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Imaging approach of small airway diseases on HRCT

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Abstract
Small airways diseases are difficult to see on routine x ray, So HRCT is modality of choice for detection of pathologies related to small airways. There are various radiological patterns on HRCT which point to the presence of small airway diseases. The present study aids to identify the signs and role of HRCT in identification and early management of small airway diseases.

Keywords: small airways, bronchiolitis, tree in bud nodules, mosaic attenuation

Introduction

Introduction to Small airways and Bronchiolitis

Small airways are bronchioles that do not contain cartilage. These small airways are located between the 4th and the 14th generation of the tracheobronchial tree, are only visualized on CT images, when diseased and comprise the smallest air conducting membranous bronchioles and respiratory bronchioles, which open into the alveoli.

Bronchiolitis or small airway disease is a generic term used clinically to describe various inflammatory diseases of the bronchioles. Small airways have been called the silent zone. Small airways appear particularly vulnerable because many particles and infectious agents may be deposited there and because of their narrow lumen make them more susceptible to complete obstruction as compared to proximal larger airways. These diseased airways are visible on HRCT as dilated, air-filled, branching, tubular or ring-like structures in the lung periphery by wall thickening and dilation. Abnormalities that involve bronchioles may originate from the bronchioles or may result from extension of disease that involve mainly the larger bronchi.

MDCT in diagnosing small airway diseases

Multidetector computed tomography (MDCT) is a powerful diagnostic tool in the assessment of both large and small airway disease. High Resolution Computed Tomography (HRCT) is the imaging technique of choice for suspected bronchiolitis

Material and Method

We retrospectively identified 50 patients referred to radiology department for HRCT chest with a principal diagnosis of small airway disease. A random sample of the entire HRCT chest patients from January 2020 to October 2020 was selected. To be eligible, patients had to present to the hospital with cough and shortness of breath and with clinical suspicion of airway disease. HRCT scans were done using 16-slice Multidetector Computed tomography (MDCT) scanner in the Radiology department of Gujarat adani institute of medical science. Complimentary expiratory scans were performed when indicated. 1 mm reconstructed images in lung window and 1.5 mm images in mediastinal window we reviewed on Osirix work station in axial, coronal and sagittal planes.

Results

Direct signs were seen in 70% of cases and indirect signs in 30%. The most Common finding was Tree in bud nodules (TIB). Consensus reporting diagnosed bronchiolar wall thickening in 5, isolated centrilobular nodules in 8, bronchiectasis in 3, mosaic pattern in 11, mucus plugs in 7, tree in bud nodules in 12 and chronic small airway pattern in 4.

Table 1

	CT pattern	Number of patients
1	Bronchiolar wall thickening	5
2	Centrilobular nodules	8
3	Tree in bud nodules	12
4	Mucus Plugs	7
5	Bronchiectasis	3
6	Mosaic low attenuation	11
7	Chronic small airways disease a. vascular attenuation b. increased lung volume c. sub segmental atelectasis	 1 1 2

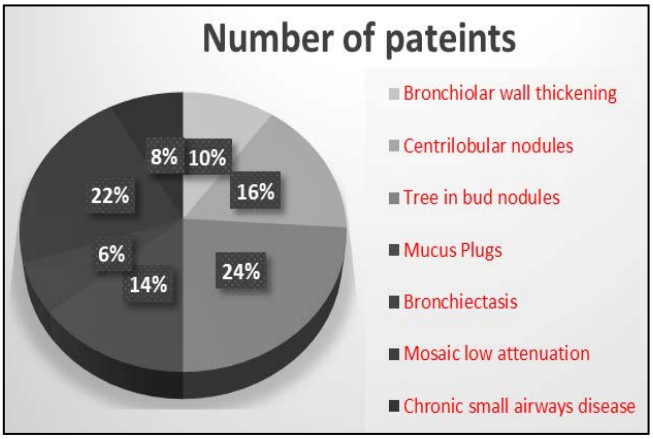

Fig 1

There was agreement between observers in the diagnosis of air trapping when the images were used in conjunction with expiratory images.

Discussion

Small airway diseases are more commonly recognized on High resolution CT. The various findings and imaging patterns which help us to detect the small airway disease can be majorly categorized into two: Direct Signs and Indirect Signs. The direct signs are encountered more frequently, in our case there are 70% out of the total cases which shows the direct signs. The indirect signs may not always present, but their presence is highly indicative of and aids in detection of small airway disease. In our study the indirect signs were present in 30% patients.

Direct signs of small airway disease include

1. Bronchiolar wall thickening
2. Mucus Plugs
3. Centrilobular Nodules (CN), which are either ill-defined ground glass opacity or well-defined centrilobular branching V or Y nodules
4. Tree-in-bud opacities
5. Bronchiectasis

Indirect signs of small airway disease include

6. Mosaic pattern of attenuation (on inspiration) and air trapping (on expiration)
7. Vascular attenuation
8. Increased lung volume
9. Sub segmental atelectasis

Imaging patterns of small airway diseases

Small airway disease can manifest with direct or indirect signs or both on high resolution computed tomography. On HRCT images, the considerable thickening of the small airway walls by inflammatory infiltrate and/or luminal and surrounding exudate render the affected small airways directly visible. When the airways are obliterated by submucosal or peribronchial fibrosis, nodular, linear, or branching peripheral opacities may be seen. The imaging detail of each finding of small airway disease is below:

1. Bronchiolar wall thickening

Small airways are not visible on HRCT scan in normal subjects. However, considerable thickening of the bronchiolar walls by inflammatory infiltrate and/or luminal and surrounding exudates render them directly visible. Bronchiolar airways should be considered thick walled if the wall is at least twice as thick as that of the normal airway or the internal diameter of the lumen is <80% of its external diameter.

2. Intraluminal Plugs

Small variable density intraluminal foci are seen in the bronchioles, which could be mucus impactation, exudates or aspiration.

3. Centrilobular Nodules

Centrilobular nodules can be classified in two varieties:

a. Poorly defined Centrilobular nodules of ground glass opacity

They tend to be fairly homogeneous in size. They are inflammatory cellular or fibrosis surrounding the centrilobular bronchiole. In these cases, impactation of bronchiole is typically absent.

b. Well defined, V or Y shaped denser centrilobular nodules.

These are seen due to intraluminal impaction.

Differential diagnosis of CN nodules include hypersensitivity pneumonitis, respiratory bronchiolitis, RB with ILD, follicular bronchiolitis, pneumoconiosis, collagen vascular diseases, atypical infections.

4. Tree in Bud Nodules

This pattern resembles a budding tree where there is dilatation and impactation of centrilobular bronchioles by pus or mucus (the branches) plus associated with peri-bronchiolar inflammation or fibrosis (the buds). Lobular bronchioles are usually not directly visible on CT because their walls are too thin. But they can become visible at the center of the secondary lobule when there is increased soft tissue in or around the bronchioles. Tree-in-bud opacities are generally taken to mean that infection is present but can be seen with any small airway disease.

5. Bronchiectasis

Bronchiectasis term defines dilated bronchioles visualized in the peripheral 1 to 2 cm of the lung, which is not normal. Bronchiectasis may be air or secretions filled. There might be luminal impactation with bronchiolar wall thickening (Tree in bud). This finding is commonly associated with large airway abnormalities.

6. Mosaic attenuation pattern

Persistent aeration caused by collateral pathways or hyper-aeration from trapped air can produce mosaic attenuation pattern. It is characterized by non-homogenous lung density, The air trapping and mosaic attenuation is more pronounced, on scans obtained at end-exhalation instead end-inspiration technique. Air trapping is indirect sign of obstructive small airways disease that is accentuated on expiratory CT. This means that the low attenuation areas seen on inspiratory scans either persist, increase in number or increase in volume. When mosaic attenuation/air trapping is the only or predominant finding the differential diagnosis is quite limited i.e. asthma, HP, constrictive bronchiolitis and vasculitis. So, expiratory CT is the key.

7. Chronic small airway disease

Chronic small airway disease findings on HRCT include vascular attenuation, increased lung volume, subsegmental atelectasis and in late stages even fibrosis.

The pattern and distribution may sometimes give an indication of the underlying etiology.

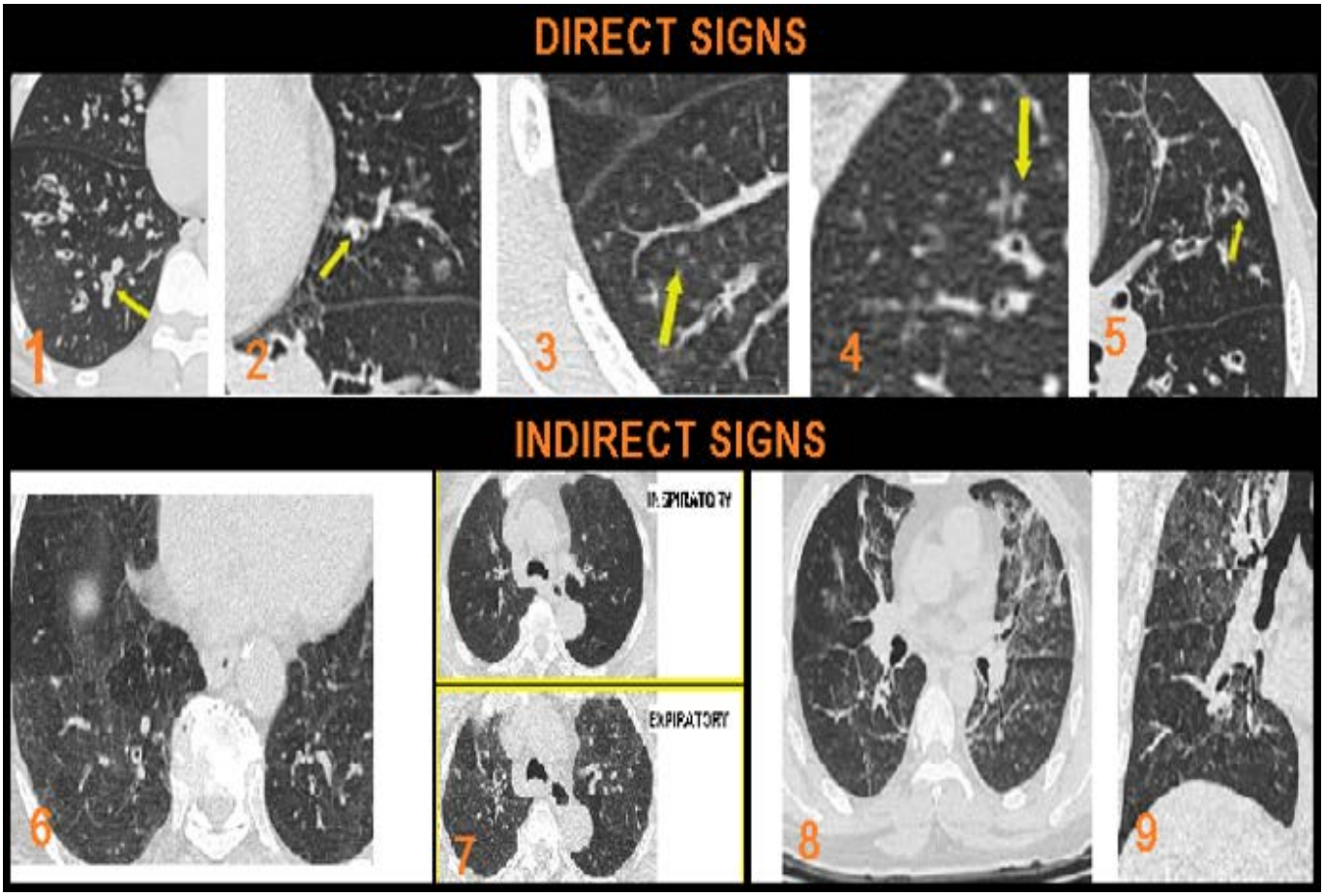

Fig 2: Direct signs of small airway disease include Bronchiolar wall thickening (1), plugs (2), Centrilobular Nodules (3), which are either ill-defined ground glass opacity or well-defined centrilobular branching V or Y nodules, Tree-in-bud opacities (4),Bronchiectasis (5). Indirect signs of small airway disease include Mosaic pattern of attenuation on inspiratory CT scan (6) and air trapping on expiratory CT scan (7), Vascular attenuation (8), Increased lung volume & Subsegmental atelectasis (8,9)

Classification of small airway diseases

A classification of bronchiolitis has been proposed based on etiology and histopathological appearance. Devakonda and fellows8 have proposed a diagnostic algorithm based on clinical context and CT findings. This proposal appears useful, considering that most patients with suspected small airways disease do not have surgical lung biopsy, but correlation with pulmonary function tests and other lab findings still required.

Proposal for New approach for Classification:

By combining the pathological classification with the radiological findings, we have tried to come up with an easy approach depending on HRCT finding pattern. In our departmental data, four basic radiologic patterns of small airway disease were observed on CT scan:

1. Bronchiolitis
2. Bronchiolitis with specific signs of air trapping
3. Centrilobular ground glass nodules
4. Extensive chronic small airway disease pattern

We divide small airway disease patterns into three main categories and have tried to make it simple. So, how to recognize bronchiolitis on HRCT?

Cellular bronchiolitis is inflammation of the bronchiolar wall with intraluminal exudates. HRCT images would show bronchiolar wall thickening, plugs, Tree in bud pattern and centrilobular nodules.

Constrictive bronchiolitis is peri-bronchiolar fibrosis with extrinsic compression and obliteration of the airway. HRCT scan would show bronchiolar wall thickening, bronchial narrowing/occlusion and mosaic air trapping.

Bronchiolitis obliterans with intraluminal polyps or BOOP. There are polypoid intraluminal plugs of proliferating fibroblasts in alveolar ducts & spaces thus CT images would show acinar ground glass haze, consolidations with bronchiectasis and plugs.

Conclusion

- HRCT images can accurately identify thickened airway walls, plugged small airways and air trapping. HRCT plays instrumental role in characterization and detection of small airway diseases which, until relatively recently, had been regarded as being beyond the scope of radiological imaging.
- HRCT images with mosaic attenuation areas should be paired with expiratory scans for early disease detection and to prevent irreversible lung damage.
- The proposed small airway disease classification should be used in everyday reporting to make characterization of disease process easier.

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