Society of Thoracic Radiology Thoracic and Cardiothoracic Imaging Fellowship Core Curriculum

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Thoracic and Cardiac Imaging Fellows are trained and mentored in the 6 general competencies put forward by the ACGME. Throughout this document, the following abbreviations for the specific competencies are used:

Patient care and Procedural Skills (PC)
Medical knowledge (MK)
Interpersonal/communication skills (ICS)
Practice-based learning and improvement (PBLI)
Professionalism (P)
Systems-based practice (SBP)

CORE CURRICULUM OBJECTIVE

The objective of this document is to establish guidelines for fellowship training in thoracic and cardiothoracic imaging for use by program directors, faculty, fellows and accrediting bodies. The goal is to provide fellowship guidelines which result in excellence in patient care (**P**), research(**MK, PBLI**), education (**PBLI, MK**), and lifelong learning (**MK, PBLI**).

GOAL OF FELLOWSHIP TRAINING

The ultimate goal of a fellowship program in thoracic or cardiothoracic imaging is for fellow graduates to acquire the knowledge and skills to become outstanding thoracic or cardiothoracic radiologists.

GENERAL ASPECTS OF TRAINING

PREREQUISITES FOR TRAINING

Prerequisites for fellowship training include completion of a four-year residency program in Diagnostic Radiology at an institution accredited by the Accreditation Council for Graduate Medical Education (ACGME) and completion of the United States Medical Licensing Examination (USMLE) (or their respective international or non-US equivalents). Fellowship candidates would preferably be in the process of preparing for certification by the American Board of Radiology (ABR).

TRAINING INSTITUTION

Training should occur at established academic medical centers. Ideally, the training institution would also include service lines in pathology, medical oncology, radiation oncology, pulmonary medicine, critical care medicine, emergency medicine, trauma care medicine, thoracic surgery, cardiology, and cardiac surgery, providing the subspecialty support and case material to train the fellow in a wide variety of cardiothoracic diseases. The patient volume in each of these service lines should provide adequate exposure to the range of diseases encountered in the practice of cardiothoracic imaging in the inpatient and outpatient setting.

The institution should have modern facilities and imaging equipment needed to accomplish the overall goals of the educational program. For programs training thoracic fellows only, this would ideally include picture archiving and communication system (PACS), computed radiography (CR) and digital radiography (DR), chest fluoroscopy, thoracic computed tomography (CT), thoracic magnetic resonance imaging (MR), thoracic intervention, and positron emission tomography (PET) imaging capabilities. For programs training fellows in both thoracic and cardiac imaging, this would also include cardiac CT and cardiac MR imaging capabilities.

The training institution should also have a library with online capabilities to access the medical literature. An Institutional Review Board should be available to review and approve research projects within the institution. The availability of an electronic medical record would be useful to access patient information and to facilitate medical records research.

DURATION OF TRAINING

In general, a full thoracic or cardiothoracic imaging training program is at least 12 months in duration. For thoracic-only fellowships, training would consist of thoracic imaging and non thoracic imaging electives (if granted). For cardiothoracic programs, training is divided between cardiac imaging, thoracic imaging and elective time (if granted).

PROGRAM FACULTY

Program Director

A single training director should be responsible for the training program. She or he should be board certified by the American Board of Radiology (ABR) and have completed a thoracic or cardiac imaging fellowship (or possess the equivalent experience and qualifications). She or he should also have served as an active faculty member in the subspecialty. The program director will coordinate and direct fellow training.

Faculty

In addition to the program director, the program should have faculty members with subspecialty training and/or equivalent experience in thoracic imaging. For cardiothoracic fellowship programs, faculty members would also be on staff with subspecialty training or equivalent experience in cardiac imaging. Ideally the faculty members would have completed subspecialty fellowships in cardiac, thoracic or cardiothoracic fellowships (or possess the equivalent experience). Faculty members should be clinically active in the specialty and active in their own individual continuing medical education. Ideally, faculty would also have interest and experience in scholarly activity and publications. Faculty members should be available to mentor fellow participation in professional societies, research/scholarly activities, and presentations at national meetings.

PROGRAM CONTENT

Cardiothoracic imaging fellowships should provide the environment for acquiring the knowledge (**MK**), interpretive skills (**MK**), procedural skills (PC), clinical judgment (**MK**), and professionalism (**P**) essential to the practice of cardiothoracic imaging. The program should also emphasize the role of the cardiopulmonary imager as consultant (**PC**) and the need to communicate effectively with referring physicians (**ICS**). Additionally, fellows should increase their knowledge, teaching skills and skills in conducting research (**MK, ICS, PBLI**).

Clinical Experience

Imaging Modalities

Trainees should be exposed to a volume and variety of cases to gain familiarity with the cardiac and thoracic diseases encountered in clinical practice (**MK, PC, PBLI, SBP**). This should include training in chest radiograph interpretation including outpatient chest radiography, inpatient chest radiography and critical care portable chest radiography. There should be exposure to chest fluoroscopy for the evaluation of the diaphragm. There should be a sufficient volume of thoracic computed tomography (CT) including routine chest CT, high resolution chest CT, pulmonary CT angiography (CTA), aortic CTA and thoracic PET/CT. There should be opportunities for training in thoracic magnetic resonance imaging (MRI) including mediastinal MR, MR evaluation of the pleura, and chest wall MR for lung cancer staging.

For cardiothoracic programs, there should also be sufficient volume of cardiac CT and cardiac MRI to meet training goals. Exposure to 3D reconstruction methods and interpretation is also recommended.

Intervention

Fellows should also have the opportunity to train in interventional thoracic procedures, especially if their career goals include thoracic intervention. This may be in the Division of Thoracic Imaging or through participation in a separate Interventional Division. These interventional procedures include thoracic biopsy, thoracic radiofrequency ablation, thoracic microwave ablation, cryoablation, thermal ablation, and pleural drainage procedures. Fellows should learn all aspects of thoracic intervention including:

1. The indications for thoracic procedures, procedural risks, benefits and alternatives to the procedure (**MK**).
2. Patient selection, appropriate use of pertinent pre-procedural tests, and the relative/absolute contraindications of each procedure (**PC, MK**).
3. How to effectively obtain informed consent and adhere to institutional universal "time out" procedural protocols (**ICS, MK, SBP**).
4. How to monitor sedation/analgesia, plan an appropriate biopsy approach, recognize pertinent anatomic landmarks, appropriately execute the biopsy, appropriately obtain samples (cytology, core biopsy and microbiology specimens), and recognize intra procedural complications (**PC, MK**).
5. The methods of post-procedure patient recovery, recognition and treatment of biopsy complications (including chest tube placement and management of hemoptysis) (**PC, MK**).
6. How to effectively communicate with patients and provide appropriate follow up and discharge instructions (**ICS, MK**).
7. The long term management of pleural drainage procedures (**PC, MK**).

Consultative Skills

In addition to interpretive and procedural skills, fellows should learn to be expert consultants in thoracic and cardiac imaging (for cardiothoracic programs) (**MK, PC, ICS, P**). Fellows should learn to perform imaging consultations with primary care physicians and subspecialists with increasing independence through the fellowship year. The fellow should learn to become the leader of the health care team with respect to the thoracic or cardiac imaging of the patient.

Academic and Nonclinical Activities

Conferences

Care of patients with cardiothoracic diseases often requires a multidisciplinary approach. Fellows should actively participate in multidisciplinary conferences, working with members of other specialties and leading the imaging discussion of the patient (**ICS, MK, PC**). The types of conferences may include pulmonary medicine, pathology, medical oncology, thoracic surgery, cardiology, and cardiac surgery conferences.

Teaching Experience

Trainees should also develop teaching skills during fellowship. Activities may include teaching of medical students, residents, nurses, and members of other medical or surgical disciplines (**ICS, MK**). Teaching may occur during case readout, case review sessions, seminars, teaching conferences, and prepared lectures. Fellows should be encouraged to organize and present one or more relevant lectures during their fellowship year (**ICS**).

Fellows should also strive to collect teaching cases throughout the fellowship year. These cases will be invaluable teaching material for future medical students, residents, and fellows in training. The process of collecting case material also serves as an excellent way to learn cardiothoracic imaging (**MK**).

For fellows accepting post fellowship teaching positions, mentorship on how to develop a resident curriculum, teaching material and organization of a cardiothoracic teaching section would be beneficial (**PBLI**).

Research Experience

Opportunities for scholarly activity mentored by fellowship faculty should be available to fellows in training (**MK, PBLI**). Such scholarly activity may include educational exhibits, clinical communications, reviews, book chapters, and original research. Fellows should be encouraged to participate in original research projects that involve data collection, statistical analysis, and interpretation of results. This work would optimally progress to authorship of a manuscript, presentation at a national meeting, and submission to a peer reviewed journal. This process will allow the fellow to learn the methods of scientific investigation and gain the skills necessary to prepare a scientific manuscript. Formal review of fellow scholarly activity at regular intervals is recommended to ensure progress toward completion of the research prior to the end of fellowship.

Journal Review

Fellows should have access to the current literature through electronic journals, and fellows should be encouraged to keep abreast of the current literature in the major journals. A journal club may be considered as a means to review the scientific methods, results, and significance of selected publications (**MK, PBLI**).

Lecture/Presentation Experience

Developing communications skills through formal lectures and oral presentations is important for fellows in training. Oral presentation of fellow scholarly activity at national meetings should be encouraged. Learning to present research and educational material in poster and exhibit form is also of educational value (**ICS, MK**).

Quality Assurance (QA)/Practice Related Issues

To gain exposure to the practical issues of radiology health care delivery, fellows may be encouraged to participate in one quality improvement project during their fellowship year (**SBP**). Together with the Fellowship Director or designated faculty mentor, the fellow may investigate one QA project to be completed prior to the end of the fellowship year[1].

EVALUATION OF TRAINEES

Formal written evaluation of fellow progress and final competence is important for training program documentation, future credentialing and certification. Training programs should have methods of evaluating fellow competence, written records detailing the progress of fellows, and a method of providing verbal and written feedback to fellows (**PBLI**).

General competencies should be evaluated such as those evaluated by the ACGME in the following areas[2]:

1. Patient care:
   Definition: Provide safe, efficient, appropriately utilized, quality controlled cardiothoracic imaging.
   Practice performance measurements: Cardiothoracic imaging section evaluation (to include pertinent safety issues such as proper methods to obtain informed consent).
2. Medical Knowledge- Fellows must demonstrate a core fund of knowledge in cardiac and thoracic anatomy, imaging anatomy, imaging signs, pathology, imaging techniques, medical therapy and surgery.
   Definition: Provide appropriate diagnostic and/or interventional cardiothoracic imaging interpretation to meet the imaging needs of patients, referring physicians, and the health care system.
   Practice performance measurements: Cardiothoracic imaging section evaluations
3. Practice based learning and improvement
   Definition: Participation in evaluation of one's personal practice in order to optimize patient care through lifelong learning.
   Practice performance measurements: Cardiothoracic imaging section evaluation
4. Interpersonal and communication skills
   Definition: Communicate effectively with patients, colleagues, referring physicians, and other members of the health care team concerning cardiothoracic imaging appropriateness, informed consent, safety issues and results of imaging tests and procedures.
   Practice performance measurements: Cardiothoracic imaging section evaluation (to include communication issues such as discussing abnormal imaging results with referring physicians).
5. Professionalism
   Definition: Commit to high standards of professional conduct demonstrating responsibility, courtesy, altruism, compassion, honesty and integrity.
   Practice performance measurements: Cardiothoracic imaging section evaluation (to include compliance with cardiothoracic imaging section policies).
6. Systems based practice
   Definition: Understand the factors that optimize coordination of care within a local health care system as well as the larger health care system in general by understanding appropriate performance and utilization of imaging resources.
   Practice performance measurements: Cardiothoracic imaging section evaluation (to include participation in multidisciplinary cardiothoracic care conferences and performance of QA project).

EVALUATION OF TRAINING PROGRAM AND FACULTY

Trainees must be given the opportunity to anonymously evaluate the fellowship program and faculty at regular intervals in a formal fashion (**PBLI**). These evaluations will be reviewed by the program director. Faculty evaluations may include assessment of:

1. Willingness of faculty to teach
2. Availability and approachability of faculty
3. Relevance of material taught
4. Whether training objectives are being met
5. Areas in which further educational effort is needed

Trainees should also be given the opportunity to evaluate the program as a whole. Fellows may evaluate the degree to which training objectives in thoracic, cardiac, procedural and research areas are being met. The program director should meet at regular intervals with fellows to evaluate the curriculum and whether fellowship training objectives are being met.

ASSESSMENT OF PROCEDURAL COMPETENCE

The faculty supervising interventional procedures should provide evaluations of fellow performance during interventional procedures (**PC, MK**). If thoracic procedures are performed outside the Division of Thoracic Imaging, evaluation should be sought from the appropriate interventional faculty. Fellows should be evaluated on several aspects of procedural competence:

1. Pre procedural knowledge: understands the indications, risks, benefits, alternatives to the procedure, pre procedure tests, absolute and relative contraindications (**MK**).
2. Consent and Universal Protocol: ability to appropriately obtain informed consent and adhere to institutional universal "time out" procedures (**ICS, SBP**).
3. Procedural skills: monitoring analgesia, plan appropriate biopsy approach, recognize pertinent anatomic landmarks, appropriately execute the biopsy, obtain samples (cytology, core biopsy and microbiology), and recognize intra procedural complications (**PC**).
4. Post Procedure Skills: understand methods of post procedure recovery, ability to manage post procedure complications (including chest tube placement and management of hemoptysis), long term pleural drainage management, and provide follow up instructions (**PC**).
5. Tracking of procedure complications (**SBP**).

CASE AND PROCEDURAL TRACKING

Fellowship programs should have the ability to track the total numbers of cases interpreted (according to modality) and total number of interventional procedures performed for fellows and fellowship graduates. Fellows should be encouraged to maintain procedure logs of all interventional cases and pertinent imaging procedures. This can be accomplished by keeping procedure logs in handwritten, electronic file or database format.

In addition to procedure logs, fellowship programs would ideally have the ability to retrospectively search radiology information systems to calculate modality specific case totals for specific procedures. This may become relevant for certain procedures requiring a minimum number of cases to be interpreted for formal certification or credentialing (such as cardiac CT, Cardiac MRI, thoracic PET/CT, etc).

SPECIFIC AREAS OF TRAINING

The following list contains material pertinent to cardiac and thoracic imaging practice (**MK**). This document is not intended to be an inclusive list of all thoracic and cardiac diseases, but rather a guide for education. It is recognized that not all patient populations and modalities will be available at all training locations. If a training program finds it impractical to provide clinical experience in an important topic either on site (or at a neighboring institution), instruction may be considered in lecture, conference, syllabus, video/DVD, reading material or other format.

THORACIC TOPICS

- Benign and Malignant Neoplasms of the Thorax
    - Lung cancer :
        - Preinvasive conditions: atypical adenomatous hyperplasia
        - Non small cell lung cancer, small cell carcinoma, adenocarcinoma in situ/minimally invasive adenocarcinoma (formerly known as bronchioalveolar cell carcinoma), invasive adenocarcinoma, neuroendocrine tumors, other forms of lung cancer
        - Staging system update for non small cell lung cancer
        - Standard treatment regimens
    - Mediastinal tumors (see mediastinum)
    - Esophageal cancer
    - Lymphoma
    - Thoracic sarcomas
    - Patterns of metastastic disease, lymphangitic carcinomatosis
    - Hamartoma/mesenchymoma
    - Plasma cell granuloma
    - Other benign tumors
- Trachea
    - Tracheal neoplasms
    - Tracheal stenosis: idiopathic, post traumatic, M. tuberculosis
    - Benign tracheal diseases: relapsing polychondritis, tracheopathia osteochondroplastica, papillomatosis, amyloid, Wegener granulomatosis, sarcoidosis
    - Tracheobronchomalacia
- Interstitial Lung Disease
    - Usual interstitial pneumonia (UIP)
    - Nonspecific interstitial pneumonia (NSIP)
    - Connective tissue disease: rheumatoid arthritis, scleroderma, systemic lupus erythematosis, polymyositis/dermatomyositis, mixed connective tissue disease, Sjogren syndrome, ankylosing spondylitis
    - Hypersensitivity pneumonitis
    - Smoking related interstitial lung disease: respiratory bronchiolitis, respiratory bronchiolitis interstitial lung disease, desquamative interstitial pneumonitis, Langerhan cell histiocytosis
    - Cryptogenic organizing pneumonia
    - Sarcoidosis

    - Cystic Lung Disease: Langerhans Cell Histiocytosis, lymphangioleiomyomatosis (LAM), lymphocytic interstitial pneumonia (LIP), amyloid, light chain deposition disease, follicular bronchiolitis, Birt Hogg Dubé, tuberous sclerosis
- Emphysema:
    - Centrilobular, paraseptal, panlobular, alpha 1 anti trypsin deficiency, giant bullous emphsyema
- Airways Disease
    - Broncholithiasis
    - Large airways disease: bronchiectasis (cylindrical, varicose, cystic), Mounier-Kuhn Syndrome, cystic fibrosis, Williams-Campbell syndrome
    - Small airways disease: obliterative bronchiolitis, diffuse panbronchiolitis, cellular bronchiolitis, bronchocentric granulomatosis
- Pleural Disease
    - Pleural effusion: including empyema, parapneumonic effusion, complicated parapneumonic effusion
    - Pleural infection (including tuberculosis)
    - Pleural Tumors/Masses: mesothelioma, pleural metastasis, fibrous tumor of the pleura, lymphoma, lipoma
    - Pneumothorax: primary, secondary, bronchopleural fistula
    - Hemothorax
    - Chylothorax
    - Asbestos related pleural disease: asbestos related pleural effusion, pleural plaques, diffuse pleural thickening, mesothelioma
    - Splenosis
- Mediastinal Disease
    - Pneumomediastinum
    - Thymic Lesions: normal thymus, thymic hyperplasia, thymoma, thymic carcinoma, thymic lymphoma, neuroendocrine tumors of the thymus, thymolipoma, thymic cyst
    - Lymphoma
    - Germ cell tumors: teratoma, seminoma and non seminomatous germ cell tumors
    - Sarcomas of the mediastinum
    - Mediastinal cysts: bronchogenic, foregut duplication, pericardial, thymic cyst
    - Sarcoidosis
    - Castleman disease
    - Lymphangioma
    - Mediastinitis: acute and chronic/fibrosing
    - Neurogenic tumors: neurofibroma, schwannoma, ganglioneuroma, paraganglioma
    - Thyroid and parathyroid lesions of the mediastinum
    - Hernias: hiatal hernia, gastric volvulus, Bochdalek and Morgagni hernias
- Infections of the Lung, Mediastinum and Pleura
    - Bacterial: staph, strep, gram negative, anaerobic, anthrax, rickettsia, Chlamydia, mycoplasma, septic emboli
    - Viral: influenza, respiratory syncytial virus, adenovirus, emerging viral infections (eg. SARS and H1N1), varicella, etc.
    - Fungal: histoplasmosis, Cryptococcus, coccidiomycosis, blastomycosis, aspergillus (invasive aspergillosis, airway invasive aspergillosis, chronic necrotizing aspergillosis, mycetoma)
    - Mycobacteria: M. tuberculosis and atypical mycobacteria

    - Nocardiosis
    - Actinomycosis
    - Mucormycosis
    - Parasitic: echinococcus, paragonimiasis, strongyloides, schistosomiasis
- The Immunocompromised Patient (Neutropenia and HIV/AIDS)
    - Human Immunodeficiency Virus (HIV) and acquired immunodeficiency syndrome (AIDS)
        - Thoracic manifestations
        - Infection: bacterial, fungal, viral, pneumocystis jiroveci, tuberculosis, atypical mycobacteria
        - Malignancy and lymphoproliferative disease: Kaposi sarcoma, lymphoma, other primary tumors
        - Immune restoration syndrome
        - Highly active antiretroviral therapy (HAART) and implications for imaging
    - Other forms of immunocompromise:
        - Neutropenic infection: bacterial, fungal, viral, pneumocystis jiroveci
        - Common variable immunodeficiency, agammaglobulinema and imaging manifestations
- Pulmonary Vascular Diseases
    - Pulmonary embolism: acute, chronic, pulmonary infarction
    - Non-thrombotic pulmonary emboli: tumor embolism, talcosis
    - Pulmonary arterial hypertension: causes and imaging manifestations
    - Eisenmenger syndrome
    - Inflammatory diseases of the pulmonary arteries: Takayasu disease, Behcet's disease
    - Pulmonary artery aneurysm/pseudoaneurysm: post infectious, post traumatic and other
    - Pulmonary artery neoplasms: pulmonary artery sarcoma
    - Pulmonary capillary hemangiomatosis
    - Pulmonary arteriovenous malformation (AVM)
    - Pulmonary veno-occlusive disease
    - Hepatopulmonary syndrome
- Occupational Lung Disease
    - Asbestos: asbestosis, asbestos related pleural disease (exudative effusion, pleural plaques, diffuse pleural thickening, mesothelioma), round atelectasis
    - Silica
    - Coal worker's pneumoconiosis
    - Mineral dust disease
    - Beryllium
    - Hard metals
    - Aluminum dust
    - Hypersensitivity pneumonitis (occupational)
    - Agricultural: organic toxic dust syndrome, silo filler's disease
- Critical Care/Intensive Care Unit Imaging
    - Tubes, lines, support devices
    - Pulmonary edema: hydrostatic edema, permeability caused by diffuse alveolar damage (DAD), permeability edema without DAD, mixed hydrostatic and permeability edema
    - Unusual causes of pulmonary edema: TRALI (transfusion related acute lung injury), drugs (e.g. all-trans retinoic acid agents), neurogenic, high altitude, re-expansion, amniotic fluid emboli
    - Nosocomial pneumonia

    - Acute Respiratory Distress Syndrome
    - Diffuse pulmonary hemorrhage
    - Aspiration: acute and chronic
    - Barotrauma
    - Advanced devices: extracorporeal membrane oxygenation (ECMO), aortic conduits, cardiac assist devices
- Drug and Radiation Induced Diseases of the Lung
    - Radiation pneumonitis
    - Patterns of drug induced interstitial lung disease: fibrosis, cryptogenic organizing pneumonia (COP), pulmonary edema, diffuse alveolar damage, obliterative bronchiolitis
    - Specific drugs: Amiodarone, Bleomycin, Busulfan, nitrofurantoin, epidermal growth factor receptor (EGFR) inhibitors
- Immunologic and Miscellaneous Diseases
    - Eosinophilic lung disease: acute and chronic
    - Allergic bronchopulmonary aspergillosis
    - Pulmonary Vasculitis: leukocytoclastic vasculitis, Churg Strauss
    - Sarcoidosis
        - Manifestations: lymph node, lung parenchymal, airway, pleural, bone
        - Radiographic staging
        - Diagnosis
        - Complications
    - Manifestations of connective tissue disease
        - Rheumatoid Arthritis: interstitial lung disease, necrobiotic nodules, airways disease, obliterative bronchiolitis, pulmonary vascular, pleural manifestations
        - Systemic lupus erythematosis: pleural disease, pericardial disease, interstitial lung disease, lupus pneumonitis, pulmonary hemorrhage, pulmonary vascular disease, diaphragm dysfunction
        - Scleroderma: interstitial lung disease, esophageal disorders, pulmonary vascular disease, calcinosis
        - Polymyositis/Dermatomyositis: interstitial lung disease, pulmonary vascular disease, diaphragmatic myositis, calcinosis
        - Sjogren syndrome: interstitial lung disease, lymphocytic interstitial pneumonia (LIP), follicular bronchiolitis, lymphoma
    - Amyloidosis
        - Systemic: types, imaging manifestations
        - Localized: tracheobronchial amyloidosis, parenchymal nodular amyloidosis, parenchymal alveolar amyloidosis
    - Pulmonary Alveolar Proteinosis
    - Pulmonary alveolar microlithiasis
    - Neurocutaneous syndromes: neurofibromatosis, tuberous sclerosis complex (chest wall, mediastinal, lung parenchymal involvement)
- Congenital Diseases of the Thorax
    - Airway: bronchial atresia, congenital lobar overinflation, tracheal bronchus, cardiac bronchus, situs abnormalities
    - Lung : hypoplasia, agenesis, congenital pulmonary airway malformation, pulmonary sequestration (intralobar and extralobar sequestration)

    - Vascular: Scimitar syndrome, anomalous pulmonary venous return (total and partial), proximal interruption of the pulmonary artery, arteriovenous malformation (AVM), pulmonary sling
    - Cysts: bronchogenic, esophageal duplication cyst
- Thoracic Trauma
    - Tracheobronchial Injury
    - Lung parenchymal injury (contusion and laceration)
    - Post traumatic pleural disease (hemothorax, pneumothorax)
    - Vascular injuries (aorta and great vessels)
    - Cardiac Injury
    - Diaphragmatic injury
    - Skeletal injuries
- Transplant Imaging
    - General transplant complications: rejection, infection, post transplant lymphoproliferative disease (PTLD), malignancy
    - Lung transplantation: unique complications including patterns of rejection, surgical failure, airway stenosis
    - Heart transplantation: unique complications including patterns of rejection, surgical complications
    - Bone marrow transplantation
        - Complications: temporal occurrence post transplant (1^{st} month, early, late)
        - Infection
        - Pulmonary hemorrhage
        - Patterns of rejection and graft versus host disease
    - Pulmonary complications of extrathoracic organ transplantation (e.g. renal, liver)
- Post Operative Chest
    - Lung cancer related procedures: thoracotomy, video assisted thoracic surgery (VATS), muscle flaps (intercostal muscle, serratus muscle), fat pads (omental, pericardial), cervical mediastinal exploration, Chamberlain procedure
    - Esophageal cancer related procedures: Ivor Lewis esophagectomy, left thoracotomy, transhiatal esophagectomy, minimally invasive esophagectomy
    - Cardiac devices: pacers, implantable cardioverter defibrillator (ICD)/biventricular pacers, septal occlusion devices, stent grafts, ventricular assist devices
    - Surgical complications: sternal dehiscence, bronchial dehiscence, bronchopleural fistula, gastric tip necrosis, esophageal leak, tracheo-esophageal fistula, cardiac herniation, cardiac torsion, lobar torsion, post pneumonectomy syndrome
    - Lung Transplant: technique and post operative appearance
    - Heart Transplant: orthotopic vs heterotopic technique, post operative appearance
- Thoracic Positron Emission Tomography (PET)
    - Lung Cancer
    - Esophageal cancer
    - Lymphoma
    - Sarcoma
    - Metastatic disease
    - Mesothelioma
    - Post transplant lymphoproliferative disease
    - PET in inflammatory diseases
- Thoracic Magnetic Resonance Imaging (MRI)

- Mediastinal mass evaluation
- Pleural evaluation: pleural mass, mesothelioma, diaphragm and chest wall invasion
- Hilar evaluation
- Chest wall evaluation for lung cancer staging

CARDIAC TOPICS

- Thoracic Aorta
  - Congenital disorders: coarctation, pseudocoarct, double aortic arch, right aortic arch
  - Aortic aneurysms and psueudoaneurysms
  - Acute aortic syndromes: dissection, intramural hematoma, penetrating ulcer
  - Trauma: traumatic aortic and great vessel injury
  - Inflammatory aortic diseases: aortitis, mycotic aneurysms
  - Connective tissue disease: Marfan syndrome, Ehler Danlos, cystic medial necrosis
- Cardiac Anatomy
  - Normal anatomy: coronary arteries, cardiac venous anatomy, pulmonary venous anatomy, cardiac chambers, papillary muscles, moderator/parietal bands
  - Pericardium
  - Sinuses of valsalva
  - Great vessel anatomy
- Cardiac Physiology and Measurements
  - Cardiac cycle and function: systole, diastole, systolic and diastolic ventricular function
  - Preload and afterload
  - Cardiac measurements: ejection fraction, stroke volume, left ventricular mass, gradient calculation (Bernoulli equation $G=4V^2$), Qp/Qs ratio, normal cardiac chamber pressures, normal pulmonary pressure, normal cardiac chamber measurements, normal aortic valve area
  - Eisenmenger physiology
- Cardiac CT and MR
  - Levels of Training
  - Assessment of Function
- Coronary Arteries
  - Variant anatomy
  - Myocardial bridging
  - Anomalous origins of coronary arteries
  - Coronary artery aneurysms (e.g. Kawasaki Disease)
- Ischemic Heart Disease
  - Coronary calcium assessment
  - Coronary artery disease including stenosis assessment
  - Acute and chronic infarction
  - Microvascular obstruction
  - Transmural and non-transmural infarction
  - Ventricular septal rupture
  - Papillary muscle dysfunction
- Myocardial Disease
  - Hypertrophic cardiomyopathy
  - Restrictive cardiomyopathy
  - Arrhythmogenic right ventricular cardiomyopathy/dysplasia

    - Dilated cardiomyopathy
    - Takotsubo cardiomyopathy
    - Myocarditis
    - Infiltrative disease (sarcoidosis and amyloidosis)
    - Left ventricular noncompaction
    - Ventricular aneurysms: true and false
    - Ventricular diverticulum
- Cardiac Valvular Disease
    - Mitral valve: stenosis and insufficiency
    - Aortic valve: stenosis, insufficiency, bicuspid aortic valve
    - Tricuspid valve
    - Pulmonic valve: stenosis and insufficiency
    - Prosthetic valves: mechanical and bioprosthetic
    - Endocarditis
    - Carcinoid heart
- Pericardial Disease
    - Pericardial cyst
    - Percarditis
    - Constrictive pericarditis
    - Pericardial absence: partial and complete
    - Malignant pericardial disease
    - Pericardial effusion, hemopericardium, pneumopericardium, tamponade
- Congenital Heart Disease
    - Atrial septal defect, patent foramen ovale, ventricular septal defect, patent ductus arteriosis, Tetralogy of Fallot
    - Truncus arteriosis
    - Ebstein anomaly
    - Heterotaxy syndrome
    - Transposition of the great vessels
    - Tricuspid atresia
    - Hypoplastic left heart
    - Anomalous pulmonary venous return: complete and partial
    - Atrioventricular canal (AV Canal) Defects
- Cardiac Tumors and Tumor Like Conditions
    - Atrial myxoma
    - Angiosarcoma
    - Lymphoma
    - Cardiac metastases
    - Cardiac rhabdomyoma
    - Fibroma
    - Paraganglioma
    - Lipomatous hypertrophy of the interatrial septum
    - Lipoma
    - Cardiac thrombus
    - Papillary fibroelastoma
- Postoperative Heart and Great Vessels
    - Coronary artery bypass graft (CABG) anatomy
    - CT of coronary artery bypass grafts

    - Post CABG complications (including aneurysm and pseudoaneurysm)
    - Coronary artery stent imaging: in stent restenosis
    - Post op valvular anatomy
    - Atrial septal defect (ASD)/patent foramen ovale (PFO) closure devices
    - Left ventricular apical aortic conduit
    - Endovascular aortic aneurysm repair (EVAR): normal imaging appearance, complications, endoleak evaluation and categorization
    - Aortic and cardiac aneurysm repair
    - Post operative appearance after congenital heart surgeries (e.g. Hemi-Fontan, Fontan, Ross, Rastalli, Norwood, Jantene, Mustard and Blalock-Taussig)
    - Cardiac herniation and torsion
- Pharmacology of Drugs Given During Cardiac Exams
    - Indications, contraindications, drug interactions, pharmacology, dose, mode of administration and monitoring of patients
    - Beta blockers, calcium channel blockers, nitroglycerine, dobutamine, adenosine

TECHNICAL ISSUES

- Radiation dose in cardiothoracic imaging: thoracic CT, cardiac CT, chest radiography, PET
    - Understand the data of the radiation dose report
    - Understand computed tomography dose index (CTDI), dose length product (DLP), tissue weighting factors and effective dose
    - Radiation dose reduction techniques in thoracic and cardiac CT
- Thoracic Computed Tomography (CT) Protocols
    - Acquisition parameters: mA, kV, pitch, thickness, collimation, detector configuration, gantry rotation speed, dose modulation techniques, reconstruction algorithm/kernel, etc.
    - Intravenous (IV) contrast administration, contraindications and premedication
    - IV contrast enhancement and injection techniques for routine chest, pulmonary CTA and aortic CTA: injection rate, contrast delay, bolus tracking techniques, saline chaser
    - Routine Chest CT protocol
    - High resolution chest CT (HRCT) protocol: including targeted reconstruction, expiratory and prone imaging
    - Pulmonary CT angiography (CTA) protocol
    - Aortic CTA protocol
    - Lung cancer screening and low dose chest CT protocol
    - Specialty protocols: airway imaging, thoracic outlet, 3D reconstruction techniques
    - Reconstructions: multiplanar reformations (MPR), maximum intensity projection (MIP)
    - Quality control in thoracic CT
- Thoracic Magnetic Resonance Imaging (MR) protocols
    - MR safety
    - MR contrast administration and contraindications
    - Acquisition parameters
    - Mediastinal mass MR protocol
    - Pleural evaluation MR protocol
    - Hilar evaluation MR protocol
    - Chest wall evaluation for lung cancer staging MR protocol

    - Quality control in thoracic MR
- Cardiac Computed Tomography (CT) protocols
    - Acquisition parameters: mA, kV, pitch, thickness, collimation, detector configuration, gantry rotation speed, dose modulation techniques, reconstruction algorithm/kernel, etc.
    - Cardiac CT contrast administration, contraindications and premedication
    - Reconstruction techniques, MPR, curved reconstruction, MIP, 3D reconstructions
    - Cardiac CTA protocols: retrospective and ECG tube modulation
    - Calcium scoring protocol
    - Pulmonary vein protocol
    - Quality control in cardiac CT
- Cardiac Magnetic Resonance Imaging (MR) protocols
    - MR safety
    - MR contrast administration and contraindications
    - Acquisition parameters
    - Cardiomyopathy protocols (including hypertrophic obstructive cardiomyopathy, arrhythmogenic right ventricular dysplasia, sarcoidosis, amyloidosis)
    - Cardiac mass protocol
    - Myocardial function and viability protocol
    - Myocarditis protocol
    - Function and valvular assessment protocol
    - Pericardial/pericardial constriction protocol
    - Congenital heart disease evaluation protocol
    - Coronary magnetic resonance angiography (MRA) protocol
    - Aortic MRA protocol
    - Pulmonary vein magnetic resonance venography (MRV) protocol
    - Cardiac shunt evaluation protocol
    - Quality control in cardiac MR
- Chest Radiography: computed radiography (CR) and digital radiography (DR)
    - Technique, patient positioning
    - Acquisition parameters, post processing techniques
    - Radiation dose
    - Quality control in CR and DR
- Thoracic Positron Emission Tomography (PET)
    - Technique and acquisition parameters
    - Pre procedure patient preparation and assessment
    - Quality control in PET imaging

REFERENCES

1. Strife J, Kun LE, Becker GJ et al. The American Board of Radiology Perspective on Maintenance of Certification: Part IV- Practice Quality Improvement in Diagnostic Radiology. AJR 2007;188:1-4.

2. Accreditation Council for Graduate Medical Education, Common Program Requirements, Effective July 1, 2011
(http://www.acgme.org/acwebsite/home/Common_Program_Requirements_07012011.pdf)

3. Collins J, Rosado de Christenson M, Gray L, et al. General competencies in radiology residency training: definitions, skills, education and assessment. Acad Radiol 2002; 9:721-726.

4. Collins J, Abbott GA, Holbert JM, et al. Revised Curriculum on Cardiothoracic Radiology for Diagnostic Radiology Residency With Goals and Objectives Related to General Competencies. Acad Radiol 2005;12:210-223.