A Curriculum in Cardiothoracic Radiology for Medical Students, with Goals and Objectives[1]

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The Liaison Committee on Medical Education is the accrediting body for medical education programs leading to the MD degree in the United States and Canada. According to the Committee's accreditation standards (1), "The curriculum must provide grounding in the body of knowledge represented in the disciplines that support the fundamental clinical subjects, for example, diagnostic imaging and clinical pathology."

In a survey of 119 directors of medical student education in radiology, 46 (39%) responded to questions regarding the teaching of radiology to medical students at their institution (2). A core radiology clerkship was required at 13 (29%) of 46 schools responding and was an elective at 33 (72%) (2). The number of schools with a required radiology clerkship has not changed since 1994 (3). The clerkship is given in the 3rd year at 12 (26%) of 46 schools, in the 4th year at 20 (44%), and in either the 3rd or 4th year at 14 (30%) (2). Twenty-six (57%) of 46 programs have computers in the department that students use during the course, usually shared with residents. Reported simultaneously with these survey results were results from a second survey of directors of medical student education, in which 69 (50%) of 139 responded (2). Six (9%) of 69 responding programs directed the medical school's gross anatomy course, and 14 (20%) taught some portion of the course.

A telephone survey (4) showed that a formal dedicated radiology clerkship was a graduation requirement in only five of the 16 top-ranked medical schools in a *U.S. News & World Report* ranking (Cornell, Duke, Harvard, University of California at San Francisco, and University of California at Los Angeles) (5). In contrast, a survey of 322 nonradiologist physicians showed that 87% believed formal radiology instruction should be mandatory (6).

Radiology can be taught to medical students through an integrated curriculum, an independent curriculum, or a combination of the two. In an integrated curriculum, radiology faculty provide radiology instruction to medical students rotating through a nonradiology course or a course that is jointly sponsored by radiology and nonradiology departments. For example, radiologists teach projectional and cross-sectional imaging to medical students enrolled in a gross anatomy course. Radiologists may give a series of imaging lectures related to topics covered in a required medicine clerkship. Collaboration can occur when radiology faculty participate in required introductory courses that expose students early in medical school to physical examination techniques, history taking, and writing patient notes. These courses have various titles, such as "Introduction to Clinical Medicine" or "Patient, Doctor, and Society." Radiology faculty can provide correlative imaging instruction in most required courses.

The Alliance of Medical Student Educators in Radiology is a group associated with the Association of University Radiologists whose purpose is to promote radiology as an essential component of the medical student curricu-

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lum (*http://taur.org/amser/*). The benefits of having a radiology clerkship as an independent course in medical school include autonomy in curriculum design and implementation, a focused period of time to teach radiology, and ease in quantifying the efforts of radiology faculty in teaching medical students.

Traditionally, radiology has been taught to medical students during a 2–4-week clerkship, sometimes required but more often elective. Students are taught through didactic lectures, participation at the viewing station, and self-study of reading material, slide-tape programs, and, more recently, electronic teaching materials. Problem-based, interactive, small-group learning is employed as a method of teaching at many medical schools. Radiology is well suited to this type of teaching.

The curriculum outlined in this document describes suggested content for medical student instruction in cardiothoracic radiology and is meant to be one component of an overall radiology curriculum for medical students. Eight goals, each with related objectives, have been identified as important content for students to master by the end of 4 years of medical school. The curriculum, organized according to these goals and objectives, follows a format similar to that of the Society of Thoracic Radiology curriculum in chest radiology for diagnostic radiology residents (7) (*http://www.thoracicrad.org/str99/rescurr/index.htm*). It can be implemented in both integrated and independent programs and modified to meet institutional needs, depending on specific curriculum requirements and available resources.

Goal I:

Understand the basic principles in producing radiologic images of the heart, lungs, mediastinum, pleura, and chest wall

Objectives:

A. Identify cardiothoracic examinations with (chest radiography, computed tomography [CT], nuclear medicine ventilation-perfusion studies) and without (magnetic resonance [MR] imaging, ultrasound) exposure to ionizing radiation
B. Describe patient positioning for anteroposterior supine, posteroanterior upright, apical lordotic, lateral, and decubitus chest radiography
C. State the result of giving intravenous contrast material before a chest CT scan (eg, enhancement of vascular structures), indications for administration of intravenous contrast material, contraindications (eg, elevated creatinine level, previous allergy to-contrast material), and potential complications (eg, spectrum of reactions to contrast material, kidney failure, extravasation)
D. State the approximate costs and charges for one-view chest radiography, two-view chest radiography, chest CT with or without intravenous contrast material, chest MR imaging or MR angiographic study, and ventilation-perfusion study

Goal II:

Understand cardiothoracic anatomy as shown on chest radiographs and chest CT scans

Objectives:

A. Identify the following anatomic structures on a posteroanterior chest radiograph, with at least 75% accuracy
    1. Lung lobes: right upper, left upper, right middle, right lower, left lower
    2. Fissures: right minor
    3. Trachea and carina
    4. Heart: right atrial, left atrial, and left ventricular margins
    5. Pulmonary arteries: main, right, left, interlobar, left lower lobe, right lower lobe
    6. Aorta: ascending, transverse, and descending portions
    7. Veins: superior vena cava and azygos
    8. Bones: spine, ribs, clavicles, scapulae, humeri, manubrium
    9. Aortopulmonary window
    10. Lateral costophrenic angles
B. Identify the following anatomic structures on a lateral chest radiograph, with at least 75% accuracy
    1. Lung lobes: right upper, left upper, right middle, left lower, right lower
    2. Fissures: right major, left major, right minor
    3. Trachea, left upper lobe bronchus
    4. Heart: right ventricular, left atrial, left ventricular margins
    5. Pulmonary arteries: right and left
    6. Aorta: ascending, transverse, and descending portions
    7. Veins: superior and inferior venae cavae
    8. Bones: spine, ribs, scapulae, sternum
    9. Right and left hemidiaphragms
    10. Retrosternal clear space
    11. Posterior costophrenic angles

C. Identify the following structures on chest CT studies, with at least 75% accuracy
   1. Lung lobes: right upper lobe, left upper lobe, right middle lobe, lingula, right lower lobe, left lower lobe
   2. Pleura
   3. Airway: trachea, carina, right main bronchus, left main bronchus
   4. Heart: right ventricle, left ventricle, right atrium, left atrium
   5. Pericardium
   6. Aorta: ascending, transverse, and descending portions
   7. Pulmonary arteries: main, right, interlobar, left lower lobe, right lower lobe
   8. Arteries: right brachiocephalic (innominate), left common carotid, left subclavian
   9. Veins: right brachiocephalic, left brachiocephalic, superior vena cava, inferior vena cava, azygos
   10. Bones: ribs, clavicles, scapulae, sternum
   11. Esophagus
   12. Thymus
   13. Thyroid
   14. Muscles: pectoralis major and minor
   15. Aortopulmonary window
   16. Fissures: right major, left major, right minor
   17. Diaphragm

Goal III:

Become familiar with the interpretation of cardiothoracic imaging studies

Objectives:

A. Demonstrate learning of the following objectives, with at least 75% accuracy
   1. Identify a pneumothorax on an upright chest radiograph and list several causes for this condition
   2. Identify a pneumothorax on a supine chest radiograph and state why the location may be different than on an upright chest radiograph
   3. Identify pneumomediastinum on a chest radiograph and list several causes for this condition
   4. Identify and list several possible causes of collapse of the following as seen on a chest radiograph: right lung, left lung, right upper lobe, right lower lobe, left upper lobe, left lower lobe
   5. Identify lobar consolidation on a chest radiograph and CT scan and list several possible causes for this condition
   6. Differentiate complete opacification of a hemithorax as either pleural effusion, lung collapse, or lung consolidation or mass based on the position of the mediastinum
   7. Describe the different appearances of pleural effusion on a chest radiograph, given differences in patient positioning
   8. Recognize the development of an enlarging pleural fluid collection on a chest radiograph of a patient with pneumonia and suggest the diagnosis of empyema and role of chest CT scanning
   9. Identify the findings of left heart failure on a chest radiograph (eg, enlarged cardiac silhouette, redistribution of vascular flow, enlarged vascular pedicle, Kerley lines, interstitial or alveolar opacities, and pleural effusions)
   10. Define, identify, and describe the importance of the silhouette sign on a chest radiograph
   11. Identify a malpositioned chest tube, feeding or nasogastric tube, endotracheal tube, pacemaker leads, pulmonary artery catheter, and central venous catheter on a chest radiograph and state the desired location for each
   12. Identify a widened mediastinum on a frontal chest radiograph and suggest the diagnosis of aortic injury in a patient with trauma or aortic dissection in a patient with acute onset of back or chest pain in the absence of trauma
   13. Identify pulmonary emphysema on a chest radiograph when the findings of hyperinflation, flattened diaphragms, increased retrosternal clear space, and bullae are present
   14. Differentiate lung masses from mediastinal masses on a chest radiograph; state whether a mediastinal mass is in the anterior, middle, or posterior mediastinal compartment; and list an appropriate differential diagnosis for a mediastinal mass in each compartment
   15. Identify a cavitary mass on a chest radiograph and CT scan and suggest the diagnoses of mycobacterial, fungal, and neoplastic disease
   16. Identify an enlarged aorta on a chest radiograph, CT scan, MR image, and/or MR angiogram and list potential causes (eg, aneurysm, dissection, aortic valve stenosis)

17. Identify enlargement of the cardiac silhouette on a frontal chest radiograph and list potential causes (including causes of cardiomegaly and pericardial effusion)
18. Identify a calcified granuloma on a chest radiograph and CT scan and state its clinical importance
19. Identify clots within the central pulmonary arteries on a chest CT scan

B. Define the following terms used in describing cardiopulmonary findings on a chest radiograph and/or CT scan: opacity, lucency, consolidation, atelectasis, nodule, mass, attenuation, enhancement
C. Define high-, intermediate-, and low-probability criteria for acute pulmonary embolism diagnoses based on ventilation-perfusion scans
D. State the importance of having prior cardiopulmonary studies for comparison (eg, differentiate acute from chronic pulmonary processes, evaluate for resolution of cardiopulmonary abnormalities, assess for benignity or malignancy based on chronicity of findings)

Goal IV:
Understand the role of the cardiothoracic radiologist
Objectives:

A. List 10 or more persons who commonly consult with a cardiothoracic radiologist, including pulmonologists, family practitioners, internists, cardiothoracic surgeons, cardiologists, radiation oncologists, residents from different specialties, medical students, patients, pathologists, and other radiologists
B. List the types of circumstances leading to consultation with a cardiothoracic radiologist
C. List the interventional procedures often performed by cardiothoracic radiologists (eg, percutaneous lung biopsies, placement of chest tubes, and pleural fluid drainage)
D. List the types of interdisciplinary conferences in which cardiothoracic radiologists participate (eg, cardiothoracic surgery conference, pulmonary medicine conference, lung cancer or tumor conference, intensive care unit conference, lung transplant conference) and explain the role of the cardiothoracic radiologist
E. Demonstrate how to access patient information needed in the interpretation of cardiothoracic imaging studies
F. Describe the role of CT scanning in the staging of bronchogenic carcinoma
G. Define the role of ventilation-perfusion scintigraphy, chest CT, chest MR imaging or MR angiography, and lower-extremity venous studies in the evaluation of a patient with suspected thromboembolic disease and state the advantages and limitations of each modality
H. Define the role of angiography, echocardiography, stress perfusion scintigraphy, chest CT, and chest MR imaging in the evaluation of a patient with suspected ischemic heart disease and state the advantages and limitations of each modality

Goal V:
Understand the role of quality assurance and quality improvement in cardiothoracic radiology
Objectives:

A. Identify upright and supine chest radiographs as suboptimal for interpretation in the following situations
   1. Low lung volumes
   2. External objects obscuring the lungs and mediastinum
   3. Portions of the lungs not included on the film
   4. Underexposure or overexposure
B. Taking into account medicolegal and patient care considerations, state an appropriate history for ordering a cardiothoracic imaging study (eg, state signs and symptoms related to the appropriate body part, known diagnoses, and abnormal laboratory values; avoid histories that begin with “rule out” or “suspected”)

Goal VI:
Understand and apply appropriateness criteria in making decisions about cardiothoracic imaging
Objectives:

A. State the initial imaging examination of choice for the following clinical conditions
   1. Shortness of breath, suspected cardiac origin (chest radiography)
   2. Fever, cough, and elevated white blood cell count (chest radiography)
   3. Suspected bronchiectasis (chest CT)
   4. Pulmonary nodule seen on a chest radiograph (chest CT)
   5. Staging of bronchogenic carcinoma seen on a chest radiograph (chest CT)

6. Chest radiograph opacity that does not clear after 2 months of treatment for pneumonia (chest CT)
7. Suspected pulmonary embolism (chest radiography)
8. Blunt trauma, suspected thoracic aortic injury (chest radiography)
9. Hemoptysis (chest radiography)
10. Possible pneumothorax related to rib fracture (chest radiography)
11. Dyspnea in a patient aged 40 years or older (chest radiography)
12. Acute asthma, suspected pneumonia or pneumothorax (chest radiography)
13. Acute exacerbation of chronic obstructive pulmonary disease (chest radiography)
14. Negative, equivocal, or nonspecific chest radiograph in a patient positive for human immunodeficiency virus with acute respiratory illness (chest CT)
15. Diffuse opacities on chest radiograph in a human immunodeficiency virus–positive patient with acute respiratory illness (low indication for imaging)
16. Screening for pulmonary metastases from bone and soft-tissue sarcoma, renal cell carcinoma, testicular cancer, malignant melanoma, and head and neck carcinoma (both chest radiograph and chest CT)
17. Acute chest pain (chest radiography)
18. Suspected interstitial lung disease on chest radiograph (chest CT)

B. State the indications for obtaining daily chest radiographs in the intensive care unit (eg, clinical deterioration, mechanical ventilation)

C. State conditions that do *not* require daily chest radiographs in the intensive care unit (eg, routine follow-up for placement of central venous catheters, pulmonary artery catheters, nasogastric tubes, or chest tubes; patients in stable condition)

Goal VII:

Integrate clinical history, imaging findings, and pathology

Objectives:

A. Given the appropriate cardiothoracic images, pathologic information, and specific diagnosis, prepare a concise presentation integrating history, imaging findings, differential diagnosis, pathologic correlation, and the reasons for choosing particular imaging studies

B. Given a clinical scenario of cardiothoracic signs and symptoms, choose the appropriate cardiothoracic imaging study for further work-up

C. Given a clinical scenario of cardiothoracic signs and symptoms and initial imaging studies, discuss the likely diagnoses and appropriate imaging, medical, or surgical management for the following conditions

1. Acute chest pain from acute pulmonary embolism
2. Acute chest pain from acute myocardial infarction
3. Acute chest pain from aortic dissection
4. Acute respiratory failure due to adult respiratory distress syndrome
5. Fever in an immunocompromised host
6. Fever in an immunocompetent host
7. Cavitary nodule on a chest radiograph
8. Pulmonary nodule on a chest radiograph
9. Pleural effusion on a chest radiograph
10. Mediastinal mass on a chest radiograph

Goal VIII:

Become familiar with cardiothoracic radiology as a career

Objectives:

A. Describe the pathway to becoming a cardiothoracic radiologist (eg, medical school, internship, 4-year radiology residency, and 1-year cardiothoracic imaging fellowship)

B. Describe the current job market in cardiothoracic radiology

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