SEMPI Priority clinical area: Pulmonary Embolism and Other Respiratory Disorders

INTRODUCTION

Imaging of the respiratory system may be necessary for a wide variety of conditions including infiltrative processes (both infectious and non-infectious), primary and metastatic neoplasms, parenchymal lung disease, pleural abnormalities, traumatic injury, surgical changes, heart/great vessel/pulmonary vasculature disease, chest wall and bony abnormalities. Similarly, a wide variety of imaging modalities can be utilized to define such conditions. Although, cough and dyspnea are the most common symptoms that initiate pulmonary evaluations, it is noteworthy that lung disorders can present as asymptomatic abnormalities on imaging studies obtained for other purposes.

RADIOLOGOLICAL EVALUATION OF RESPIRATORY CONDITIONS

Plain Film Chest X-rays and Fluoroscopy

When imaging structures in and around the thorax, plain film x-rays (XR) are used for identifying abnormalities in the lung, pleura, chest wall, diaphragm, mediastinum, hilum, and heart. Chest XR is usually the initial imaging modality used to evaluate the lung as it provides a large volume of information relative to cost, radiation dose, and ease of performance. However, it is important to note that chest XR has its limitations such that a 'normal' reading can be rendered in a wide variety of disease states resulting in sensitivity and specificity values of 80% or less for diffuse lung processes (i.e., bronchiectasis, emphysema, infiltrative disorders) (Epler et al., 1978).

Chest XR is performed in posteroanterior (PA) and lateral views to minimize artifact. Lateral decubitus views may be used to distinguish loculated from free-flowing pleural effusion, but CT or ultrasonography can provide more information (Kuhlman & Singha, 1997; Eibenberger et al., 1994). Portable anteroposterior (AP) views are almost always suboptimal and should be used only when patients are too ill to be positioned for a PA view or be transported to the radiology department.

Fluoroscopy provides real time imaging and allows evaluation of movement. Among other things fluoroscopy can detect unilateral diaphragmatic paralysis where a paralyzed hemi-diaphragm moves cranially (paradoxically) while the unaffected hemi-diaphragm moves caudally. Fluoroscopy can also assist guidance of biopsy forceps or brushings during bronchoscopy.

Computed Tomography

Computed tomography (CT) defines intrathoracic structures and abnormalities more clearly than a chest x-ray. Conventional (planar) CT provides multiple, cross-sectional images, 10 mm in thickness, through the thorax. Chest CT is normally done at full **inspiration** to provide the best delineation of lung parenchyma, airways, and vasculature, as well as delineate abnormal findings such as masses, infiltrates, or fibrosis. Recently, the benefit of lung CT as a screening tool for lung cancer in high-risk patient populations has been demonstrated (Kovalchik et al., 2013). CT is widely available, provides highly detailed images that may preclude the need for invasive tissue biopsy, and can facilitate less-invasive fine needle biopsy procedures. Disadvantages include motion artifact, artifacts related to bone and implants and radiation exposure. **High-resolution CT (HRCT)** provides even greater structural detail by using cross-sectional images, 1 mm in thickness. HRCT is particularly helpful in evaluating interstitial lung diseases (e.g., sarcoidosis, fibrosing alveolitis, and lymphangitic carcinomatosis) as well as bronchiectasis (Desai et al., 2019). HRCT at full expiration can document air trapping, which is typical of obliterative bronchiolitis as well as other airway diseases. **Helical ('spiral') CT or CT pulmonary angiography (CTPA)** is a CT technique in which the source and detector travel along a helical path with the patient moving through the bore of the scanner while the gantry rotates. It uses an IV bolus of iodinated radiocontrast agent to highlight the pulmonary arteries that is comparable to that used in conventional angiography, and offers advantages of speed, low radiation exposure, and an ability to construct 3-D images providing greater anatomic detail when compared to individual slice technology (Patel & Kazerooni, 2005). Spiral CT/CTPA provides a readily available, noninvasive test for pulmonary embolism with high diagnostic accuracy and negative predictive value. In addition, spiral CT provides an alternative diagnosis (to that of pulmonary embolism) in a high percentage of patients.

Magnetic Resonance Imaging (MR)

MR has a more limited role in pulmonary imaging but is preferred over CT in specific circumstances such as imaging in children, during pregnancy, and with younger patients who need repeated imaging studies. Specific situations where MR is superior to CT include complicated chest mass lesions with suspected mediastinum or chest wall invasion; cystic fibrosis; differentiation of atelectasis from lung mass; and perioperative surgical planning (Remy-Jardin et al., 2007). In patients with suspected pulmonary embolism, MR can be used if CTPA is contraindicated (Biederer et al., 2012).

Advantages include absence of radiation, visualization of vascular structures, lack of artifact due to bone, and excellent soft-tissue delineation. Disadvantages of MR include respiratory and cardiac motion, longer procedure time, higher cost, and potential contraindications including implanted devices and metallic foreign bodies.

Ultrasonography (US)

US is useful in the evaluation of pleural effusions as it is more sensitive than XR at detecting the presence of pleural fluid and differentiating it from lung consolidation, and better delineates it from pleural thickening and pleural masses (Pasin et al., 2017). It is comparable to CT (95% sensitivity) for detection of pleural disease in patients with a "white out" on chest x-ray (Feller-Kopman, 2006). US can facilitate thoracentesis, assist with central venous catheter placement, identify pneumonia as well as a pneumothorax at the bedside and has the added advantages of no radiation exposure, portability, and real-time imaging (Zanobetti et al., 2017). Transthoracic and peripheral lower extremity venous US can be used in some emergent situations to evaluate for Pulmonary Embolism (Jiang et al., 2015; Squizzato et al., 2013). US is more dependent on operator skill than other imaging techniques.

Endobronchial ultrasonography (EBUS) is increasingly being used as an adjunct to bronchoscopy to help localize lung masses and enlarged lymph nodes. EBUS has been incorporated into routine practice in many centers because of its high diagnostic value and low risk. It may replace more invasive methods for staging lung cancer and evaluating mediastinal lymphadenopathy (e.g. in tuberculosis). Diagnostic yield of transbronchial lymph node aspiration is higher using EBUS than conventional un-guided techniques (Chen et al., 2015; Li et al., 2015). A recent report suggests a role for EBUS in evaluation of Pulmonary Embolism (Aumiller et al., 2009).

Nuclear Imaging

Nuclear scanning techniques used to image the chest include ventilation/perfusion (V/Q) scanning and positron emission tomography (PET):

V/Q scanning uses inhaled radionuclides to detect ventilation and IV radionuclides to detect perfusion. Areas of ventilation without perfusion, perfusion without ventilation, or matched increases and decreases in both can be detected. V/Q scanning is most commonly used for diagnosing pulmonary embolism (PE) but has largely been replaced by CT pulmonary angiography (CTPA-see above). However, V/Q scanning is still indicated in the diagnostic evaluation for chronic thromboembolic pulmonary hypertension and in cases of suspected PE when CTPA is contraindicated (pregnancy, iodine allergy, advanced kidney disease) (Revel et al., 2011). Split-function ventilation scanning, in which the degree of ventilation is quantified for each lobe, is used to predict the effect of lobar or lung resection on pulmonary function.

Single-photon emission computed tomography (SPECT) is a nuclear medicine tomographic imaging technique that provides 3D information (rather than planar) thus improving the accuracy of V/Q scintigraphy (Reinartz et al., 2004). Addition of low dose CT to SPECT (SPECT/CT) increases the sensitivity and specificity to levels comparable with CTPA with lower radiation exposure. Disadvantages include availability, (often not available 24/7), and cost (Mortensen & Gutte, 2014).

Positron Emission Tomography (PET) uses radioactively labeled molecules (e.g., fluorodeoxy-glucose) to measure metabolic activity in tissues. It is used in pulmonary disorders to determine whether lung nodules or mediastinal lymph nodes harbor tumor ('metabolic staging') and whether cancer is recurrent in previously irradiated, scarred areas of the lung. PET can offer certain advantages compared to CT for mediastinal staging since PET can identify tumor in normal-sized lymph nodes and at extra thoracic sites, thus decreasing the need for invasive procedures such as mediastinoscopy and needle biopsy. The sensitivity of PET (80 to 95%) is comparable to that of histologic tissue examination (Islam & Walker, 2013). False-positive results can occur with inflammatory lesions, such as granulomas. Conversely, slow-growing tumors (e.g., bronchoalveolar carcinoma, carcinoid tumor, some metastatic cancers) can cause false-negative results.

PET/CT combines nuclear molecular imaging with CT technology to provide both anatomic (limited to lung parenchyma or involving surrounding structures) as well as cellular function information (e.g., fibrosis, malignancy, ARDS, granuloma formation) and the extent to which local structures are involved (parenchymal inflammation) (Scherer & Chen, 2016). This, in turn, can assist in patient selection for targeted interventions. For example, PET/CT may alter staging in patients with lung cancer which impacts treatment as well as prognosis.

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