

Revised Curriculum on Cardiothoracic Radiology for Diagnostic Radiology Residency With Goals and Objectives Related to General Competencies¹

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This document is a revision of a previously published cardiothoracic curriculum for diagnostic radiology residency (1), and reflects interval changes in the clinical practice of cardiothoracic radiology and changes in the Accreditation Council for Graduate Medical Education (ACGME) requirements for diagnostic radiology training programs. The revised ACGME Program Requirements for Residency Education in Diagnostic Radiology (2) went into effect December 2003.

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The residency program director is responsible for the “preparation of a written statement outlining the educational goals of the program with respect to knowledge, skills, and other attributes of residents for each major assignment and each level of the program” (2). Since the first cardiothoracic curriculum was published, the ACGME has added new language to the program requirements regarding six areas of competency. Programs must define the specific knowledge, skills, behaviors, and atti-

tudes required and provide educational experiences as needed for their residents to demonstrate competence in the following six areas: patient care, medical knowledge, professionalism, interpersonal/communication skills, practice-based learning and improvement, and systems-based practice. These six areas, as they specifically relate to radiology, have been defined previously (3).

The nine subspecialty areas of a radiology residency program listed in the ACGME requirements are neuroradiology, musculoskeletal radiology, vascular and interventional radiology, chest radiology, breast imaging, abdominal radiology, pediatric radiology, ultrasonography (including obstetrical and vascular ultrasound), and nuclear radiology (2). Note that although there is no specific subspecialty defined as cardiac radiology, ACGME requires training and experience in radiographic interpretation, computed tomography (CT), magnetic resonance imaging (MRI), angiography, and nuclear radiology examinations of the cardiovascular system (heart and great vessels). Didactic instruction is required in cardiac anatomy, physiology, and pathology, including the coronary arteries, as essential to the interpretation of cardiac imaging studies, and to include both the adult and the pediatric age group.

Acad Radiol 2005; 12:210–223

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doi:10.1016/j.acra.2004.12.013

The Society of Thoracic Radiology Education Committee has therefore incorporated traditional “thoracic” or pulmonary, pleural, and mediastinal radiology with adult-acquired and congenital cardiac radiology into a single curriculum document on cardiothoracic radiology.

This curriculum document focuses on adult radiology, because pediatric radiology is recognized as a separate subspecialty by the ACGME. Similarly, nuclear radiology is listed as a separate subspecialty. Components of a cardiothoracic radiology curriculum may practically occur during one or more organ-specific or technology-specific rotations during residency, including rotations in thoracic radiology, cardiac radiology, pediatric radiology, nuclear radiology, magnetic resonance imaging, computed tomography, or vascular and interventional radiology. Recognizing that it is difficult to draw clear boundaries between subspecialties, aspects of other radiology subspecialties pertinent to adult thoracic radiology are also included in this curriculum document. Physics, as applied to cardiothoracic radiology, is generally covered in a separate physics course and is not included in this document.

The cardiothoracic curriculum should reflect an appropriate balance of chest radiography, chest CT, chest MRI, and procedural experience. Integrated rotations encompassing all of these activities, or dedicated thoracic radiology cross-sectional rotations are preferred, rather than thoracic radiology as part of a general “body imaging” rotation.

The residency program director is responsible for regular evaluation of residents’ knowledge, skills, and overall performance, including the development of professional attitudes consistent with being a physician. The evaluation must concern itself with intellectual abilities, attitudes and character skills, and clinical and technical competence, in addition to the six competencies listed previously. The goals and objectives provided in this graduated curriculum can be used as a template by program directors or thoracic radiology faculty as part of the evaluation process. Objectives that relate to specific competencies are indicated in this document with the following labeling system: medical knowledge (MK), patient care (PC), professionalism (P), interpersonal/communication skills (ICS), practice-based learning and improvement (PBLI), and systems-based practice (SBP).

This curriculum, prepared by the Society of Thoracic Radiology Education Committee, is based on three 4-week rotations in thoracic radiology. Programs may be organized into a different number of rotations of different length, and this curriculum can be modified to reflect

variations in training programs. Goals and objectives encompassing clinical knowledge, technical, communication, and decision-making skills are outlined for each level of training, based on three rotations in thoracic radiology. Because the timing of resident exposure to each part of the curriculum will depend on the organization of individual residency programs, the individual program should modify this curriculum as appropriate. Recommended study materials and required conference attendance are an important component of a complete curriculum document. Similarly, because they are often specific to individual departments, a detailed listing is not provided in this document.

YEAR ONE (FIRST 4-WEEK ROTATION)

I. Goals

After completion of the first thoracic radiology rotation, the resident will be able to:

1. demonstrate learning of the knowledge-based objectives.
2. accurately and concisely dictate a chest radiograph report.
3. communicate effectively with referring clinicians and supervisory staff.
4. understand standard patient positioning in thoracic radiology.
5. obtain pertinent patient information relative to radiologic examinations.
6. demonstrate knowledge of the clinical indications for obtaining chest radiographs and when a chest CT or MR may be necessary.
7. demonstrate a responsible work ethic.
8. perform image-guided procedures of the chest.
9. participate in quality improvement/quality assurance and other operational activities.

II. Objectives

A. Knowledge-based

At the end of the first thoracic radiology rotation, the resident will demonstrate learning of at least one-third of the knowledge-based objectives (*see Addendum*) (PC) (MK).

B. Technical, communication, and decision-making skills

At the end of the first thoracic radiology rotation,

the resident will demonstrate the following technical, communication, and decision-making skills:

1. Dictate accurate and concise chest radiograph reports that include patient name, patient medical record number, date of exam, date of comparison exam, type of exam, indication for exam, brief and concise description of the findings, and short impression (ICS)
2. Communicate with ordering physicians about all significant or unexpected radiologic findings and document who was called and the date and time of the call in the dictated report (IPC) (PC)
3. Obtain relevant patient history from electronic records, dictated reports, or by communicating with referring clinicians (PC)
4. Describe patient positioning and indications for posteroanterior (PA), anteroposterior (A), lateral decubitus, and lordotic chest radiographs (PC) (MK)
5. When assisting referring clinicians with imaging interpretation and patient management, decide when it is appropriate to obtain help from supervisory faculty (P)
6. Arrive for the rotation assignment on time and prepared after reviewing recommended study materials (P)
7. Successfully perform thoracic biopsies and image-guided therapies (eg, pleural drainage and radiofrequency ablation if performed at the institution) with faculty supervision commensurate with experience and individual competence (PC)
8. Before performing interventional procedures, counsel patients and obtain informed consent (eg, explain conduct and purpose for procedure, explain risks, benefits and alternatives, solicit and answer patient questions) without discriminating based on religious, ethnic, sexual, or educational differences and honoring patient confidentiality (ICS) (P)
9. Document (via electronic or written format) the performance, interpretation, and complications of all procedures performed (PBLI)
10. Participate in discussions with faculty regarding operational challenges and potential systems solutions regarding all aspects of radiologic service and patient care (SBP)
11. Use appropriate chest radiograph, CT, and MRI

nomenclature when dictating reports and consulting with health care professionals (ICS).

III. CONFERENCES AND STUDY MATERIALS

A. Conferences

The ACGME requires didactic conferences as part of the radiology residency training program. Examples of the types of conferences that should be part of a resident's educational program are listed in the following section. Thoracic radiology teaching conferences are mandatory. Other conferences, such as a lung transplantation conference, are not available at all training programs; when available, they should be considered for inclusion in the curriculum depending on the specifics of the individual training program and medical center. Note that although some of these conferences are sponsored by a radiology department, others may be sponsored by other departments or multidisciplinary programs. It is recommended that this latter type of conference be included to facilitate the radiology residents' understanding of the use of imaging and clinical circumstances in which imaging is requested. It is desirable that residents actively participate in the preparation and presentation of conferences (MK) (PBLI) (SBP).

- Radiology resident-specific thoracic radiology teaching conference
- Journal review
- Radiology grand rounds
- Pulmonary medicine conference
- Intensive care unit conference
- Thoracic oncology conference
- Cardiothoracic surgery conference
- Lung transplantation conference
- Quality assurance/quality improvement conference (departmental and institutional)
- Other

B. Teaching

Supervise or act as consultants to junior residents and medical students (PBLI).

C. Study materials

Many types of educational materials may be included in this portion of a curriculum document, including books, book chapters, or review articles.

Hard-copy teaching files (eg, American College of Radiology (ACR) or individual department file), computer-based educational programs, and radiology education web sites or teaching files (eg, ACR CD-ROM) should also be included, as recommended by the residency program director or designated faculty within the subspecialty of thoracic radiology (MK).

YEAR 2 (OR SECOND 4-WEEK ROTATION)

I. Goals

After completion of the second thoracic radiology rotation, and in addition to those goals listed for Year 1, the resident will:

1. demonstrate learning of the knowledge-based learning objectives.
2. continue to build on chest radiograph interpretive skills.
3. develop skills in protocoling, monitoring, and interpreting chest CT scans.
4. demonstrate an understanding of ACR Appropriateness Criteria and ACR Practice Standards and Technical Guidelines for thoracic radiology.
5. demonstrate an ability to generate and interpret multiplanar reformatted (MPR) or three-dimensional images of CT or MRI studies as appropriate.

II. Objectives

A. The resident will demonstrate learning of at least two-thirds of the knowledge-based objectives listed for Year 1 (*see* Addendum), in addition to identifying the following structures on chest CT and chest MRI (MK).

- Lungs—right, left, right upper, middle, and lower lobes, left upper lobe (anteroposterior, anterior and lingular segments), and left lower lobe
- Pleura and extrapleural fat
- Airway—trachea, main bronchi, carina, and lobar bronchi
- Heart—left ventricle, right ventricle, moderator band, left atrium, left atrial appendage, right atrium, right atrial appendage, mitral valve, aortic valve, tricuspid valve, pulmonary valve, coronary arteries (left main, left anterior descending, left circumflex, right, posterior descending), coronary veins, coronary sinus
- Pericardium—including pericardial recesses

- Pulmonary arteries—main, right, left, interlobar, segmental
- Aorta—ascending, sinuses of Valsalva, arch, descending
- Arteries—brachiocephalic (innominate), common carotid, subclavian, axillary, vertebral, internal mammary, intercostal
- Veins—pulmonary, superior vena cava, inferior vena cava, brachiocephalic, subclavian, axillary, internal jugular, external jugular, azygos, hemiazygos, left superior intercostal, internal mammary
- Bones—ribs and costochondral cartilages, clavicles, scapulae, sternum, spine
- Esophagus
- Thymus
- Thyroid gland
- Muscles—sternocleidomastoid, anterior and middle scalene, infrahyoid, pectoralis major and minor, deltoid, trapezius, infraspinatus, supraspinatus, subscapularis, latissimus dorsi, serratus anterior
- Aortopulmonary window
- Azygoesophageal recess
- Gastrohepatic ligament, celiac axis
- Diaphragm
- Identify the following additional structures on chest CT:
 - Lungs—all lobes and segments; secondary pulmonary lobules
 - Fissures—major, minor, azygos, accessory (superior and inferior)
 - Airway—lobar and segmental bronchi
 - Inferior pulmonary ligaments

B. At the end of the second thoracic radiology rotation, the resident will demonstrate the following technical, communication, and decision-making skills, in addition to those listed for Year 1.

1. Appropriately protocol all requests for chest CT to include thin-section images, high-resolution images, expiratory images, or prone images when appropriate, and use of intravenous contrast, given the patient history (PC)
2. Monitor all chest CT examinations and determine if additional imaging is needed before the patient CT examination is completed (if this is an institutional practice) (PC)
3. Demonstrate the ability to effectively present thoracic radiology cases to other residents in a confer-

ence setting by appropriately selecting cases, interacting with residents, and presenting a brief discussion of the diagnosis for each case (PBLI)

4. Demonstrate the ability to manage an intravenous contrast reaction that occurs during a chest CT examination (PC)
5. Act as a consultant for referring clinicians and recommend the appropriate use of imaging studies (ICS)
6. Describe the principles of chest fluoroscopy, including the assessment of the diaphragm (PC)
7. Demonstrate knowledge of CT parameters contributing to patient radiation exposure and techniques that can be used to limit radiation exposure (PC).

III. Conferences and Study Materials

A. Conferences—same as for Year 1

B. Teaching

Supervise or act as consultants to junior residents and medical students (PBLI)

C. Study materials

Compared with the first rotation, more advanced educational resources should be provided for the second rotation in thoracic radiology. Although materials for the first rotation may be books, book chapters, or teaching files based primarily on thoracic radiography, more advanced rotations should incorporate primary journal citations, and books, book chapters, or teaching files specific to advanced modalities (eg, chest CT, MRI) or interventional thoracic radiology (eg, lung biopsy).

5. correlate pathologic and clinical data with radiographic and chest CT findings.

II. Objectives

A. At the end of the third thoracic radiology rotation or senior year of radiology residency, the resident will demonstrate knowledge of all of the knowledge-based objectives introduced in Years 1 and 2 (MK).

B. Technical and communication skills

After completion of the third thoracic radiology rotation, the resident will demonstrate the following technical, communication, and decision-making skills, in addition to those listed for Years 1 and 2.

1. Dictate accurate, concise chest radiograph, CT scan, and MR reports with at least 75% accuracy; the reports will contain no major interpretive errors (ICS)
2. State the clinical indications for performing chest CT and MRI (MK) (PC)
3. Describe a chest CT protocol optimized for evaluating each of the following (PC):
 - thoracic aorta and great vessels
 - coronary calcium
 - pulmonary vein anatomy
 - suspected pulmonary embolism
 - tracheobronchial tree
 - suspected bronchiectasis
 - lung cancer staging
 - esophageal cancer staging
 - suspected pulmonary metastases
 - suspected pulmonary nodule on a radiograph
 - shortness of breath
 - hemoptysis
 - cardiac mass
 - coronary arteries
 - suspected pericardial disease
4. Understand the technical principles of all chest MRI exams and describe a protocol optimized for evaluating each of the following (MK) (PC):
 - thoracic aorta
 - pulmonary arteries
 - thoracic veins (superior vena cava, brachiocephalic veins)
 - pericardium
 - cardiomyopathy and cardiac and paracardiac masses, including tumors

YEARS 3-4 (THIRD 4-WEEK ROTATION)

I. Goals

After completion of the third thoracic radiology rotation, and in addition to the goals listed for Years 1 and 2, the resident will:

1. demonstrate learning of the knowledge-based objectives.
2. refine skills in interpretation of radiographs and chest CT scans.
3. develop skills in protocoling, monitoring, and interpreting chest MR studies, including cardiovascular MRI.
4. become a more autonomous consultant and teacher.

- ischemic heart disease, including function, viability and perfusion
 - valvular heart disease
 - right ventricular dysplasia
 - congenital heart disease in an adult
 - superior sulcus tumor
5. In collaboration with a pathologist, present an interesting cardiothoracic imaging case, with a confirmed diagnosis, correlating clinical history with pathologic and radiologic findings, to residents and faculty (MK) (ICS) (PBLI).
 6. Work in the reading room independently, assisting clinicians with radiologic interpretation, and teaching other residents and medical students assigned to thoracic radiology (PC) (ICS) (P) (PBLI).

III. Conferences and Study Materials

A. Conferences

Same as for Year 1; may require preparation and presentation of radiology materials for multidisciplinary conferences.

B. Teaching

Supervise or act as consultants to junior residents and medical students (PBLI).

C. Study materials

In addition to the materials listed for the first two rotations, more detailed technical references should be assigned, whether in books or supplemented by state of the art technical publications in radiology journals (MK).

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ADDENDUM

Knowledge-Based Objectives

Normal Anatomy.—

1. Name and define the three zones of the airways.
2. Define a secondary pulmonary lobule.

3. Define an acinus.
4. Name the lobar and segmental bronchi of both lungs.
5. Identify the following structures on the posteroanterior (PA) chest radiograph:
 - Lungs—right, left, right upper, middle and lower lobes, left upper (including lingula) and lower lobes
 - Fissures—minor, superior accessory, inferior accessory, azygos
 - Airway—trachea, carina, main bronchi
 - Heart—right atrium, left atrial appendage, left ventricle, location of the four cardiac valves
 - Pulmonary arteries—main, right, left, interlobar, truncus anterior
 - Aorta—ascending, arch, descending
 - Veins—superior vena cava, azygos, left superior intercostal (“aortic nipple”)
 - Bones—spine, ribs, clavicles, scapulae, humeri
 - Right paratracheal stripe
 - Junction lines—anterior, posterior
 - Aortopulmonary window
 - Azygoesophageal recess
 - Paraspinal lines
 - Left subclavian artery
6. Identify the following structures on the lateral chest radiograph:
 - Lungs—right, left, right upper, middle and lower lobes, left upper (including lingula) and lower lobes
 - Fissures—major, minor, superior accessory
 - Airway—trachea, upper lobe bronchi, posterior wall of bronchus intermedius
 - Heart—right ventricle, right ventricular outflow tract, left atrium, left ventricle, the location of the four cardiac valves
 - Pulmonary arteries—right, left
 - Aorta—ascending, arch, descending
 - Veins—superior vena cava, inferior vena cava, left brachiocephalic (innominate), pulmonary vein confluence
 - Bones—spine, ribs, scapulae, humeri, sternum
 - Retrosternal line
 - Posterior tracheal stripe
 - Right and left hemidiaphragms
 - Raider’s triangle
 - Brachiocephalic (innominate) artery

Signs in Thoracic Radiology.—

1. Define, identify and state the significance of the following on a radiograph:

- air bronchogram—indicates a parenchymal process, including nonobstructive atelectasis, as distinguished from pleural or mediastinal processes
- air crescent sign—indicates a lung cavity, often resulting from fungal infection or saprophytic colonization
- deep sulcus sign on a supine radiograph—indicates pneumothorax
- continuous diaphragm sign—indicates pneumomediastinum
- ring around the artery sign (air around pulmonary artery, particularly on lateral chest radiograph)—indicates pneumomediastinum
- fallen lung sign—indicates a fractured bronchus
- flat waist sign—indicates left lower lobe collapse
- gloved finger sign—indicates bronchial impaction, which can be seen in allergic bronchopulmonary aspergillosis
- Golden S sign—indicates lobar collapse caused by a central mass, suggesting an obstructing bronchogenic carcinoma in an adult
- luftsichel sign—indicates upper lobe collapse, suggesting an obstructing bronchogenic carcinoma in an adult
- Hampton's hump—pleural-based, wedge-shaped opacity indicating a pulmonary infarct
- silhouette sign—loss of the contour of the heart, aorta or diaphragm allowing localization of a parenchymal process (eg, a process involving the medial segment of the right middle lobe obscures the right heart border, a lingular process obscures the left heart border, a basilar segmental lower lobe process obscures the diaphragm)
- cervicothoracic sign—a mediastinal opacity that projects above the clavicles is retrotracheal and posteriorly situated, whereas an opacity effaced along its superior aspect and projecting at or below the clavicles is situated anteriorly
- tapered margins sign—a lesion in the chest wall, mediastinum or pleura may have smooth tapered borders and obtuse angles with the chest wall or mediastinum while parenchymal lesions usually form acute angles
- figure 3 sign—abnormal contour of the descending aorta, indicating coarctation of the aorta

- fat pad sign or sandwich sign—indicates pericardial effusion on lateral chest radiograph
- scimitar sign—an abnormal pulmonary vein in venolobar syndrome
- double density sign—opacity projecting over the right side of the heart, indicating enlargement of the left atrium
- hilum overlay sign and hilum convergence sign—used to distinguish a hilar mass from a non-hilar mass

2. Define, identify and state the significance of the following on a chest CT:

- CT angiogram sign—enhancing pulmonary vessels against a background of low attenuation material in the lung
- halo sign—suggesting invasive pulmonary aspergillosis in a leukemic patient
- split pleura sign—a sign of empyema and other inflammatory pleural processes

Interstitial Lung Disease.—

1. List and identify on a chest radiograph and chest CT four patterns (nodular, reticular, reticulonodular, and linear) of interstitial lung disease (ILD).
2. Make a specific diagnosis of ILD when supportive findings are present in the history or on radiologic imaging (eg, dilated esophagus and ILD in scleroderma, enlarged heart and a pacemaker or defibrillator in a patient with prior sternotomy and ILD secondary to amiodarone drug toxicity).
3. Identify Kerley A and B lines on a chest radiograph and explain their etiology.
4. Recognize the changes of congestive heart failure on a chest radiograph—enlarged cardiac silhouette, pleural effusions, vascular redistribution, interstitial or alveolar edema, Kerley lines, enlarged azygos vein, increased ratio of artery to bronchus diameter.
5. Define the terms “asbestos-related pleural disease” and “asbestosis”; identify each on a chest radiograph and chest CT.
6. Describe what a “B” reader is as related to the evaluation of pneumoconioses.
7. Identify honeycombing on a radiograph and chest CT, state the significance of this finding (end-stage lung disease), and list the common causes of honeycomb lung.
8. Describe the radiographic classification of sarcoidosis.

9. Recognize progressive massive fibrosis/conglomerate masses secondary to silicosis or coal worker's pneumoconiosis on radiography and chest CT.
10. Recognize the typical appearance and upper lobe predominant distribution of irregular lung cysts or nodules on chest CT of a patient with Langerhans cell histiocytosis.
11. List four causes of unilateral ILD.
12. List three causes of lower lobe predominant ILD.
13. List two causes of upper lobe predominant ILD.
14. Identify a secondary pulmonary lobule on CT.
15. Recognize findings of lymphangioleiomyomatosis on a chest radiograph and CT.
16. Identify and give appropriate differential diagnoses when the patterns of septal thickening, perilymphatic nodules, bronchiolar opacities ("tree-in-bud"), air trapping, cysts, and ground glass opacities are seen on CT.

Alveolar Lung Disease.—

1. List four broad categories of acute alveolar lung disease (ALD).
2. List five broad categories of chronic ALD.
3. Name three pulmonary-renal syndromes.
4. List five of the most common causes of acute respiratory distress syndrome.
5. Name four predisposing causes of cryptogenic organizing pneumonia.
6. Suggest a specific diagnosis of ALD when supportive findings are present in the history or on the chest radiograph (eg, broken femur and ALD in fat embolization syndrome, ALD and renal failure in a pulmonary-renal syndrome, ALD treated with bronchoalveolar lavage in alveolar proteinosis).
7. Recognize a pattern of peripheral ALD on radiography or chest CT and give an appropriate differential diagnosis, including a single most likely diagnosis when supported by associated radiologic findings or clinical information (eg, peripheral lung disease associated with paratracheal and bilateral hilar adenopathy in an asymptomatic patient with "alveolar" sarcoidosis, peripheral lung disease associated with a markedly elevated blood eosinophil count in a patient with eosinophilic pneumonia, peripheral opacities associated with multiple rib fractures and pneumothorax in a patient with acute thoracic trauma and pulmonary contusions).

Atelectasis, Airways, and Obstructive Lung Disease.—

1. Recognize partial or complete atelectasis of the following on a chest radiograph:
 - right upper lobe
 - right middle lobe
 - right lower lobe
 - right upper and middle lobe
 - right middle and lower lobe
 - left upper lobe
 - left lower lobe.
2. Recognize complete collapse of the right or left lung on a chest radiograph and list an appropriate differential diagnosis for the etiology of the collapse.
3. Distinguish lung collapse from massive pleural effusion on a frontal chest radiograph.
4. Name the four types of bronchiectasis and identify each type on a chest CT.
5. Name five common causes of bronchiectasis.
6. Recognize the typical appearance of cystic fibrosis on chest radiography and CT.
7. Name the important things to look for on a chest radiograph when the patient history is "asthma."
8. Define tracheomegaly.
9. Recognize tracheal and bronchial stenosis on chest CT and name the most common causes.
10. Name the three types of pulmonary emphysema and identify each type on a chest CT.
11. Recognize alpha-1-antitrypsin deficiency on a chest radiograph and CT.
12. Recognize Kartagener syndrome on a chest radiograph and name the three components of the syndrome.
13. Define the term *giant bulla*, differentiate giant bulla from pulmonary emphysema, and state the role of imaging in patient selection for bullectomy.
14. State the imaging findings used to identify surgical candidates for giant bullectomy and for lung volume reduction surgery.
15. Recognize and describe the significance of a pattern of mosaic lung attenuation on chest CT.

Mediastinal Masses and Mediastinal/Hilar Lymph Node Enlargement.—

1. State the anatomic boundaries of the anterior, middle, posterior, and superior mediastinum.
2. Name the four most common causes of an anterior mediastinal mass and localize a mass to the anterior mediastinum on a chest radiograph, CT, and MRI.

3. Name the three most common causes of a middle mediastinal mass and localize a mass in the middle mediastinum on a chest radiograph, CT, and MRI.
4. Name the most common cause of a posterior mediastinal mass and localize a mass in the posterior mediastinum on a chest radiograph, CT, and MRI.
5. Name two causes of a mass that straddles the thoracic inlet and localize a mass to the thoracic inlet on a chest radiograph, CT, and MRI.
6. Identify normal vessels or vascular abnormality on chest CT and chest MRI that may mimic a solid mass.
7. Name five etiologies of bilateral hilar lymph node enlargement.
8. State the three most common locations (Garland's triad) of thoracic lymph node enlargement in sarcoidosis.
9. List the four most common etiologies of "egg-shell" calcified lymph nodes in the thorax.
10. Recognize a cystic mass in the mediastinum and suggest the possible diagnosis of a bronchogenic, pericardial, thymic, or esophageal duplication cyst.
11. Recognize the findings of mediastinal fibrosis on chest CT.

Solitary and Multiple Pulmonary Nodules.—

1. Define the terms pulmonary nodule and pulmonary mass.
2. Name the three most common causes of a solitary pulmonary nodule.
3. Name four important considerations in the evaluation of a solitary pulmonary nodule.
4. Name six causes of cavitory pulmonary nodules.
5. Name four causes of multiple pulmonary nodules.
6. Describe the indications for percutaneous biopsy of a solitary pulmonary nodule.
7. Describe the indications for percutaneous biopsy when there are multiple pulmonary nodules.
8. Describe the complications and the frequency with which complications occur because of percutaneous lung biopsy using CT or fluoroscopic guidance.
9. Describe the indications for chest tube placement as a treatment for pneumothorax related to percutaneous lung biopsy.
10. Describe the role of positron emission tomography in the evaluation of a solitary pulmonary nodule.
11. Describe an appropriate imaging algorithm to evaluate a solitary pulmonary nodule.

Benign and Malignant Neoplasms of the Lung and Esophagus.—

1. Name the four major histologic types of bronchogenic carcinoma and state the difference between non-small-cell and small-cell lung cancer.
2. Name the type of non-small-cell lung cancer that most commonly cavitates.
3. Name the types of bronchogenic carcinoma that are usually central.
4. Describe the TNM classification for staging non-small-cell lung cancer, including the components of each stage (I, II, III, IV, and substages) and the definition of each component (T1-4, N0-3, M0-1).
5. Describe the staging of small-cell lung cancer.
6. Name the four most common extrathoracic sites of metastases for non-small-cell and small-cell lung cancer.
7. Name the stages of non-small-cell lung cancer are potentially resectable.
8. Recognize abnormal contralateral mediastinal shift on a postpneumonectomy chest radiograph and state five possible etiologies for the abnormal shift.
9. Name the most common thoracic locations for adenoid cystic carcinoma and carcinoid tumors to occur.
10. Suggest the possibility of radiation change as a cause of new apical opacification on a chest radiograph of a patient with evidence of mastectomy or axillary node dissection.
11. Describe the acute and chronic radiographic and CT appearances of radiation injury in the thorax (lung, pleura, pericardium, esophagus) and the temporal relationship to radiation therapy.
12. State the role of MRI in lung cancer staging (eg, chest wall invasion, superior sulcus, Pancoast tumor).
13. Describe the role of positron emission tomography in lung cancer staging.
14. Describe the TNM classification for staging esophageal carcinoma, including the components of each stage (I, II, III, IV) and the definition of each component (T, N, and M).
15. Describe the role of imaging in the staging of esophageal carcinoma.
16. Name the stages of esophageal carcinoma are potentially resectable.
17. Describe the classification of lymphoma, the role of imaging in the staging of lymphoma and the

typical and atypical imaging findings of thoracic lymphoma.

18. Define primary pulmonary lymphoma.
19. Describe the typical chest radiograph and chest CT appearances of Kaposi sarcoma.

Thoracic Trauma.—

1. Identify a widened mediastinum on a trauma radiograph and state the differential diagnosis (including aortic/arterial injury, venous injury, fracture of sternum or spine).
2. Identify and describe the indirect and direct signs of aortic injury on contrast-enhanced chest CT.
3. Identify and state the significance of chronic traumatic pseudoaneurysm of the aorta on a chest radiograph, CT, or MRI.
4. Identify fractured ribs, clavicle, spine, and scapula on a chest radiograph or CT.
5. Name five common causes of abnormal lung opacity on a trauma radiograph or CT.
6. Identify an abnormally positioned diaphragm or loss of definition of a diaphragm on a trauma chest radiograph and suggest the diagnosis of a ruptured diaphragm.
7. Recognize and describe the signs of diaphragmatic rupture on a chest CT.
8. Identify a pneumothorax, pneumopericardium, and pneumomediastinum on a trauma chest radiograph.
9. Identify the fallen lung sign on a chest radiograph or CT and suggest the diagnosis of tracheobronchial tear.
10. Identify a cavitary lesion on a posttrauma radiograph or chest CT and suggest the diagnosis of laceration with pneumatocele formation, hematoma or abscess secondary to aspiration.
11. Name the three most common causes of pneumomediastinum in the setting of trauma.
12. Recognize and distinguish between pulmonary contusion and laceration.

Chest Wall, Pleura, and Diaphragm.—

1. Recognize and name four causes of a large unilateral pleural effusion on a chest radiograph or CT.
2. Recognize a pneumothorax on an upright and supine chest radiograph.
3. Recognize a pleural based mass with bone destruc-

tion or infiltration of the chest wall on a chest radiograph or CT and name four likely causes.

4. Recognize pleural calcification on a chest radiograph or CT and suggest the diagnosis of asbestos exposure (bilateral involvement) or old tuberculosis or trauma (unilateral involvement).
5. Recognize the typical chest radiographic appearances of pleural effusion, given differences in patient positioning, and describe the role of the lateral decubitus view to evaluate pleural effusion.
6. Recognize apparent unilateral elevation of the diaphragm on a chest radiograph and suggest a specific etiology with supportive history and associated chest radiograph findings (eg, subdiaphragmatic abscess after abdominal surgery, diaphragm rupture after trauma, phrenic nerve involvement with lung cancer).
7. Recognize imaging findings suggesting a tension pneumothorax and understand the acute clinical implications.
8. Recognize diffuse pleural thickening, as seen in fibrothorax, malignant mesothelioma, and pleural metastases.
9. Describe and recognize the radiographic and CT findings of malignant mesothelioma.
10. Describe the difference in appearance of a pulmonary abscess and an empyema on chest CT and how the two are differently managed.
11. Distinguish pleural from intraperitoneal fluid on chest CT.

Infection and Immunity.—

1. Describe the radiographic manifestations of primary pulmonary tuberculosis.
2. Name the most common segmental sites of involvement for postprimary tuberculosis in the lung.
3. Define a Ghon lesion (calcified pulmonary parenchymal granuloma) and Ranke complex (calcified node and Ghon lesion); recognize both on a chest radiograph and CT and describe their significance.
4. Name and describe the types of pulmonary aspergillus disease.
5. Identify an intracavitary fungus ball on chest radiography and CT.
6. Describe the radiographic appearances of cytomegalovirus pneumonia.

7. Name the major categories of disease causing chest radiograph or CT abnormalities in the immunocompromised patient.
8. Other than bacterial infection, name two important infections and two important neoplasms to consider in patients with AIDS and chest radiograph or CT abnormalities.
9. Describe the chest radiograph and CT appearances of *Pneumocystis carinii* (*jiroveci*) pneumonia
10. Name the four most important etiologies of hilar and mediastinal lymphadenopathy in patients with AIDS.
11. Describe the time course and chest radiographic appearance of a blood transfusion reaction.
12. Describe the radiographic appearances of mycoplasma pneumonia.
13. Describe the chest radiographic and CT appearance of a miliary pattern and provide a differential diagnosis.
14. Name the diagnostic considerations in a patient who presents with recurrent or persistent pneumonias.
15. Name the endemic mycoses and the specific geographic regions where they are found, and describe their radiographic manifestations.
16. Name the most common pulmonary infections seen after solid-organ (ie, liver, renal, lung, cardiac) and bone marrow transplantation.
17. Describe the chest radiographic and CT findings of posttransplant lymphoproliferative disorders.

Unilateral Hyperlucent Hemithorax.—

1. Recognize a unilateral hyperlucent hemithorax on a chest radiograph or CT.
2. Identify the common causes for unilateral hyperlucent hemithorax on a chest radiograph.
3. Give an appropriate differential diagnosis when a hyperlucent hemithorax is seen on a chest radiograph, and suggest a specific diagnosis when certain associated findings are seen (ie, absence of a breast in a patient after mastectomy, absence of a pectoralis muscle in a patient with Poland syndrome, unilateral bullous disease/emphysema, or air trapping on expiration in a patient with Swyer-James syndrome or an endobronchial foreign body).

Congenital Lung Disease.—

1. Name the components of pulmonary venolobar syndrome.
2. Recognize venolobar syndrome on a frontal chest radiograph, chest CT, and chest MRI, and explain the etiology of the retrosternal band of opacity seen on the lateral radiograph.
3. Recognize a mass in the posterior segment of a lower lobe on a chest radiograph and CT and suggest the possible diagnosis of pulmonary sequestration.
4. Describe the differences between intralobar and extralobar sequestration.
5. Recognize bronchial atresia on a chest radiograph and CT and name the most common lobes in which it occurs.

Pulmonary Vasculature.—

1. Recognize enlarged pulmonary arteries on a chest radiograph and distinguish them from enlarged hilar lymph nodes.
2. Recognize enlargement of the central pulmonary arteries with diminution of the peripheral pulmonary arteries on a chest radiograph and suggest the diagnosis of pulmonary arterial hypertension.
3. Name five common causes of pulmonary arterial hypertension.
4. Recognize lobar and segmental pulmonary emboli on chest CT and chest MRI (including magnetic resonance angiography).
5. Define the role of ventilation-perfusion scintigraphy, chest CT, chest MRI/MRA, CT venography, and lower extremity venous ultrasound studies in the evaluation of a patient with suspected venous thromboembolic disease, including the advantages and limitations of each modality depending on patient presentation.
6. Describe the anatomy of and identify the right and left superior and inferior pulmonary veins on chest CT and MRI and the use of radiofrequency ablation of pulmonary veins for treatment of atrial fibrillation.
7. Recognize variations in pulmonary venous anatomy, such as a separate right middle lobe vein and common ostium of the left superior and inferior pulmonary veins.

Thoracic Aorta and Great Vessels.—

1. State the normal dimensions of the thoracic aorta.
2. Describe the classifications of aortic dissection (DeBakey I, II, III; Stanford A, B) and implications for classification on medical versus surgical management.
3. Describe and recognize the findings of, and distinguish between each of the following on CT and MR:
 - aortic aneurysm
 - aortic dissection
 - aortic intramural hematoma
 - penetrating atherosclerotic ulcer
 - ulcerated plaque
 - ruptured aortic aneurysm
 - sinus of Valsalva aneurysm
 - subclavian or brachiocephalic artery aneurysm
 - aortic coarctation
 - aortic pseudocoarctation
 - pulsation artifact at aortic root
4. Recognize a right aortic arch and a double aortic arch on a chest radiograph, chest CT, and chest MRI.
5. State the significance of a right aortic arch with mirror image branching versus with an aberrant subclavian artery.
6. Recognize a cervical aortic arch on a chest radiograph and CT.
7. Recognize an aberrant subclavian artery on chest CT.
8. Recognize normal variants of aortic arch branching, including common origin of brachiocephalic and left common carotid arteries ("bovine arch"), and separate origin of vertebral artery from arch on CT and MRI/MRA.
9. Define the terms *aneurysm* and *pseudoaneurysm*.
10. Describe the cardiac anomalies commonly associated with aortic coarctation.
11. Describe and identify the findings of Takayasu arteritis on chest CT and chest MRI.
12. Describe the advantages and disadvantages of CT, MRI/MRA, and transesophageal echocardiography in the evaluation of the thoracic aorta.

Ischemic Heart Disease.—

1. Describe the anatomy of the coronary arteries and identify the following on a coronary arteriogram, MRI, and CT:
 - right coronary artery
 - left main coronary artery

- left anterior descending coronary artery
 - left circumflex coronary artery
 - obtuse marginal
 - diagonals
 - acute marginals
 - septal perforators
2. Describe the clinical significance of coronary arterial calcification on a chest radiograph.
 3. Recognize coronary arterial calcification on CT and describe the current role of coronary artery calcium scoring with helical or electron beam CT.
 4. Name the coronary artery that is usually diseased when there is papillary muscle dysfunction.
 5. Describe the common acute complications of myocardial infarction, including left ventricular failure, myocardial rupture, and papillary muscle rupture, and recognize radiologic findings indicating each.
 6. Describe the common late complications of myocardial infarction, including ischemic cardiomyopathy, left ventricular aneurysm, left ventricular pseudoaneurysm, coronary-cameral fistula, dyskinesia, and akinesis, and recognize radiologic findings indicating each.
 7. Identify signs of left heart failure on a chest radiograph and CT.
 8. Define ejection fraction, including the normal value for left ventricular ejection fraction.
 9. Identify myocardial calcification on CT and describe the etiology and significance of this finding.
 10. Describe the difference between a left ventricular aneurysm and pseudoaneurysm.
 11. Define and identify myocardial bridging on CT.
 12. Define the role of angiography, echocardiography, stress perfusion scintigraphy, chest CT, and chest MRI in the evaluation of a patient with suspected ischemic heart disease as well as stunned myocardium and hibernating myocardium versus areas of infarction, including the advantages and limitations of each modality.
 13. Differentiate viable from nonviable myocardium on MRI.
 14. Identify myocardial perfusion defects on MRI.
 15. Calculate right and left ventricular volumes, including ejection fraction, stroke volume, end-diastolic volume, and end-systolic volume using MRI and CT.

Myocardial Disease.—

1. Define the types of cardiomyopathy (dilated, hypertrophic, restrictive) and list the common causes of each.
2. Define right ventricular dysplasia, describe the role of MRI in its diagnosis, and identify MRI findings that support the diagnosis.
3. Name the most common benign primary cardiac tumors, including myxoma, lipoma, fibroma, and rhabdomyoma.
4. Name the most common malignant primary cardiac tumors, including angiosarcoma, rhabdomyosarcoma, and lymphoma.
5. Distinguish cardiac tumor from thrombus on CT and MRI.
6. Name the most common malignancies to metastasize to the heart, and describe the appearance on a chest radiograph, chest CT and chest MR
7. Describe the advantages and disadvantages of echocardiography, CT, and MRI for evaluation of cardiomyopathy and cardiac tumors.
8. Recognize calcification of papillary muscles as distinct from myocardial calcifications and describe the significance of each.

Cardiac Valvular Disease.—

1. Identify and describe the findings of each on a chest radiograph:
 - enlarged right atrium
 - enlarged left atrium
 - enlarged right ventricle
 - enlarged left ventricle
2. Describe and recognize the chest radiograph findings associated with each of the following valvular diseases:
 - mitral regurgitation
 - mitral stenosis
 - aortic regurgitation
 - aortic stenosis
 - tricuspid regurgitation
3. Recognize an enlarged ascending aorta and aortic valve calcification on a chest radiograph and suggest the diagnosis of aortic stenosis when these findings are present.
4. Recognize an enlarged left atrium, vascular redistribution, and mitral valve calcification on a chest radiograph and suggest the diagnosis of mitral stenosis when these findings are present.

5. State the most common etiologies of the following:
 - aortic stenosis
 - aortic regurgitation
 - mitral stenosis
 - mitral regurgitation
 - tricuspid regurgitation
 - pulmonary stenosis
6. Name the cardiac diseases associated with mitral annulus calcification
7. Identify endocarditis or complications of endocarditis on a chest radiograph, CT, and MRI.
8. Describe the advantages and disadvantages of echocardiography and MRI for evaluation of valvular heart disease.
9. Describe the pulse sequences and appropriate planes for evaluating cardiac valvular disease and making quantitative measurements including pressure gradients, regurgitant fractions, and valve areas.

Pericardial Disease.—

1. Recognize pericardial calcification on a chest radiograph and CT and name the most common causes.
2. Describe and identify two chest radiographic signs of a pericardial effusion.
3. Name five causes of a pericardial effusion.
4. Describe and recognize the findings of each of the following on a chest radiograph, CT, and MR:
 - pericardial cyst
 - constrictive pericarditis
 - pericardial hematoma
 - pericardial metastases
 - partial and complete absence of the pericardium
 - pneumopericardium
5. Describe the role of MRI in diagnosing constrictive pericarditis and differentiating constrictive pericarditis from restrictive cardiomyopathy.

Congenital Heart Disease in the Adult.—

1. Recognize increased vascularity and decreased vascularity on a chest radiograph and name the common causes of each.
2. Describe and recognize the following on a chest radiograph, CT, or MRI.

Heart disease presenting during adulthood:

- Left-to-right shunts and Eisenmenger physiology
- Atrial septal defect

- Ventricular septal defect
- Partial anomalous pulmonary venous connection
- Patent ductus arteriosus
- Coarctation of the aorta
- Tetralogy of Fallot and pulmonary atresia with ventricular septal defect
- Congenitally corrected transposition of the great arteries
- Persistent left superior vena cava
- Truncus arteriosus
- Ebstein anomaly
- Cardiac malposition, including abnormal situs
- Coronary artery anomalies

Heart disease originally treated in childhood:

- Coarctation of the aorta
 - Tetralogy of Fallot and pulmonary atresia with ventricular septal defect
 - Complete transposition of the great arteries
 - Congenitally corrected transposition of the great arteries
 - Truncus arteriosus
 - Commonly performed surgical corrections for congenital heart disease
3. Define the role of angiography, echocardiography, chest CT, and chest MRI in the evaluation of an adult patient with congenital heart disease, including the advantages and limitations of each modality depending on patient presentation.

Monitoring and support devices—"tubes and lines".—

1. Describe and identify on chest radiography the normal appearance and complications associated with each of the following:
- endotracheal tube
 - central venous catheter
 - peripherally inserted central venous catheter

- pulmonary artery catheter
 - feeding tube
 - nasogastric tube
 - chest tube
 - intra-aortic balloon pump
 - pacemaker generator and leads (including triple lead devices)
 - automatic implantable cardiac defibrillator
 - left ventricular assist device
 - atrial septal defect closure device
 - pericardial drain
 - extracorporeal life support cannulae
 - intraesophageal manometer, temperature probe or pH probe
 - tracheal, bronchial or esophageal stent
2. Explain how an intra-aortic balloon pump works.
3. Describe the venous anatomy and expected course of veins from the axillary vein to the right atrium relative to anatomic landmarks.
4. Recognize the difference between a skinfold and pneumothorax on a portable chest radiograph.

Postoperative thorax.—

1. Identify normal postoperative findings and complications of the following procedures on chest radiography, CT, and MRI:
- wedge resection, lobectomy, pneumonectomy
 - coronary artery bypass graft surgery
 - cardiac valve replacement
 - aortic graft
 - aortic stent
 - transhiatal esophagectomy
 - lung transplantation
 - heart transplantation
 - lung volume reduction surgery.