Imaging of Small Airways and Emphysema

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KEYWORDS

• Bronchiolitis • Small airway disease • High-resolution computed tomography • Emphysema

KEY POINTS

- Diagnosing bronchiolitis with chest radiography is difficult.
- High-resolution computed tomography of the chest typically includes imaging during both inspiration and expiration. Images are acquired to allow for thin-section reconstruction (0.625 to 2 mm thickness).
- Expiratory imaging improves detection of air trapping.
- The 2 main categories of bronchiolitis are defined based on inflammatory/cellular or fibrotic/constrictive histopathologic features.
- Direct signs of bronchiolitis include centrilobular nodules, tree-in-bud pattern, and peribronchiolar ground-glass opacities.
- Indirect signs of bronchiolitis include air trapping and mosaic perfusion.
- Presence, absence, and distribution of direct and indirect signs can suggest a specific disease process.
- The 3 main subtypes of emphysema are centrilobular, paraseptal, and panlobular emphysema; each has a classic imaging appearance.

INTRODUCTION

Effectively using imaging to diagnose bronchiolitis or emphysema requires a basic knowledge of the imaging modalities used, exam protocols performed and the imaging findings that represent the hallmark of disease. With respect to bronchiolitis, high-resolution chest computed tomography (CT) is one of the most useful techniques available because it shows highly specific direct and indirect imaging signs. The direct signs of bronchiolitis include centrilobular nodules, tree-in-bud pattern, and centrilobular/peribronchial ground-glass opacities. The indirect signs of bronchiolitis include air trapping and mosaic perfusion. The distribution and combination of these various signs can further classify bronchiolitis as either cellular/inflammatory or fibrotic/constrictive. Emphysema is characterized by destruction of the airspaces, and a brief discussion of imaging findings of this class of disease is also included. Typical CT findings include destruction of airspace, attenuated vasculatures, and hyperlucent as well as hyperinflated lungs.

BRONCHIOLITIS

Tools for Imaging

Chest radiography

Chest radiography (CXR) is of low utility when evaluating bronchiolitis. The main value of CXR, which

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has lower radiation and a quicker examination compared with CT, is in the exclusion of other diagnoses, such as pneumonia or pneumothorax.[1–3] The CXR often appears normal in cases of bronchiolitis until late in the disease course.[1,2]

Computed tomography

High-resolution CT (HRCT) is commonly used in adults when evaluating bronchiolitis. This technique uses more radiation compared with a routine chest CT so that thin-slice reconstructions of 0.625 mm can be created with an acceptable signal-to-noise ratio. HRCT examinations can vary based on the clinical indication and can contain a combination of prone or supine and inspiration or expiration images. Imaging patients in the prone position during inspiration is used to differentiate dependent atelectasis from early interstitial lung disease and can usually be omitted in the work-up of potential bronchiolitis.

The standard HRCT protocol at the authors' institution is described in **Table 1**. Inspiration and expiration images are important in diagnosing bronchiolitis because they can detect air trapping. A mosaic attenuation pattern that appears on expiratory images but not inspiratory images suggests the presence of air trapping, which has been suggested as one of the earliest imaging findings of small airway disease, specifically in obliterative bronchiolitis.[4] Additionally, the presence of air trapping on expiratory imaging has been shown to correlate well with obstructive findings on pulmonary function tests.[5,6] Although mosaic attenuation can be seen on the inspiratory images, a diagnosis of air trapping cannot be confidently made, as small vessel disease may also present with mosaic attenuation (**Fig. 1**). Expiratory imaging is usually performed using an axial acquisition, obtaining representative slices in the upper, mid, and lower lungs.[4] This axial acquisition technique is used instead of the helical acquisition because it decreases radiation but maintains diagnostic quality.

Several other methods of imaging the small airways have been described but are not commonly seen in clinical practice. One of these methods is dynamic imaging (4-dimensional CT) during inspiration and expiration. This method is currently used mainly as a research tool and not yet widely clinically accepted because of concerns over radiation dose, but studies have shown that results correlate with obstructive findings measured with pulmonary function tests.[7,8]

IMAGING FINDINGS

A thorough understanding of the anatomy of the secondary pulmonary lobule assists in understanding the direct and indirect imaging findings of bronchiolitis commonly seen on HRCT. The secondary pulmonary lobule is the smallest unit of the lung that can be imaged and has a polyhedral shape approximately 2 cm in diameter that is bordered by connective tissue planes of the interlobular septa (**Fig. 2**).[9] The secondary lobules are further subdivided into 6 to 8 polyhedral primary lobules (with central terminal bronchioles) and subsequently into pyramidal acini, with respiratory bronchioles at their apices. Importantly, the apices of the acini (the centers of the primary lobules) are located approximately halfway between the center of the secondary lobule and the interlobular septa; disease processes that affect them are commonly regarded as centrilobular even though they are not strictly located at the center of the secondary lobule.

Branches of the pulmonary artery accompany the bronchioles to the level of the respiratory bronchioles and are, thus, found at the apices of the acini. The pulmonary arterial system further branches into capillaries, which traverse the alveolar septa before coalescing in larger venules that run in the secondary lobular septa. One set of lymphatics originates near the respiratory bronchioles and tracks back to the hilum in the bronchovascular bundles. A second set tracks to the

Table 1
Computed tomography protocols

Scan Type	Respiration	Patient Position	Extent	Interval (mm)	Slice Thickness (mm)	Reconstruction Algorithms
Helical	Inspiration	Supine	Lung apex to mid kidney	0.625	2.5 1.25	Standard Bone
Axial	Expiration	Supine	Lung apex to diaphragm	20.0	1.25	Bone
Axial	Inspiration	Prone	Lung apex to diaphragm	20.0	1.25	Bone