\text{F}$  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:  $^{99m}\text{Tc}$  HDP/MDP;  $^{18}\text{F}$  NaF,  $^{18}\text{F}$  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:  $^{99m}\text{Tc}$  MAA,  $^{133}\text{Xe}$  gas, and  $^{99m}\text{Tc}$  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:  $^{99m}\text{Tc}$  MAA,  $^{133}\text{Xe}$  gas, and  $^{99m}\text{Tc}$  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, prepulmonectomy and pulmonary transplant evaluation, and pulmonary hypertension
- c) Ventilation/perfusion, chronic obstructive airways disease (COPD) and airways disease
  - i) Radiopharmaceuticals:  $^{99m}\text{Tc}$  MAA,  $^{133}\text{Xe}$  gas, and  $^{99m}\text{Tc}$  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 prebullectomy evaluation
- d) Benign neoplasm/mass/solitary pulmonary nodule

- i) Radiopharmaceuticals:  $^{18}\text{F}$  FDG
- ii) Imaging techniques: PET and PET-CT
- iii) Typical indications: hamartoma, granuloma, and excluding malignancy
- e) Malignant neoplasm, primary
  - i) Radiopharmaceuticals:  $^{111}\text{In}$  pentetreotide (OctreoScan) and  $^{18}\text{F}$  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:  $^{99\text{m}}\text{Tc}$  HDP/MDP;  $^{18}\text{F}$  NaF, and  $^{18}\text{F}$  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:  $^{99\text{m}}\text{Tc}$  HDP/MDP,  $^{99\text{m}}\text{Tc}$  MAA,  $^{133}\text{Xe}$ , and  $^{99\text{m}}\text{Tc}$  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:  $^{67}\text{Ga}$  citrate,  $^{111}\text{In}/^{99\text{m}}\text{Tc}$  WBCs, and  $^{18}\text{F}$  FDG
  - ii) Imaging techniques: planar, SPECT and/or SPECT-CT; PET and PET-CT
  - iii) Typical indications: sarcoidosis, occupational lung disease, pneumonia, abscess, tuberculosis, MAI, 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:  $^{99\text{m}}\text{Tc}$  MAG-3,  $^{99\text{m}}\text{Tc}$  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:  $^{99\text{m}}\text{Tc}$  MAG-3,  $^{99\text{m}}\text{Tc}$  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:  $^{99m}\text{Tc}$  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:  $^{99m}\text{Tc}$  MAG-3 and  $^{99m}\text{Tc}$  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:  $^{99m}\text{Tc}$  MAG-3 and  $^{99m}\text{Tc}$  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:  $^{18}\text{F}$  FDG
  - ii) Imaging techniques: PET and PET-CT
  - iii) Typical indications: angiomyolipoma and complex cystic mass
- g) Malignant neoplasm, primary
- i) Radiopharmaceuticals:  $^{18}\text{FFDG}$
  - ii) Imaging techniques: PET and PET-CT
  - iii) Typical indications: lymphoma and renal cell cancer
- h) Malignant neoplasm, metastatic
- i) Radiopharmaceuticals:  $^{99m}\text{Tc}$  HDP/MDP;  $^{18}\text{FNaF}$ , and  $^{18}\text{FFDG}$
  - 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:  $^{99m}\text{Tc}$  DMSA,  $^{67}\text{Ga}$  citrate,  $^{111}\text{In}/^{99m}\text{Tc}$  WBCs, and  $^{18}\text{FFDG}$
  - 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) Pachygryria
    - (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) Oligodendrogloma
    - (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 neurenteric 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 (Jatene 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-inflammatory/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/typhlitis
  - (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) Chondrodyplasia 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)
- vi) 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) Ventriculoperitoneal (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
- e) Informatics and management of imaging departments
  - i) Computer technology basics
  - ii) Picture archiving and communications systems (PACS)
  - iii) Radiology information systems (RIS)
  - iv) Hospital information systems (HIS)
  - v) DICOM and other protocols for radiology data management
  - vi) Security and privacy issues and approaches

**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)
  - vii) 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 versus 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<sub>vol</sub>
  - 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-beaming 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 ( $B_0$ ): the Larmor equation and precessional frequency
  - v) Net magnetization due to  $B_0$  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, isotope, 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:  $^{99m}\text{Tc}$
- 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:  $^{99}\text{Mo}/^{99m}\text{Tc}$ ,  $^{82}\text{Sr}/^{82}\text{Rb}$
- 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
- I) 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) GI 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 pharmacist
    - v) Authorized medical physicist (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  $^{131}\text{I}$  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 ( $^{131}\text{I}$  and  $^{123}\text{I}$ )
- h) Thyroid scan - technetium pertechnetate
- i) Parathyroid scan –  $^{99\text{m}}\text{Tc}$  sestamibi
- j) Radionuclide studies: diagnosis and treatment of endocrine disorders (includes octreotide and MIBG imaging)
- k) FDG-PET/CT

## **Quality and Safety**

The Quality & Safety portion of the ABR Core Exam is intended to focus on established knowledge in the area of Radiology Quality and Safety. Since the range of content relevant to the topic of Radiology Quality & Safety 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 are expected to know. This should be considered to be 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 an actual textbook, other definitive source material or education you should be receiving during your residency training program.

The Quality and Safety study guide is broken into two parts. Part I is an overview of concepts and serves as a framework and Part II contains more detailed and practical material.

[CLICK HERE](#) to access the Quality and Safety study guide.

## 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
- cc) Interlobular and intralobular septal thickening and reticulation
- dd) Juxtaphrenic peak
- ee) Secondary pulmonary lobule
- ff) Mass and nodule
- gg) Parenchymal and subpleural bands
- hh) Pleural plaques or pseudoplaques
- ii) Reverse halo sign
- jj) Signet ring sign (also known as pearl ring sign)
- kk) 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

- vv) Double density sign
- ww) Unilateral hyperlucent lung/hemithorax
- xx) Opaque hemithorax with contralateral versus ipsilateral mediastinal shift

**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 paracapacitrial
- 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

- c. Techniques
- d. Accuracy
- e. Complications
- f. Post-procedure care

## 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
- xi) 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  $\beta$ -hCG levels and menstrual dates
  - (2) Multiple gestations (chorionicity and amniocity)
  - (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 (Caesarian 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/measurements/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) Spermatocele/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) Intradural 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
- I) 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

## Sample Questions

1. The iliopsoas bursa normally communicates with the hip joint at which of the following sites?

- A. Between the iliofemoral and pubofemoral ligaments
- B. Between the iliofemoral and ischiofemoral ligaments
- C. Between the zona orbicularis and pubofemoral ligaments
- D. Between the zona orbicularis and ischiofemoral ligaments

2. Based on the image, what is the most likely diagnosis?



- A. Rheumatoid arthritis
- B. Reactive arthritis
- C. Multicentric reticulohistiocytosis
- D. Gout

3a. Based on the image, what is the most appropriate next step in diagnosis?



- A. Biopsy
- B. Additional sequence with contrast enhancement
- C. CT
- D. Radionuclide scan
- E. Comparison with radiographs

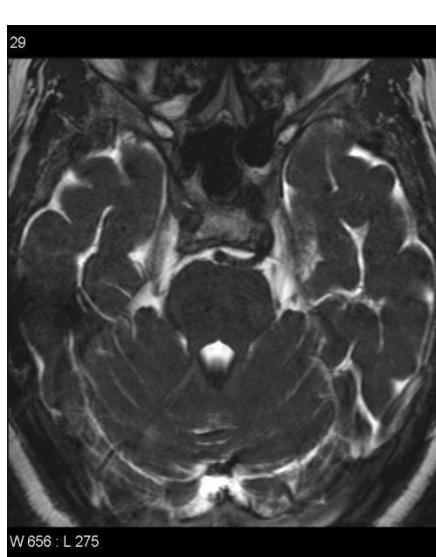
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3b. Based on the images, what is the most likely diagnosis?



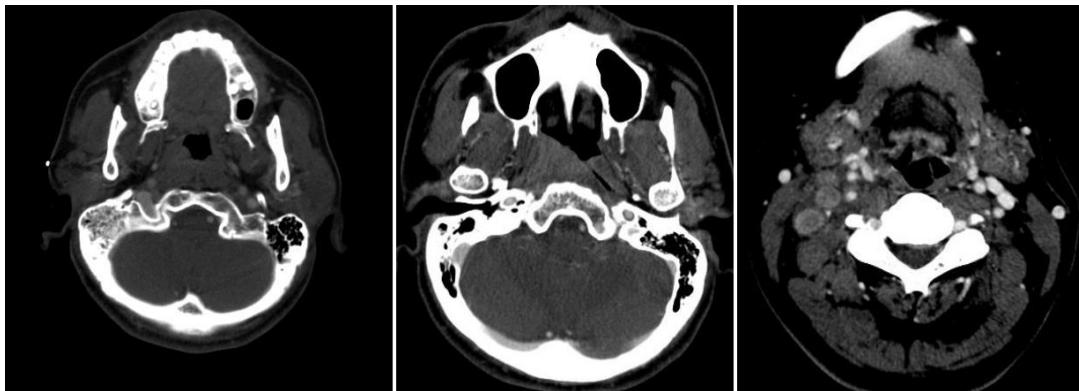
- A. Metastasis
- B. Hemangioma
- C. Lymphoma
- D. Paget disease

4. A 72-year-old patient presents with left facial pain. The images show what vascular anomaly?



- A. Persistent trigeminal artery
- B. Persistent hypoglossal artery
- C. Persistent dorsal ophthalmic artery
- D. Persistent primitive olfactory artery

5a. A 51-year-old Chinese man has a 1-year history of otalgia. He presents with a palpable neck mass. Based on the images, in addition to lymphadenopathy, what is the most likely diagnosis?



- A. Mastoiditis
- B. Nasopharyngeal carcinoma
- C. Supraglottic carcinoma
- D. Cat scratch disease

**BLOCKED RETURN:** You cannot go back and change your answer after proceeding.

5b. Nasopharyngeal carcinoma is most commonly associated with which of the following infections?

- A. Epstein-Barr virus
- B. Varicella zoster virus
- C. Parvovirus
- D. Human papillomavirus
- E. Coxsackie virus

6. For each image, select the most likely clinical scenario. Each option may be used once, more than once, or not at all.

- A. 3-year-old child with altered mental status
- B. 10-year-old child with seizures since birth
- C. 30-year-old patient involved in a motor vehicle collision, no skull fracture
- D. 70-year-old patient with history of multiple falls
- E. Acute mental status change, dehydration
- F. Dementia
- G. Severe hypertension with sudden headache
- H. Trauma with skull fracture
- I. "Worst headache of life"

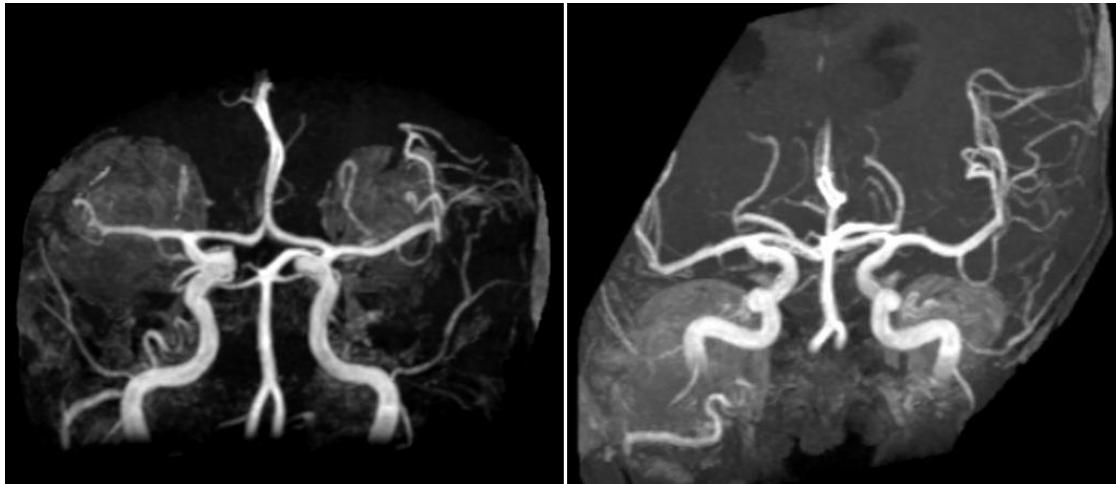


A.



B.

7. Based on the two images from an MR angiogram, what is the most likely explanation for the observed signal loss?



- A. Occlusion of right middle cerebral artery (MCA) branches
- B. Motion on the source data
- C. Improper processing of the maximum intensity projection (MIP)
- D. Saturation of protons
- E. Inadequate contrast bolus

- 8a. A 16-year-old, healthy young woman presents to the emergency department with a 10-day history of malaise, fever, and worsening right lower quadrant abdominal pain. Clinical evaluation finds a fever of 39.0° C, leukocytosis, and peritoneal irritation. Based on the CT images, what is the most appropriate course of action?



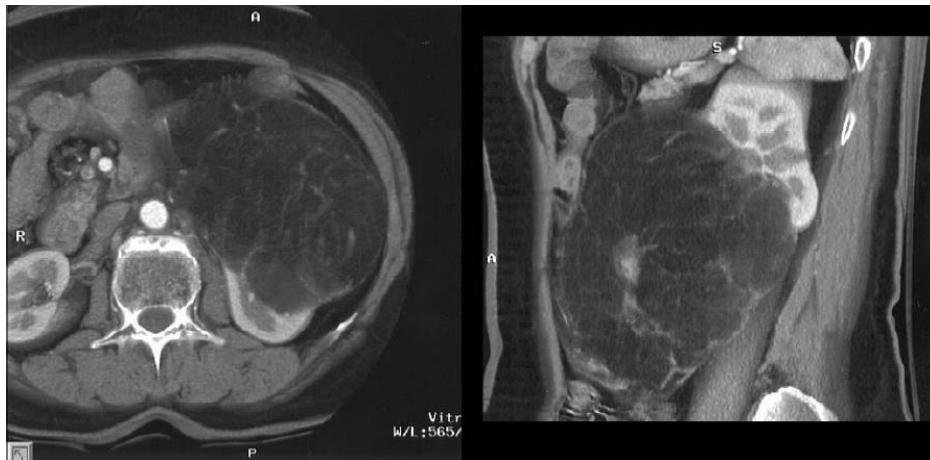
- A. Broad spectrum antibiotics, followed by close observation
- B. Broad spectrum antibiotics, followed by transrectal drainage
- C. Transabdominal drainage, followed by broad spectrum antibiotics
- D. Transgluteal drainage, followed by broad spectrum antibiotics

**BLOCKED RETURN:** You cannot go back and change your answer after proceeding.

- 8b. Transrectal drainage yields 300 mL of purulent material. Immediately after the procedure, the patient's temperature drops to 38.2° C, but 4 hours later, her fever increases to 38.7° C, and she has a shaking chill. Drainage is now blood tinged, and examination finds a heart rate of 110 and blood pressure of 110/70. What is the most appropriate course of action?

- A. Immediate surgical exploration
- B. Repeat CT scan
- C. Addition of antifungal agents to antibiotic regimen
- D. Emergent angiography for possible GI bleed
- E. Addition of antipyretics

9. A 58-year-old woman presents with recurrent abdominal pain and undergoes a CT examination of the abdomen. What is the most likely diagnosis?

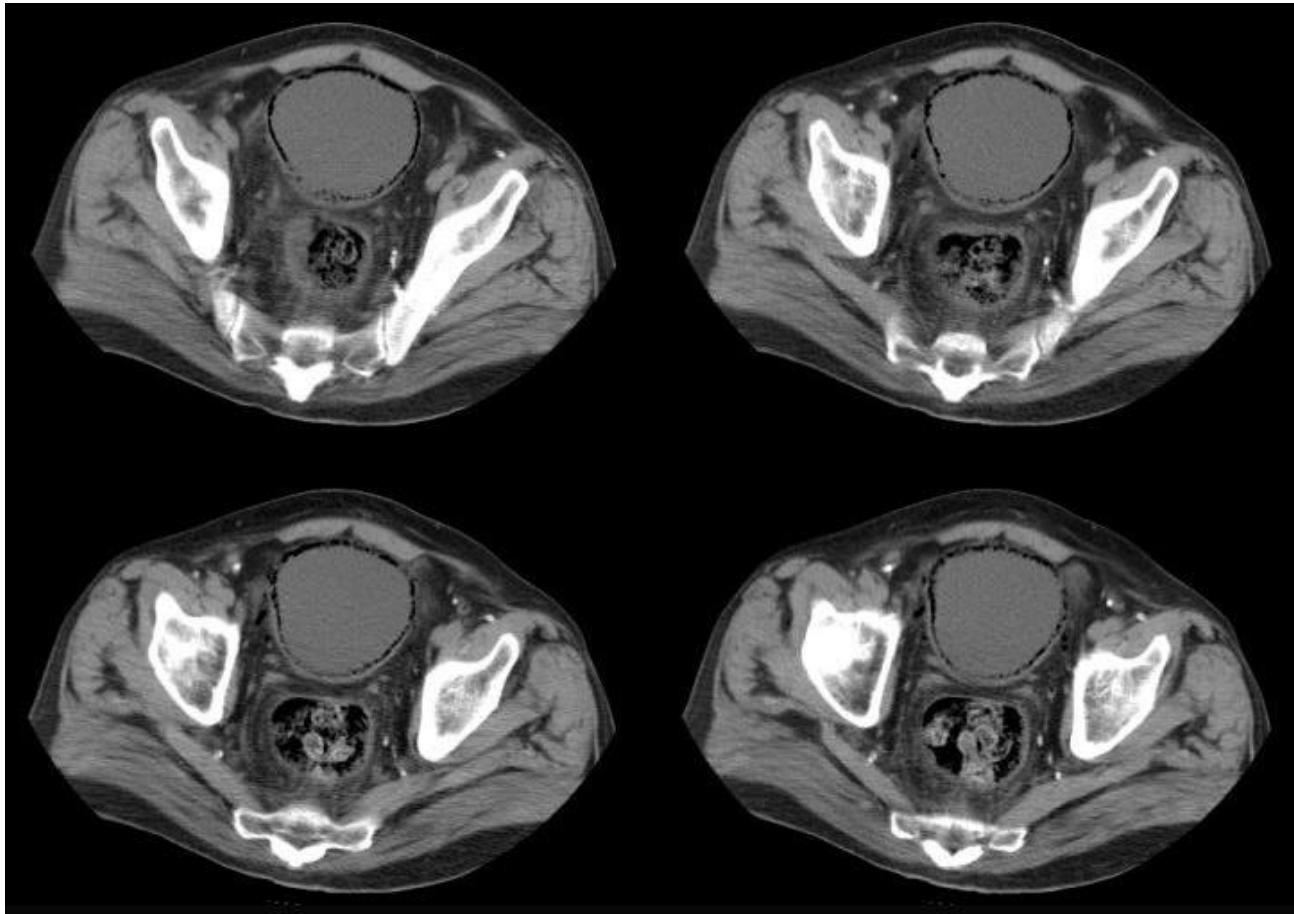


- A. Renal carcinoma
- B. Renal lymphoma
- C. Renal infarct
- D. Focal pyelonephritis
- E. Angiomyolipoma

10. A 46-year-old-man presents with acute flank pain and hematuria. What is the most appropriate next imaging test?

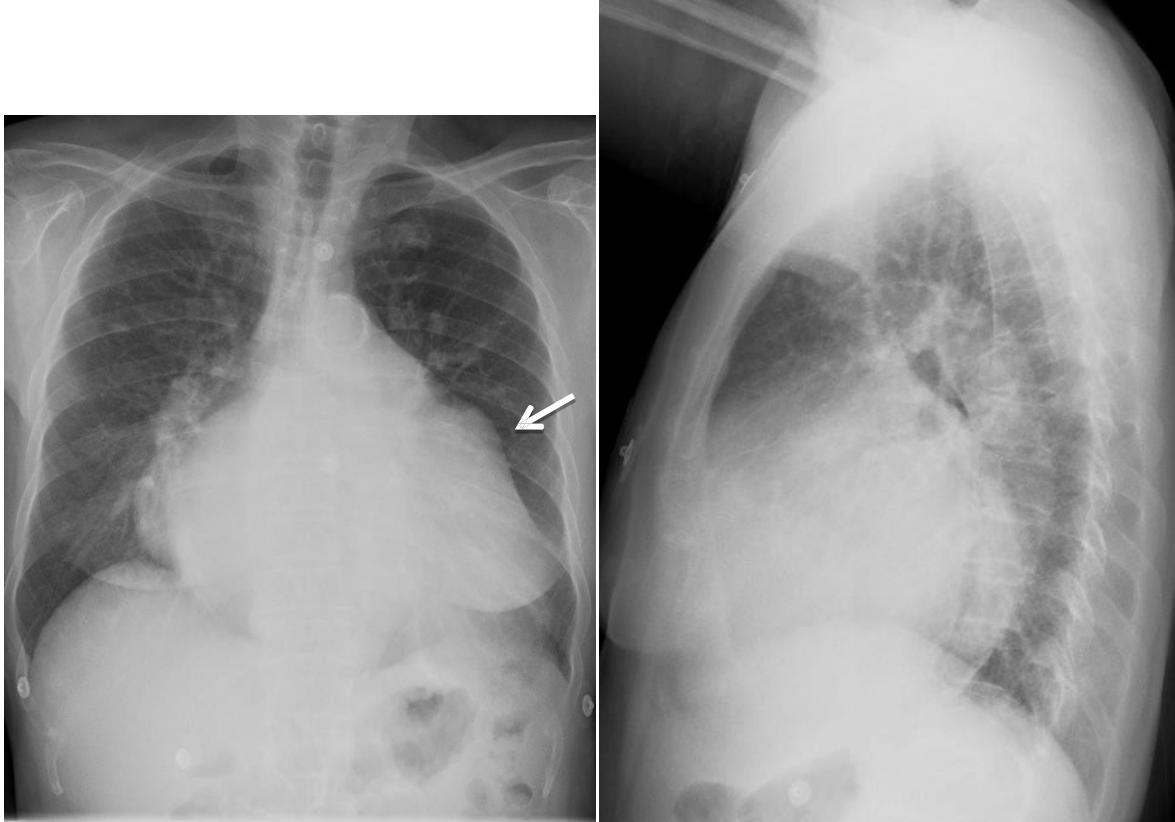
- A. Unenhanced MRI
- B. Contrast-enhanced MRI
- C. Unenhanced CT scan
- D. Contrast-enhanced CT scan

11. A 50-year-old woman who has diabetes presents with fever and undergoes a CT examination of the abdomen. What is the most likely diagnosis?



- A. Urothelial carcinoma
- B. Cytoxin cytopathy
- C. Emphysematous cystitis
- D. Lymphoma
- E. Iatrogenic trauma

12a. Which chamber is indicated by the arrow?



A. Left atrium B.

Right atrium C.

Left ventricle

D. Right ventricle

12b. What is the most likely diagnosis?

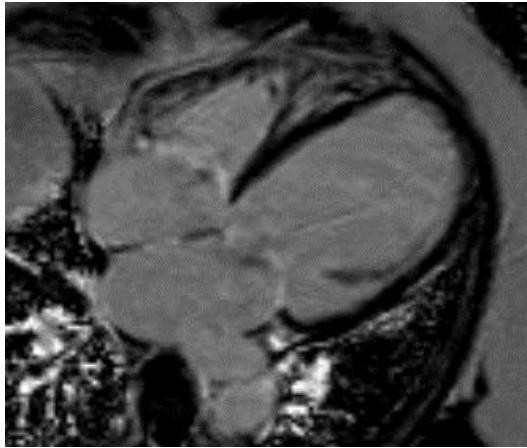
A. Aortic stenosis

B. Aortic regurgitation

C. Mitral stenosis

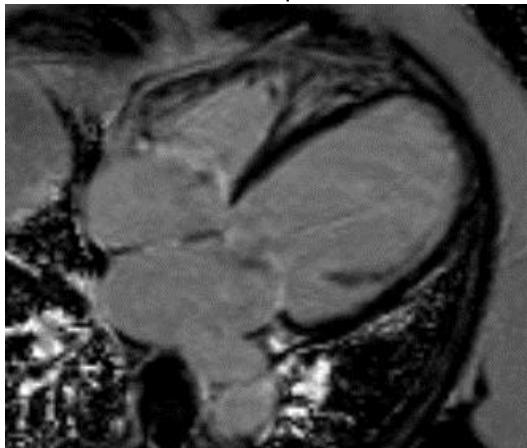
D. Mitral regurgitation

13a. Which chamber is dilated?



- A. Left atrium
- B. Right atrium
- C. Left ventricle
- D. Right ventricle

13b. Which MRI technique was used to obtain the delayed enhancement sequence?



- A. Inversion recovery
- B. Double inversion recovery
- C. Triple inversion recovery

13c. The same patient presents with lateral wall hypokinesis. What is the most appropriate management?

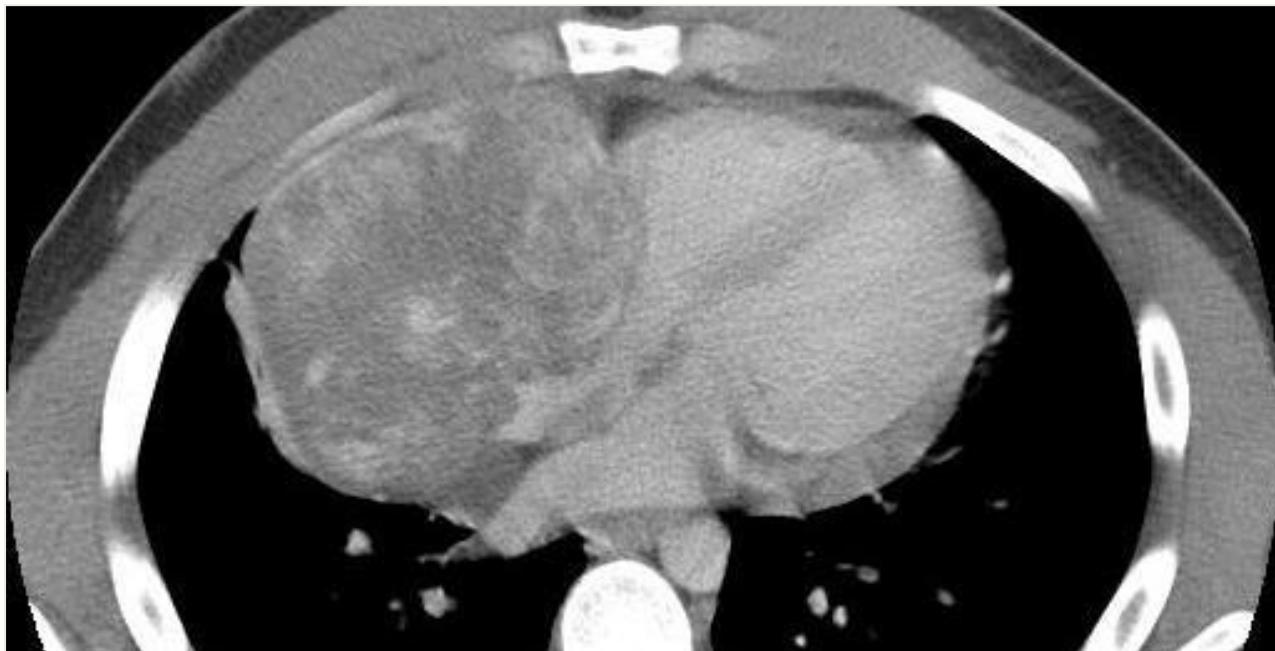
- A. Medical management
- B. Angioplasty and stent placement
- C. Coronary artery bypass graft surgery

**BLOCKED RETURN:** You cannot go back and change your answer after proceeding.

13d. Which vessel should be stented?

- A. Left main
- B. Left anterior descending
- C. Left circumflex
- D. Right

14. Based on the image, what is the most likely diagnosis?



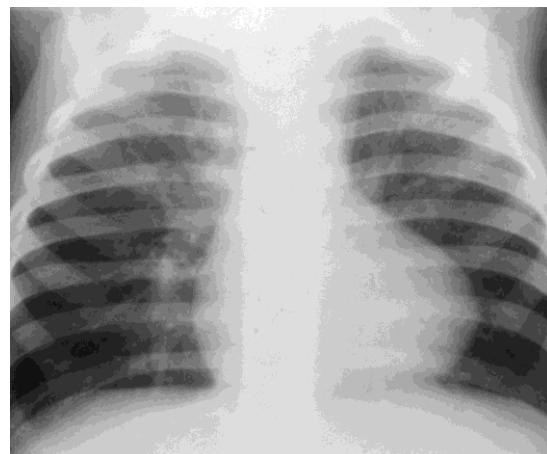
- A. Angiosarcoma
- B. Fibroelastoma
- C. Fibroma
- D. Hamartoma
- E. Hemangioma
- F. Lipoma
- G. Lymphoma
- H. Mesothelioma
- I. Myxoma
- J. Rhabdomyoma
- K. Rhabdomyosarcoma
- L. Teratoma
- M. Xanthogranuloma

15. For each image below, select the most likely clinical symptom. Each option may be used once, more than once, or not at all.

- A. Chest pain
- B. Cyanosis
- C. Dyspnea on exertion
- D. Exercise-induced lightheadedness
- E. Hypertension
- F. Pulsatile mass
- G. Pulsus paradoxus
- H. Shortness of breath



15a



15b

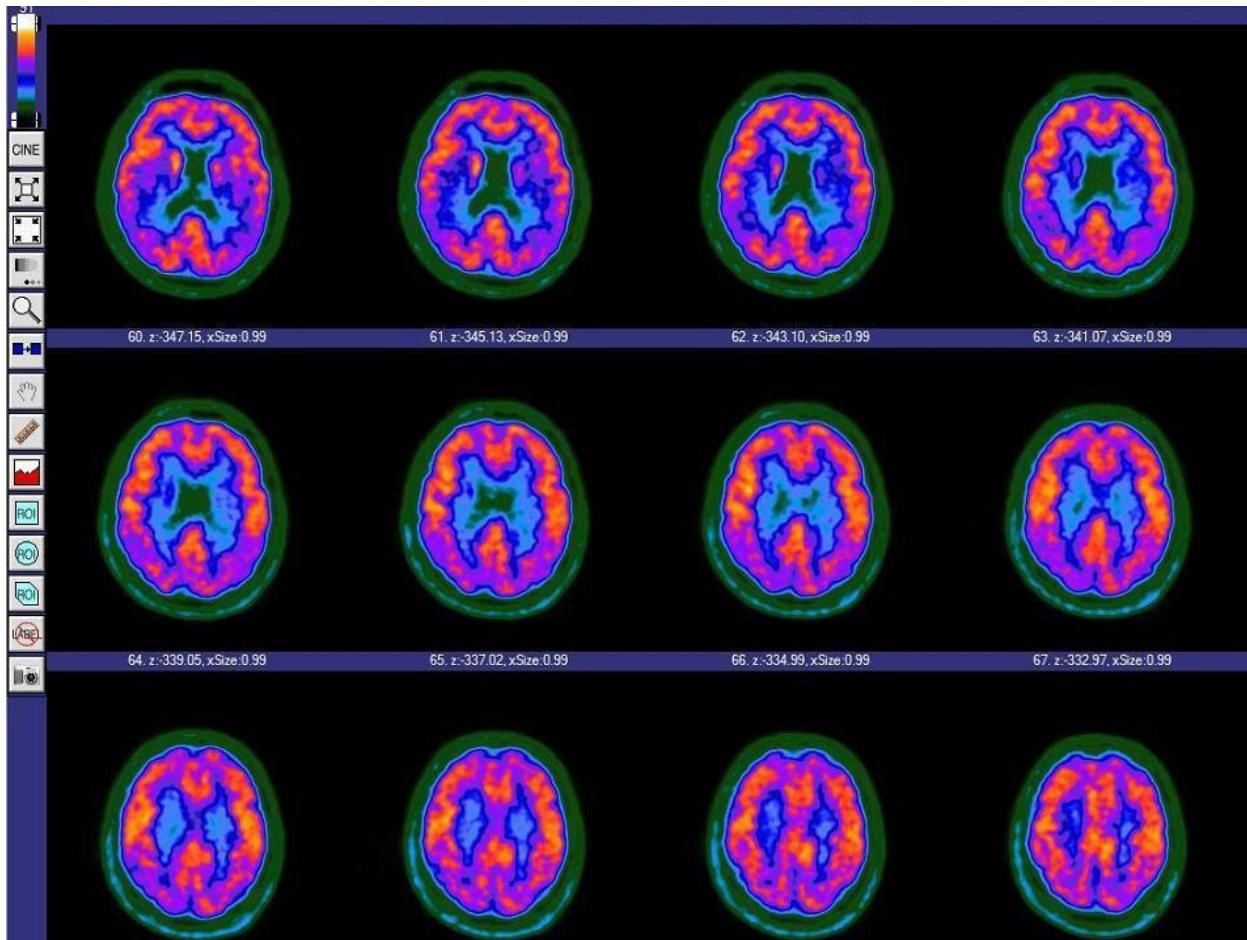
16. On a myocardial perfusion imaging study that shows normal wall motion and thickening on gated images, a fixed inferior defect is most likely caused by which of the following?

- A. Infarct
- B. Soft tissue attenuation artifact
- C. Ischemia
- D. Left bundle branch block related artifact

17. A 3-month-old girl is scheduled for a  $^{99m}$ Tc-DMSA renal scan. What is the most appropriate premedication for the study?

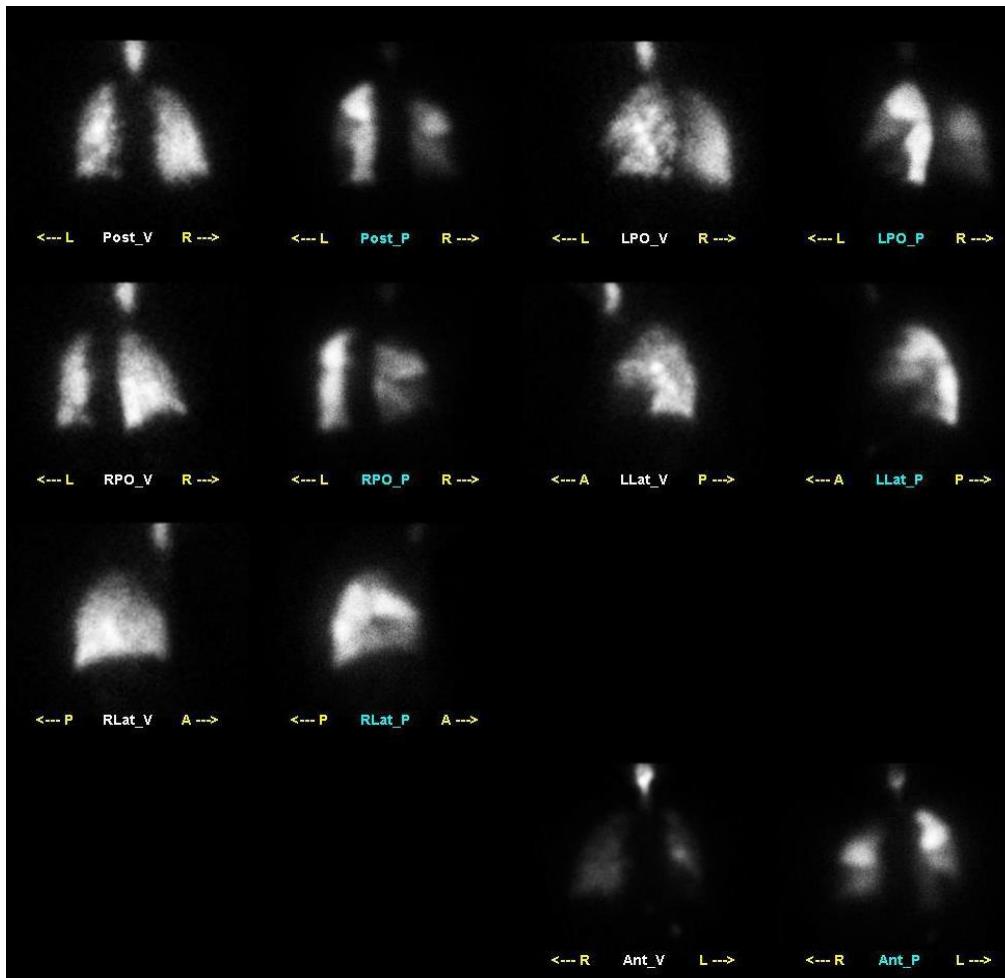
- A. Phenobarbital
- B. Cimetidine
- C. Furosemide
- D. Captopril
- E. None

18. Based on the images, what is the most likely diagnosis?



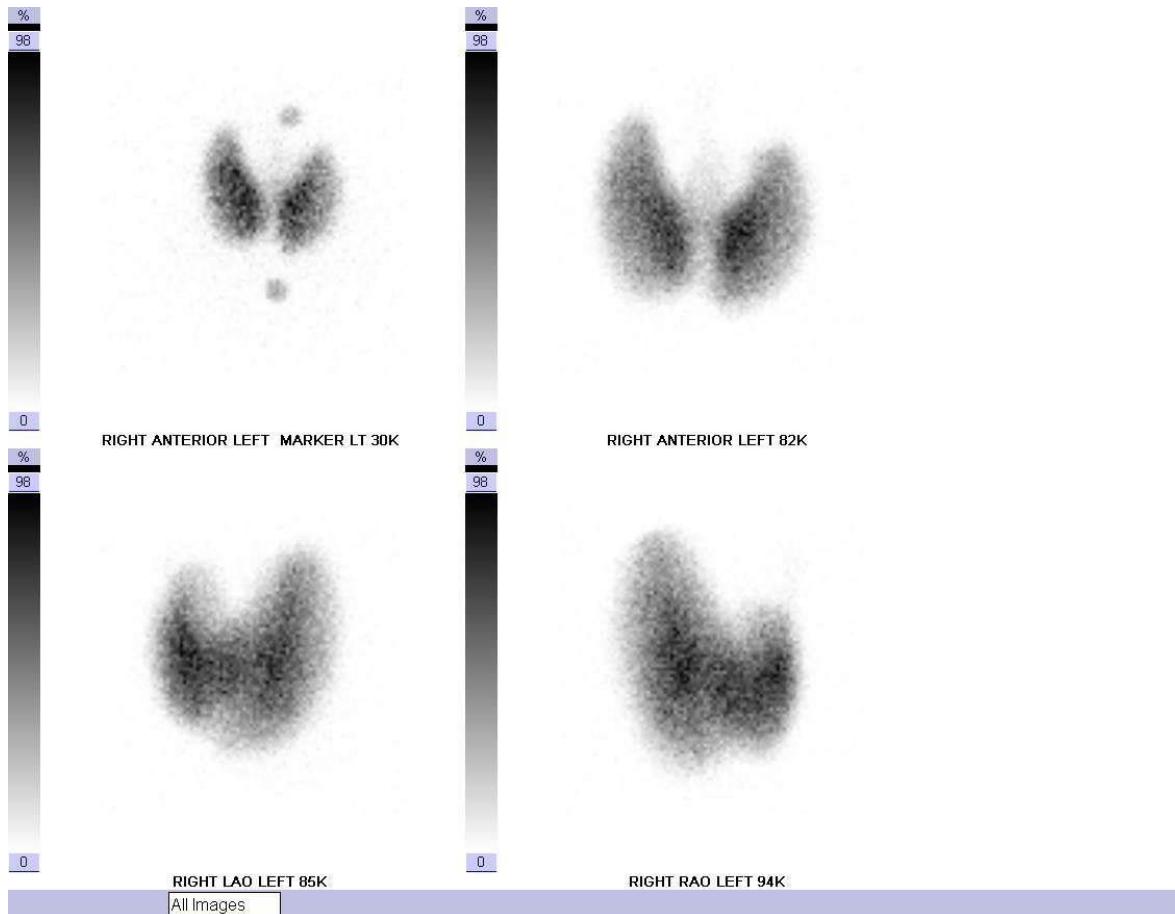
- A. Multi-infarct dementia
- B. Frontotemporal dementia
- C. Alzheimer dementia
- D. Lewy body dementia

19. Based on the ventilation perfusion lung scan, what is the probability of pulmonary embolism?



- A. High
- B. Intermediate
- C. Low
- D. Very low
- E. Normal

20a. A 35-year-old man is clinically and biochemically thyrotoxic. Based on the scan and 24-hour radioiodine uptake of 80%, what is the most likely diagnosis?



- A. Subacute thyroiditis
- B. Hashimoto thyroiditis
- C. Graves disease
- D. Toxic multinodular goiter
- E. Toxic adenoma

**BLOCKED RETURN:** You cannot go back and change your answer after proceeding.

20b. Which of the following is the most appropriate radionuclide therapy?

- A.  $^{131}\text{I}$  sodium iodide, 10 mCi (370 MBq)
- B.  $^{131}\text{I}$  sodium iodide, 100 mCi (3700 MBq)
- C.  $^{123}\text{I}$  sodium iodide, 10 mCi (370 MBq)
- D.  $^{123}\text{I}$  sodium iodide, 100 mCi (3700 MBq)

21a. A 46-year-old woman presents with pelvic pain. What is the most likely diagnosis?



- A. Myometrial contraction
- B. Adenomyosis
- C. Cervical stenosis
- D. Fibroid

**BLOCKED RETURN:** You cannot go back and change your answer after proceeding.

21b. On MRI, diagnosis of adenomyosis can be confidently made when the junctional zone measures which of the following?

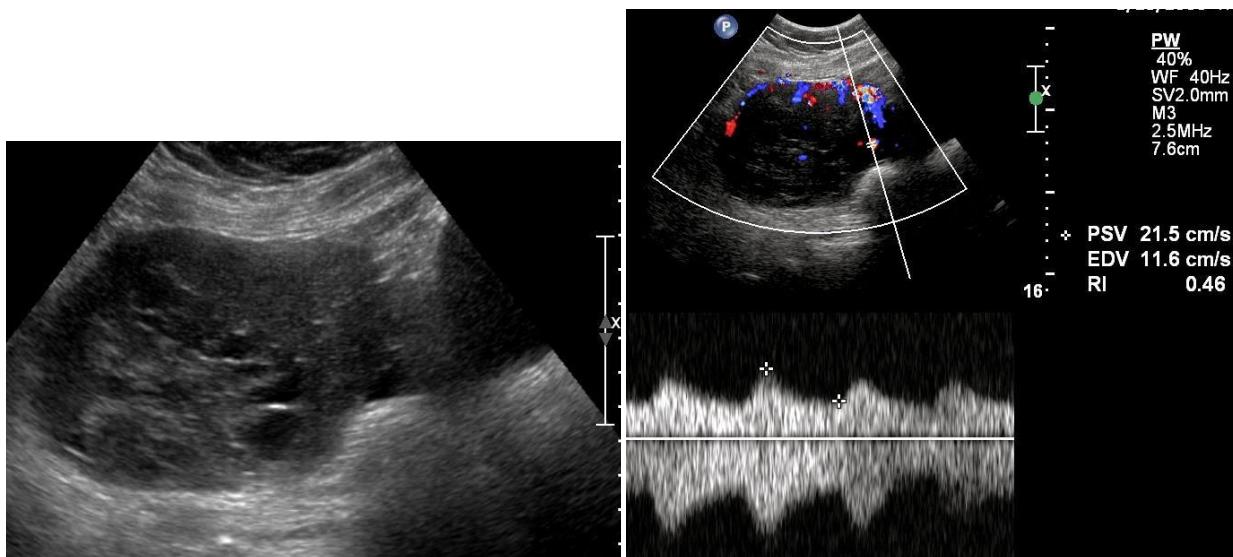
- A. < 8 mm
- B. 8 mm
- C. < 10 mm
- D. ≥ 12 mm

**BLOCKED RETURN:** You cannot go back and change your answer after proceeding.

21c. Which of the following is an ancillary criterion for the diagnosis of adenomyosis?

- A. High-signal endocervical glands
- B. Well-defined margins
- C. High-signal foci in junctional zone
- D. Low-signal pseudocapsule

22a. A postmenopausal woman with vaginal bleeding has biopsy-proven endometrial hyperplasia. Transvaginal sonography of the right adnexal region is performed. What is the most likely diagnosis?



- A. Granulosa cell tumor
- B. Mucinous cystadenocarcinoma
- C. Endometrioma
- D. Pedunculated myoma

**BLOCKED RETURN:** You cannot go back and change your answer after proceeding.

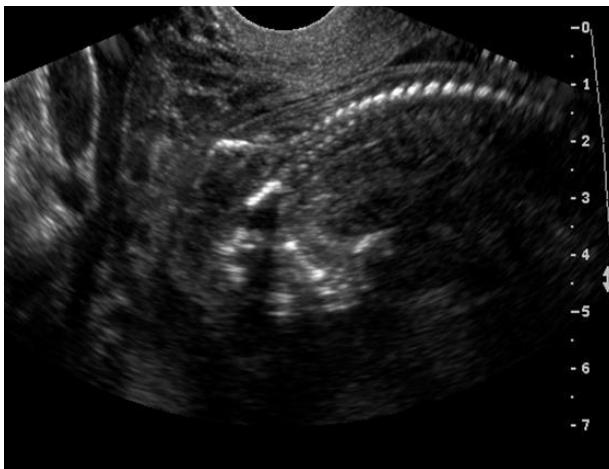
22b. Which of the following is a characteristic of granulosa cell tumors?

- A. Epithelial origin
- B. Hyperandrogenism
- C. Common juvenile type
- D. Low malignant potential
- E. Typically bilateral

23a. A 27-year-old pregnant woman has an ultrasound examination. What is the most likely diagnosis?



Transabdominal ultrasound



Transvaginal ultrasound

- A. Meningomyelocele
- B. Anencephaly
- C. Encephalocele
- D. Alobar holoprosencephaly

**BLOCKED RETURN:** You cannot go back and change your answer after proceeding.

23b. Anencephaly is associated with which one of the following?

- A. Visibility only after first trimester
- B. Normal maternal serum  $\alpha$ -fetoprotein
- C. Absence of neural tissue above the orbits
- D. Cyclopia and a proboscis

24. In a patient with no known primary malignancy and the incidental finding shown in the image, what is the likelihood of adrenal malignancy?



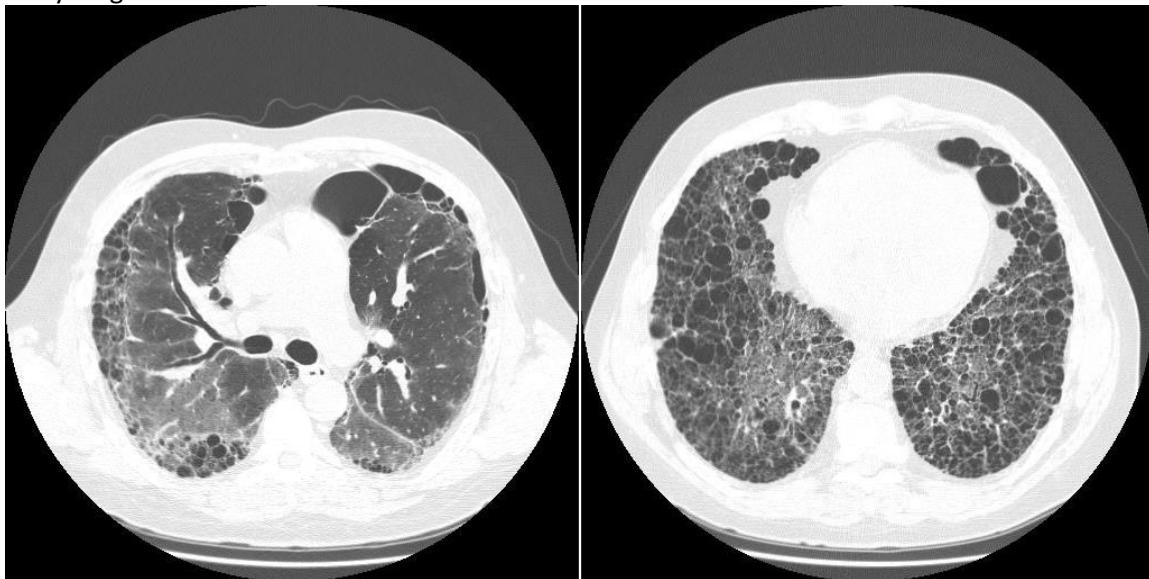
- A. < 1%
- B. 10%
- C. 25%
- D. 33%

25. Based on the image, what is the most likely diagnosis of the thyroid lesion?



- A. Colloid cyst
- B. Follicular adenoma
- C. Medullary carcinoma
- D. Papillary malignancy

26a. A 60-year-old man presents with dyspnea on exertion. Based on the CT images, what is the most likely diagnosis?



- A. Usual interstitial pneumonia
- B. Desquamative interstitial pneumonia
- C. Nonspecific interstitial pneumonia
- D. Lymphocytic interstitial pneumonia
- E. Acute interstitial pneumonia

**BLOCKED RETURN:** You cannot go back and change your answer after proceeding.

26b. The referring pulmonologist suspects idiopathic pulmonary fibrosis. After a CT examination is performed, what is the most appropriate next step?

- A. Bronchoscopic biopsy
- B. Open-lung biopsy
- C. Bronchoscopic alveolar lavage
- D. No intervention required
- E. Percutaneous biopsy

27a. A 45-year-old man presents after a high-speed motor vehicle collision. Based on the image, CT imaging should be performed to **EXCLUDE** which of the following conditions?



- A. Ruptured esophagus
- B. Aortic injury
- C. Diaphragm rupture
- D. Sternoclavicular dislocation

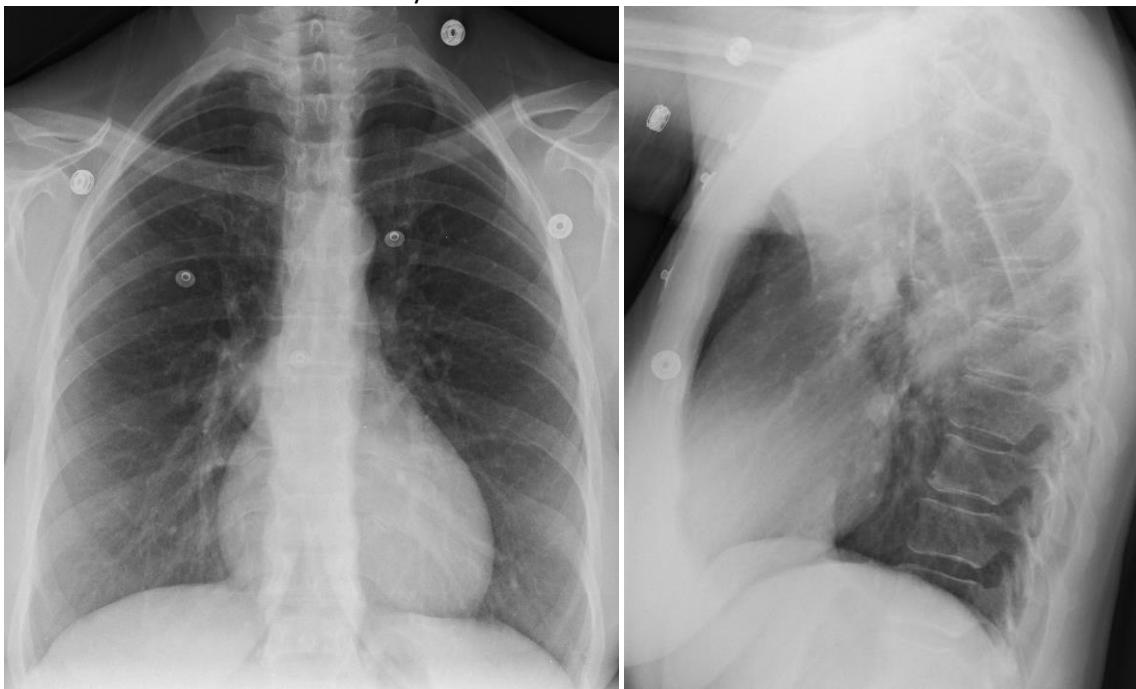
**BLOCKED RETURN:** You cannot go back and change your answer after proceeding.

27b. What is the most appropriate next step in management?



- A. No intervention required
- B. Diagnostic angiogram
- C. Surgical treatment
- D. Echocardiogram

28a. A 30-year-old woman has a routine chest radiograph, and an abnormality is discovered. Where in the mediastinum is the abnormality located?



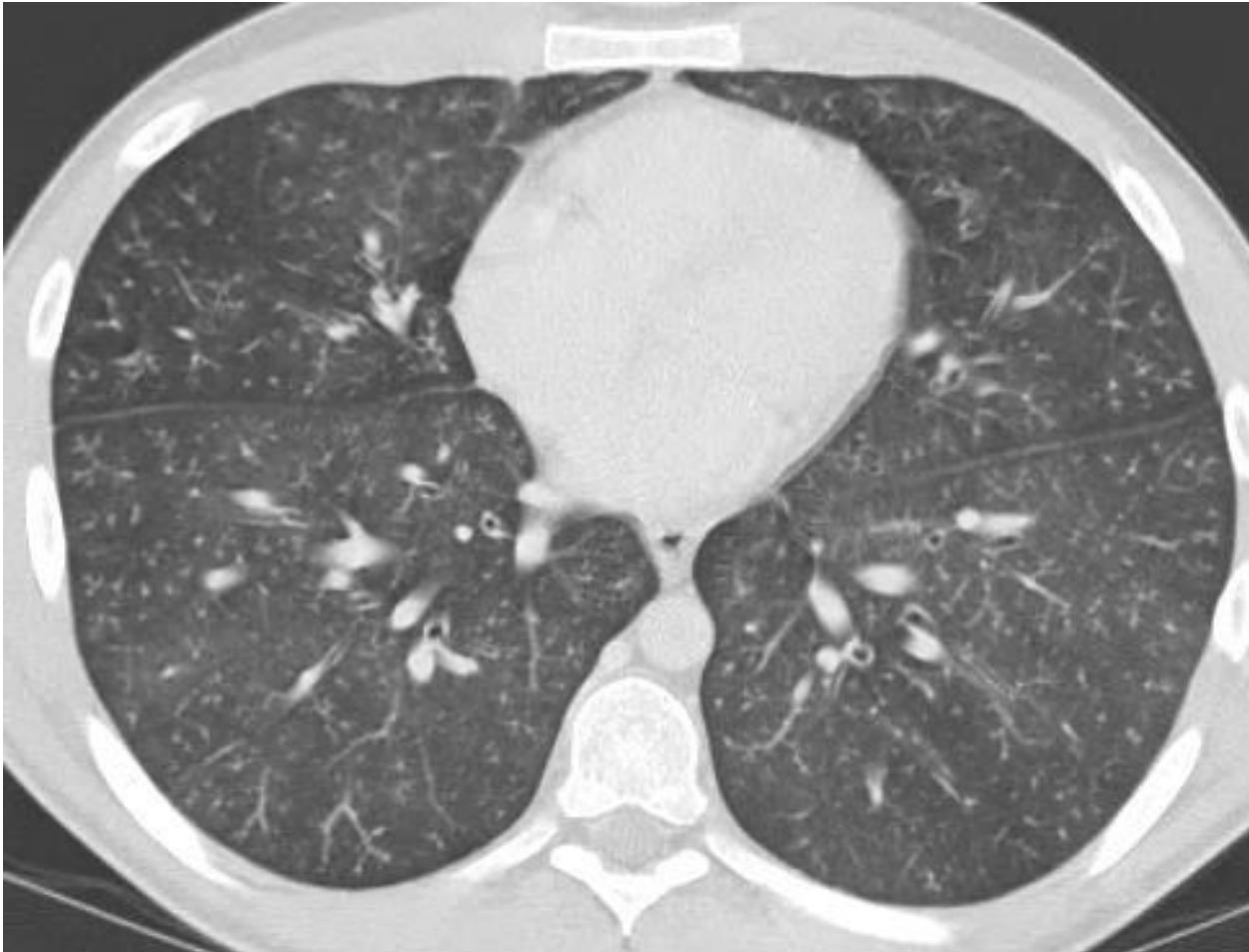
- A. Anterior
- B. Middle
- C. Posterior
- D. Superior

28b. Based on the CT image, what is the most likely diagnosis?



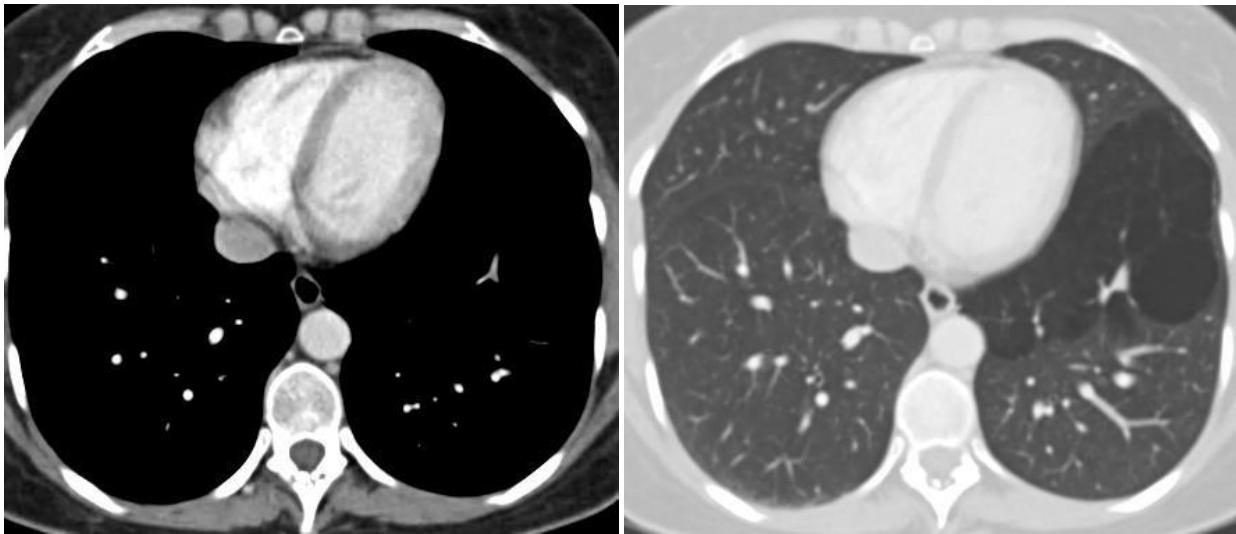
- A. Hamartoma
- B. Lymphadenopathy
- C. Schwannoma
- D. Duplication cyst
- E. Extramedullary hematopoiesis

29. Which of the following best describes the pattern on the CT image?



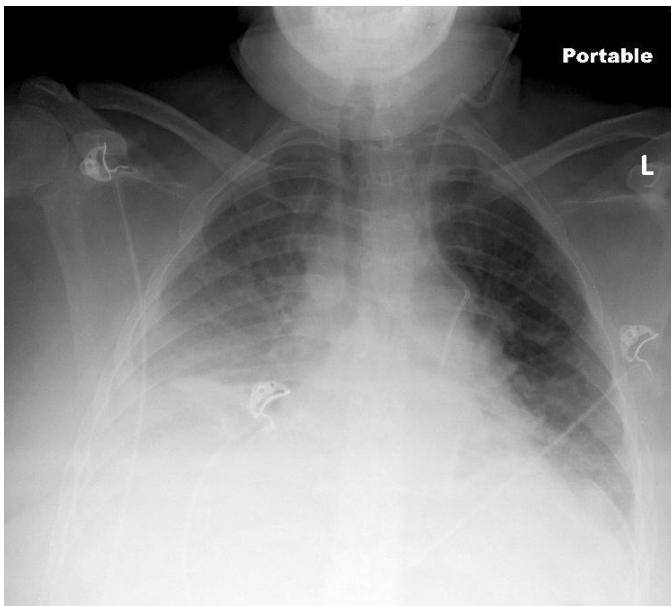
- A. Crazy paving
- B. Ground glass
- C. Perilymphatic nodules
- D. Mosaic attenuation

30. A 21-year-old woman presents for routine follow-up. Based on the CT images, what is the most appropriate next step?



- A. Percutaneous biopsy
- B. PET
- C. MRI
- D. Follow-up CT in 6 months
- E. No intervention

31. A portable chest radiograph is obtained for a 48-year-old woman. The catheter left of midline is in what vein?



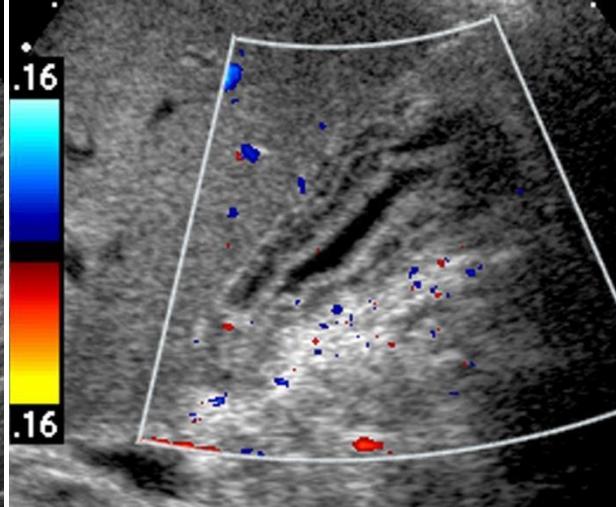
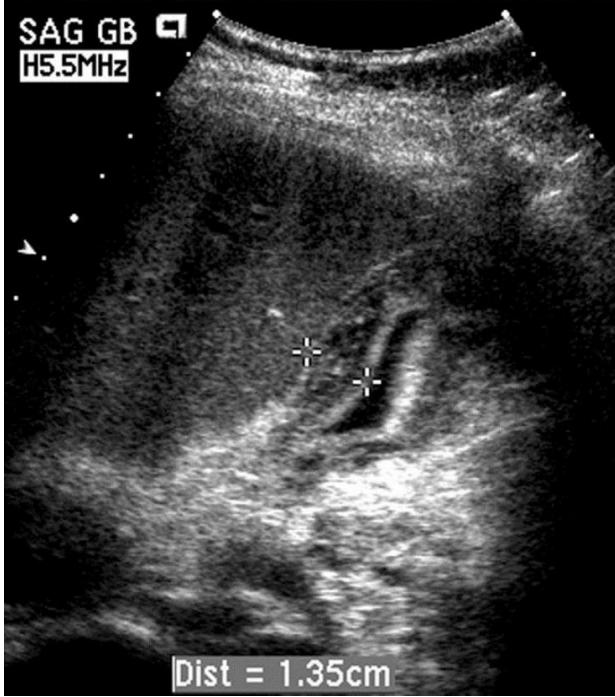
- A. Left upper lobe anomalous pulmonary vein
- B. Left superior vena cava
- C. Left internal mammary vein
- D. Hemiazygous vein
- E. Pericardiophrenic vein

32. A 26-year-old pregnant woman has an elevated serum  $\alpha$ -fetoprotein level. What is the most likely diagnosis?



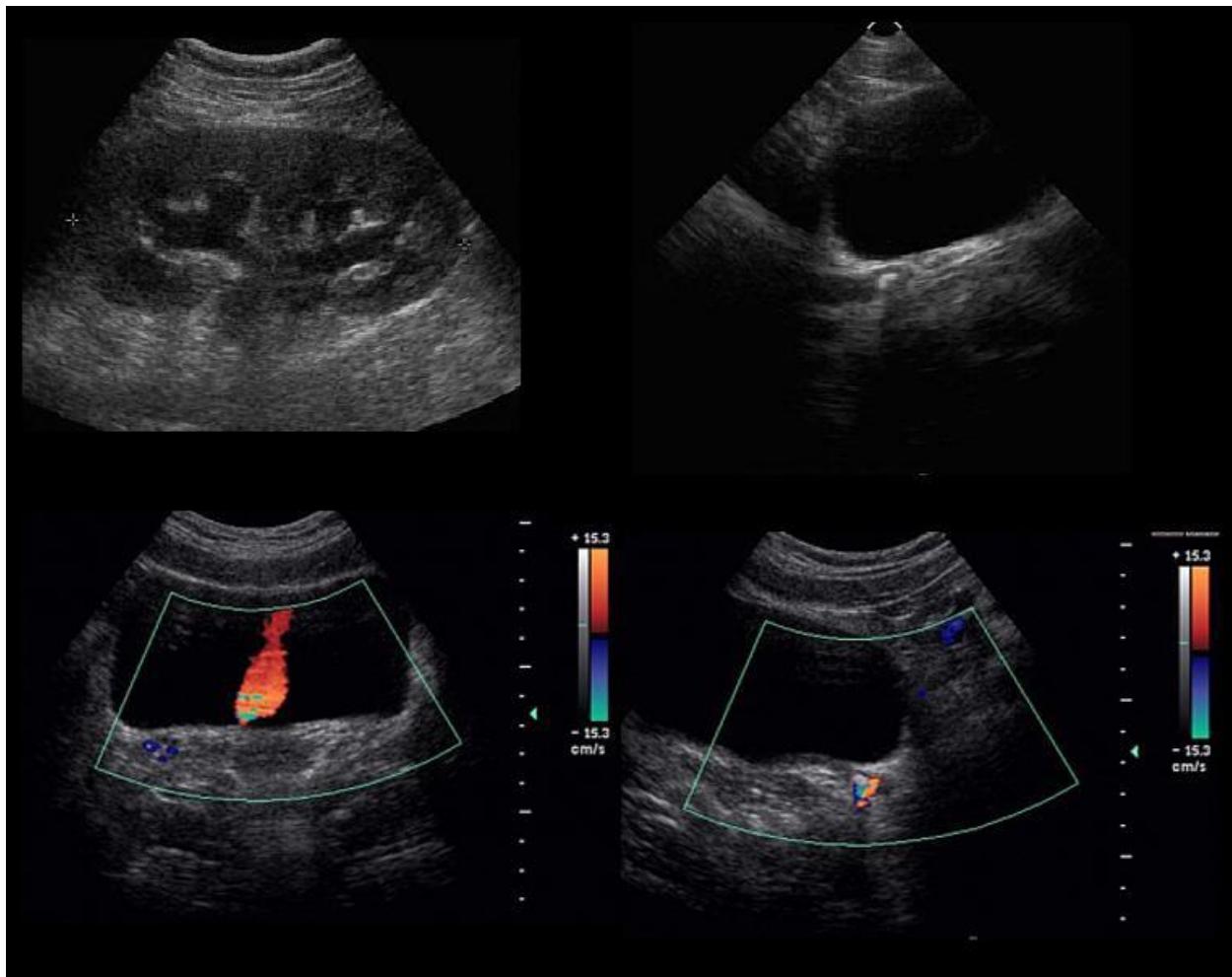
- A. Chiari II malformation
- B. Cystic hygroma
- C. Encephalocele
- D. Cervical teratoma
- E. Dandy-Walker malformation

33. A 44-year-old woman presents to the emergency department with right upper quadrant pain. Which of the following is the **LEAST** likely cause of the gallbladder wall thickening?



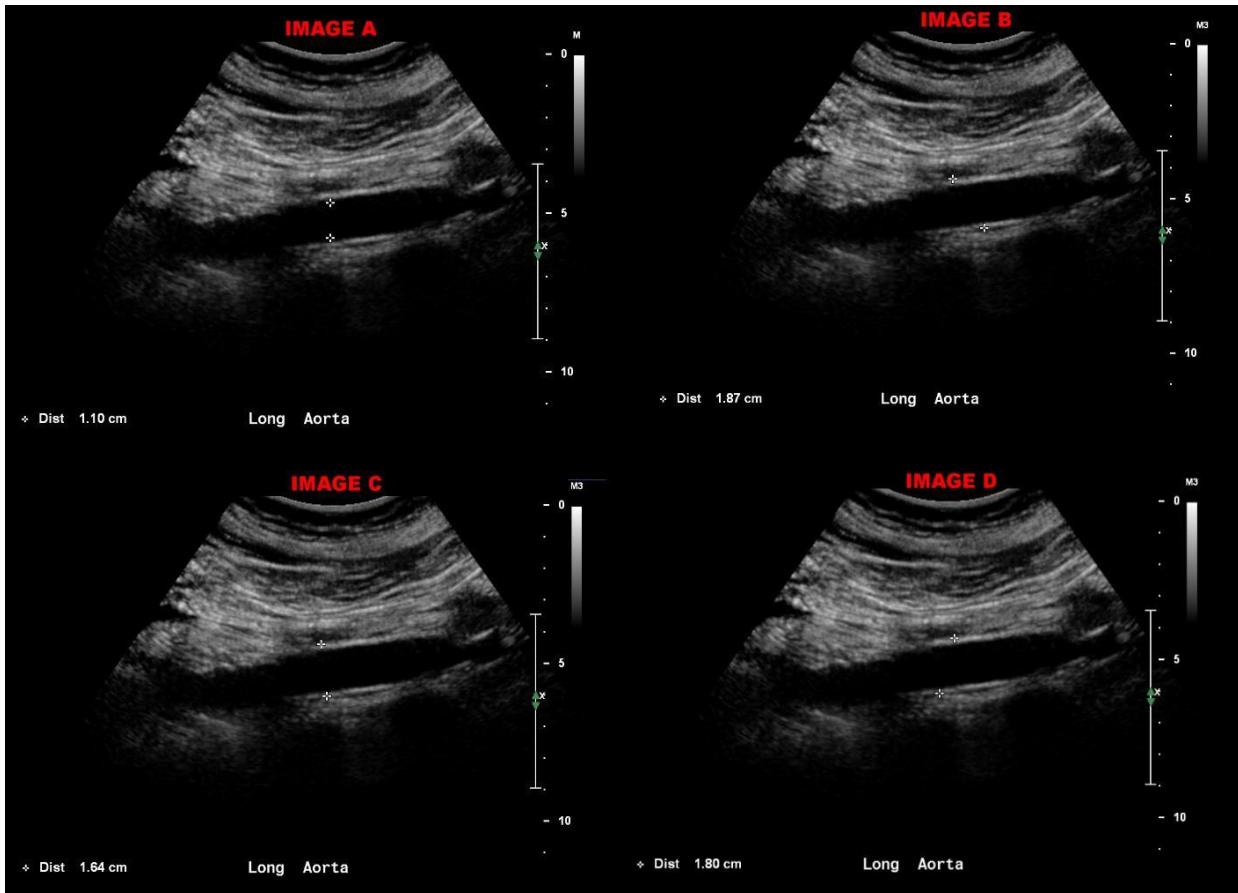
- A. Hepatitis
- B. Acute cholecystitis
- C. Chemotherapy-induced changes
- D. Congestive heart failure

34. A 39-year-old woman presents with left flank pain. What is the most likely diagnosis?



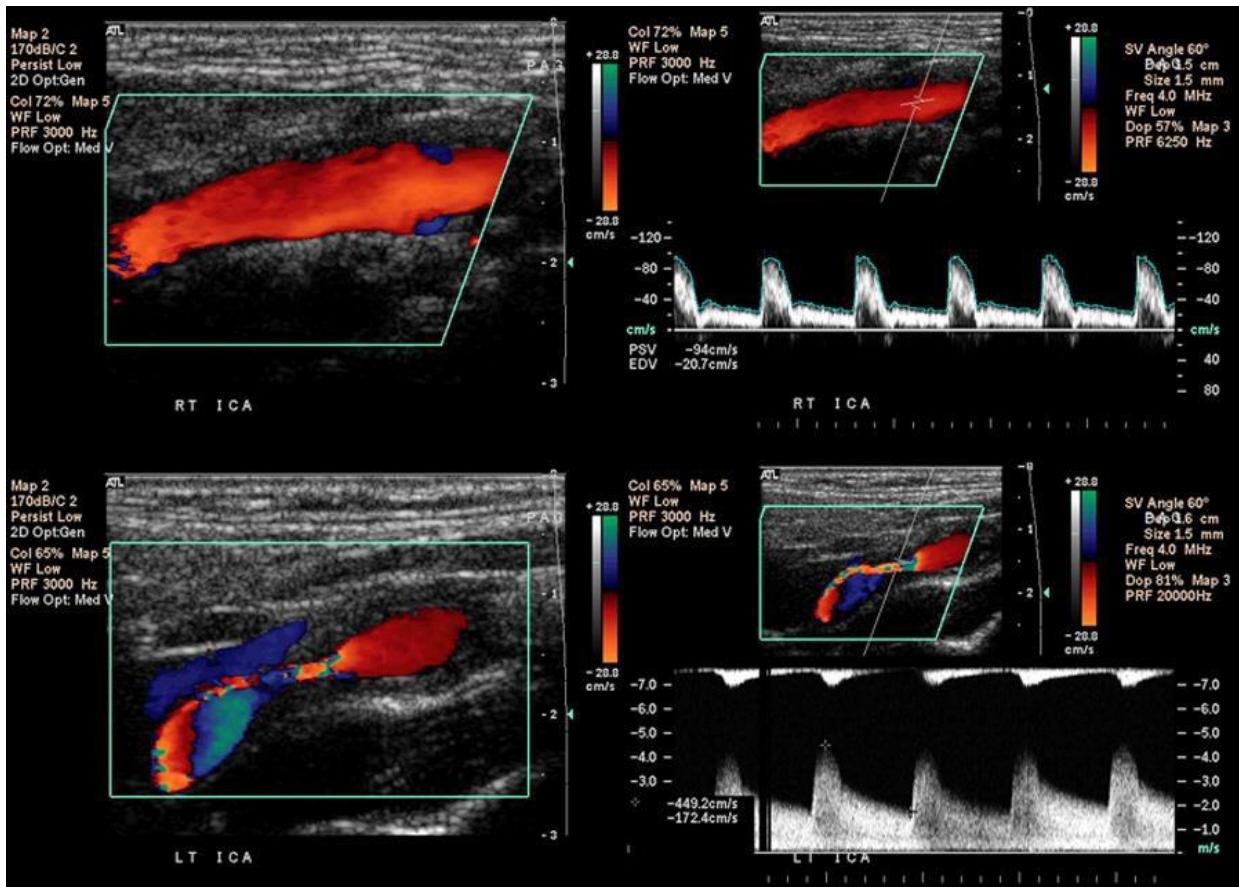
- A. Left ureterovesical junction calculus
- B. Pyelonephritis with urinary retention
- C. Vesicoureteral reflux
- D. Acute bleeding into the bladder

35. A 66-year-old man is referred for a screening ultrasound of the aorta. On which image is the diameter of the aorta measured correctly?



- A. Image A
- B. Image B
- C. Image C
- D. Image D

36. A 68-year-old man presents with a transient ischemic attack. What is the most likely diagnosis?



- A. 50% to 69% right internal carotid artery stenosis
- B. > 70% right internal carotid artery stenosis
- C. 50% to 69% left internal carotid artery stenosis
- D. > 70% left internal carotid artery stenosis

37. What is the most appropriate next step in management?



- A. Angiography
  - B. Observation
  - C. Operative repair
38. X-rays are produced in a conventional x-ray tube by which of the following mechanisms?
- A. Deceleration of high speed electrons
  - B. Neutron collision with anode material
  - C. Pair production
  - D. Formation of Auger electrons
39. If the x-ray tube voltage is increased from 60 to 70 kVp, how would mAs need to be adjusted to maintain the same amount of radiation exposure to the image detector?
- A. Reduce mAs by  $\frac{1}{4}$
  - B. Reduce mAs by  $\frac{1}{2}$
  - C. Increase mAs by  $\frac{1}{2}$
  - D. Increase mAs by  $\frac{1}{4}$
40. The quality or penetrating power of a diagnostic x-ray beam can be increased by which of the following actions?
- A. Increasing the kVp
  - B. Decreasing the beam filtration
  - C. Increasing mAs
  - D. Decreasing the exposure time

41. Changing the focal spot size from 0.6 mm to 1.0 mm has which of the following effects?

- A. The resolution in the produced image is improved.
- B. The heat absorption capacity of the anode is increased.
- C. Visualization of high contrast objects in the image is improved.
- D. The patient dose is decreased.

42. In the computed radiography (CR) image, what is the most likely cause of the artifact indicated by the arrow?



Image from: Cesar LJ et al, 2001, Artifacts found in computed radiography, BJR 74: 195-202.

- A. Debris on the CR reader light guide
- B. Debris on the CR imaging plate
- C. Line of dead pixels
- D. Grid lines

43. In the computed radiography (CR) image, what is the most likely cause of the artifact indicated by the arrow?

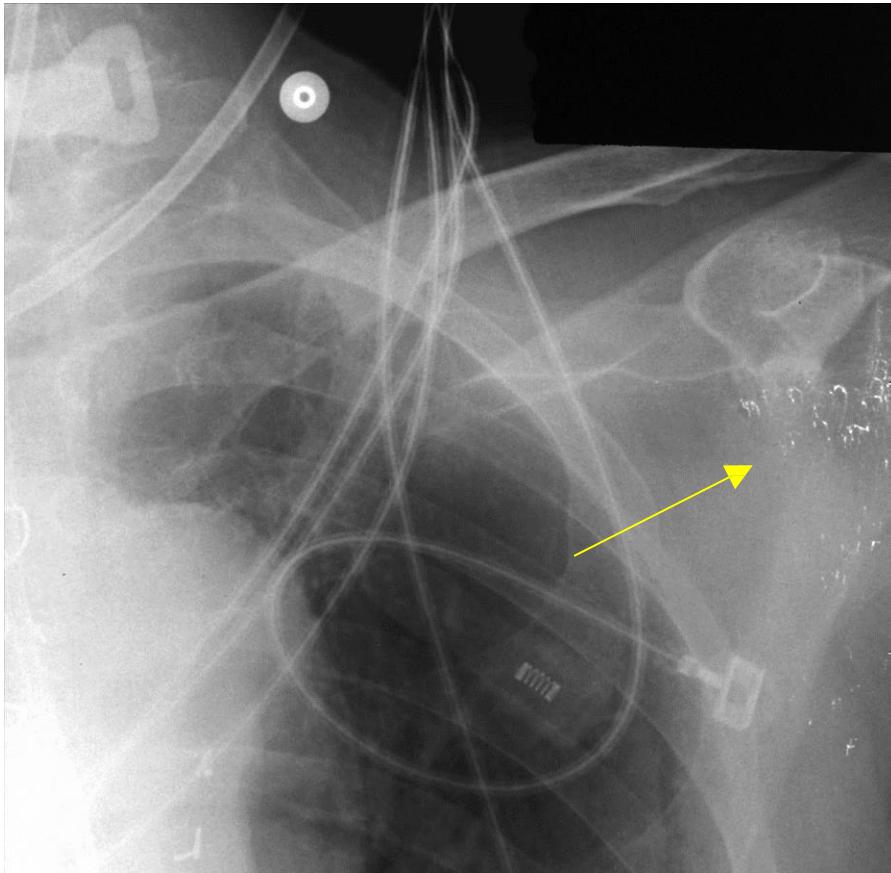


Image from: Cesar LJ et al, 2001, Artifacts found in computed radiography, BJR 74: 195-202.

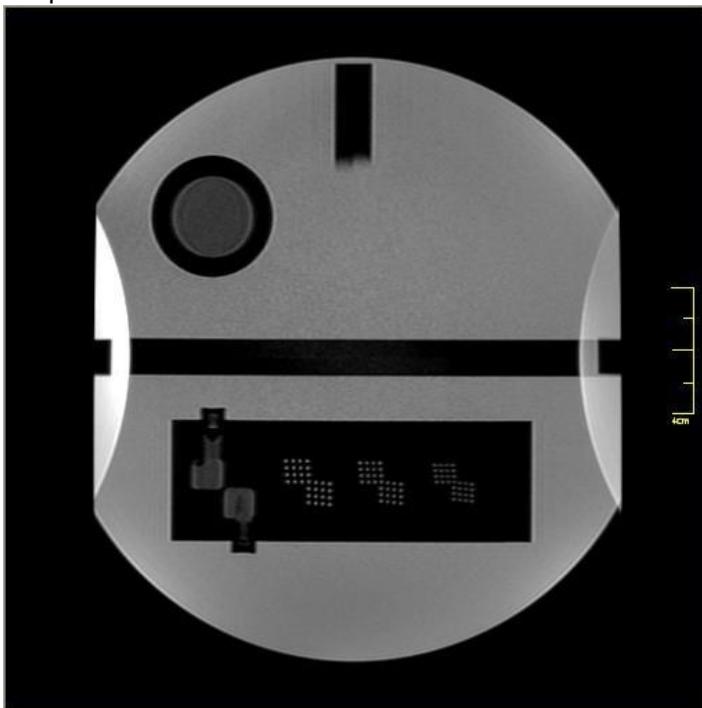
- A. Debris on the CR reader light guide
- B. Debris on the CR imaging plate
- C. Debris on the outside of the CR cassette
- D. Debris on the grid

44. To minimize geometric unsharpness, the radiograph should be acquired with which of the following geometric configurations?



- A. Hand directly on image receptor
- B. Hand on table Bucky surface
- C. Hand midway between image receptor and x-ray tube
- D. Hand near exit of collimator assembly

45. The image of the ACR MR accreditation phantom illustrates a wrap-around artifact. What is a possible action to correct the artifact?



- A. Inverting the frequency and phase directions
  - B. Keeping all image parameters the same and using a larger coil
  - C. Increasing the image repetition time
  - D. Increasing the field of view
46. A measure of radiation and organ system-specific damage in humans is described by which of the following?
- A. Activity
  - B. Exposure
  - C. Kerma
  - D. Effective dose
47. In a multislice fast-spin-echo (FSE) pulse sequence ( $TE/TR = 100/4000$  ms, echo train length [ETL] = 12, field of view [FOV] = 30 cm,  $256 \times 256$ ), which of the following modifications would further reduce the imaging time?
- A. Reducing the TE to 50 milliseconds
  - B. Reducing the FOV to 25 cm
  - C. Reducing the ETL to 10
  - D. Reducing the TR to 3000 milliseconds

48. If the physical half-life and biologic half-life for a radiopharmaceutical are both equal to 6 hours, what is the effective half-life?

A. 1 hour

B. 3 hours

C. 6 hours

D. 12 hours

49. Which device is used to accurately assay a radioactive sample with an activity of 10 kBq?

A. Dose calibrator

B. Thyroid probe

C. Well counter

D. Geiger-Müller counter

50. Which of the following factors influences the spatial resolution of a gamma camera the most?

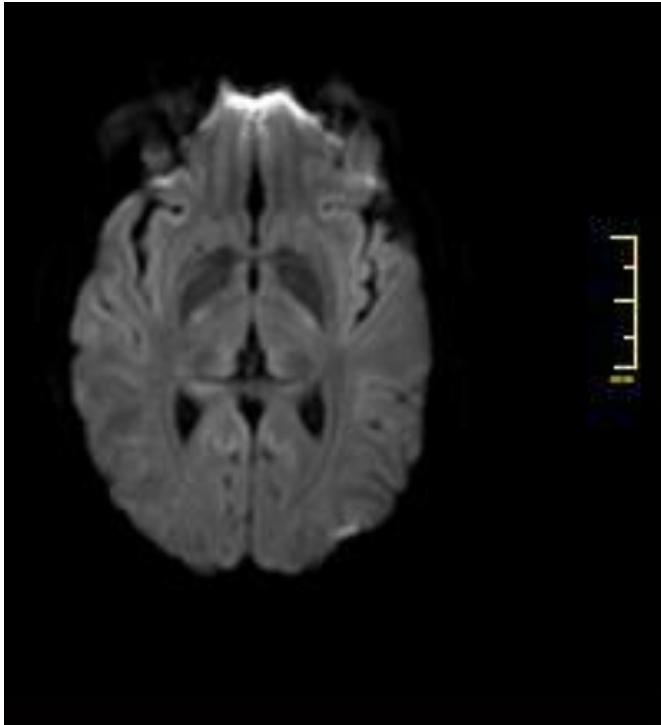
A. Source-to-collimator distance

B. Source activity

C. Field uniformity

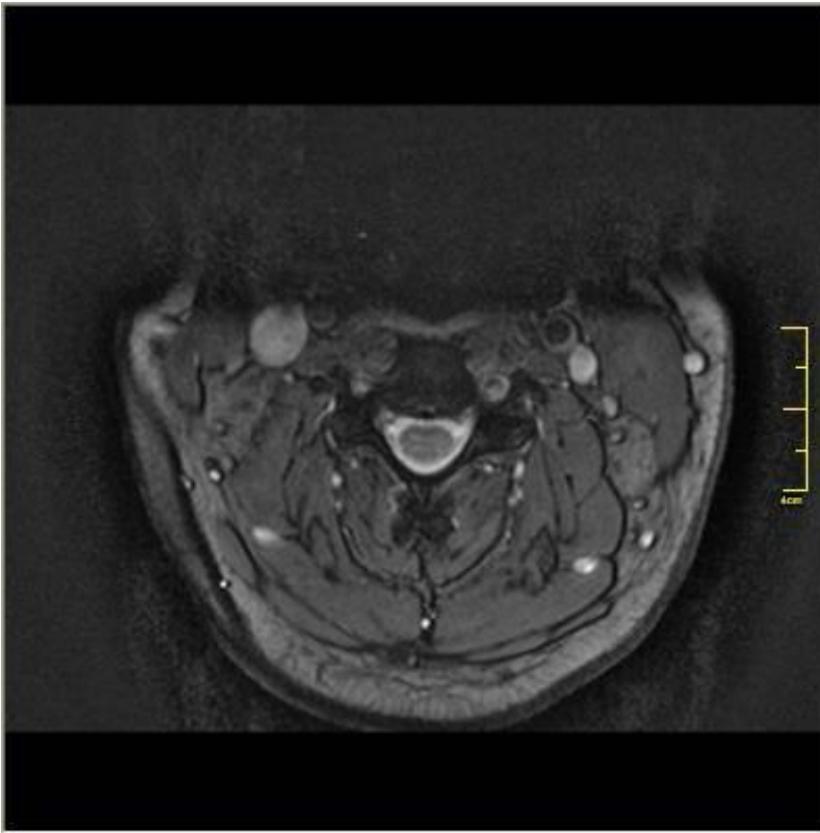
D. Spatial linearity

51. The image is an example of which of the following?



- A. Contrast enhancement
- B. Susceptibility artifact
- C. Gradient nonlinearity
- D. Radiofrequency coil heating

52. The image illustrates which of the following?



- A. Beam collimation
- B. Spatial saturation
- C. Malfunctioning coil
- D. Breathing artifact

53. The amount of space needed to store a chest image on PACs depends in part on which of the following?

- A. Specified mA
- B. Acquisition time
- C. Grid use
- D. Number of pixels

54. A 100% ripple is characteristic of what type of x-ray generator?

- A. Portable
- B. Single-phase
- C. Three-phase
- D. High-frequency inverter
- E. Constant potential

55. In the CT image of the head, what is the most likely cause of the “streak” artifact?



- A. Partial volume effect
- B. Wrong reconstruction filter
- C. Low kVp selection
- D. Partial data loss

56. The beam of an ultrasound system can be focused and steered with which of the following?

- A. Time gain compensation system
- B. Scan converter
- C. M-mode processing
- D. Phased array

57. In the image of a kidney, where does the signal from the capsule of the kidney originate?



- A. Specular reflection
- B. Refraction
- C. Attenuation
- D. Scattering
- E. Nonspecular reflection

**Answers**

- |      |   |     |   |
|------|---|-----|---|
| 1)   | A | 29) | D |
| 2)   | D | 30) | E |
| 3a)  | E | 31) | D |
| 3b)  | D | 32) | C |
| 4)   | A | 33) | B |
| 5a)  | B | 34) | A |
| 5b)  | A | 35) | C |
| 6a)  | H | 36) | D |
| 6b)  | G | 37) | C |
| 7)   | C | 38) | A |
| 8a)  | B | 39) | B |
| 8b)  | E | 40) | A |
| 9)   | E | 41) | B |
| 10)  | C | 42) | A |
| 11)  | C | 43) | B |
| 12a) | A | 44) | A |
| 12b) | D | 45) | D |
| 13a) | C | 46) | D |
| 13b) | A | 47) | D |
| 13c) | B | 48) | B |
| 13d) | C | 49) | C |
| 14a) | A | 50) | A |
| 15a) | E | 51) | B |
| 15b) | B | 52) | B |
| 16)  | B | 53) | D |
| 17)  | E | 54) | B |
| 18)  | C | 55) | D |
| 19)  | A | 56) | D |
| 20a) | C | 57) | A |
| 20b) | A |     |   |
| 21a) | B |     |   |
| 21b) | D |     |   |
| 21c) | C |     |   |
| 22a) | A |     |   |
| 22b) | D |     |   |
| 23a) | B |     |   |
| 23b) | C |     |   |
| 24)  | A |     |   |
| 25)  | A |     |   |
| 26a) | A |     |   |
| 26b) | D |     |   |
| 27a) | B |     |   |
| 27b) | C |     |   |
| 28a) | B |     |   |
| 28b) | D |     |   |