2017 WCTI

“A Breath of Fresh Air” – Update of Imaging in Asthma

Diffuse lung diseases
Emphysema and airways diseases

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Learning Objectives

• Identify common Multidetector CT findings in patients with asthma.
• Understand that different phenotypes exist in asthma and how imaging may aid in diagnosing these.
• Demonstrate additional CT findings that may suggest a disease association or recognized complication of asthma.
• Be aware of differential diagnoses that may mimic the clinical features of asthma.
• Discuss the utility of CT to offer improved patient selection for treatments, and the ability to gain quantitative measures to assess treatment response.
Introduction

• Asthma is a common condition affecting 5.4 million people in the United Kingdom with 1 in 12 adults suffering from the condition\(^1\).
• There is significant morbidity and mortality associated with the condition, in 2014 over 1200 patients died from asthma\(^1\).
• As a result there is a significant health resource directed to helping patients with asthma.

• In this presentation we will highlight some of the patients discussed at our specialist difficult asthma multidisciplinary meeting highlighting the vital role the Radiologist provides.
Imaging Findings In Asthma

- Asthma is characterized by airway inflammation. The pathological manifestations include bronchial wall thickening and mucus production. With ongoing inflammation chronic changes can occur with airway thickening and irreversible airway obstruction. The entire tracheobronchial tree can be affected.
- Plain radiographs have a limited role in the diagnosis of asthma but are an essential preliminary investigation during an acute exacerbation.

Figure: Complications of asthma. (a) Left apical pneumothorax (b) Pneumomediastinum, (c) Left upper and right lower lobe collapse.
Imaging Findings in Asthma – Large Airways Disease

The classical finding is bronchial wall thickening and is seen in up to 62% of imaged patients\(^2\). The finding of bronchial wall thickening is associated with increased asthma severity and longer duration of disease.

Figure: Bronchial wall thickening in the right upper lobe (arrow).
Imaging Findings in Asthma – Large Airways Disease

Bronchiectasis is seen in 40% of patients with severe asthma\(^2\).

The presence of bronchiectasis correlates with longer disease duration and poorer lung function.

Figure: Bronchiectasis in the middle lobe and lingula complicating asthma with background mosaic attenuation.
Imaging Findings in Asthma – Small Airways Disease

- **AIR TRAPPING:** Abnormal retention of air within the lung parenchyma due to airway obstruction or reduced lung compliance.
- Air trapping is confirmed when lung parenchyma remains lucent on expiratory scans or shows a less than expected normal increase in density.
- Air trapping is seen in normality, typically several lobules in the apical segments of the lower lobes and the dependent lung bases.

![Normal expiratory images at two levels. Note the lobule of air trapping in the dependent region of the right lower lobe (arrow).](image-url)
Imaging Findings in Asthma – Small Airways Disease

- In patients whom expiratory scans have not been obtained the inspiratory scan may demonstrate mosaic attenuation.
- In patients with mosaic attenuation due to airways disease, dilated or thickened airways in the lucent lung region can be observed.
- Minimum intensity projections (MinIP) can be helpful to confirm underlying mosaic attenuation in such patients.

Figure: (a) underlying mosaic attenuation, likely small airways disease given the bronchial wall thickening (arrows). Use of a sagittal MinIP (c) making the regional variation in attenuation more conspicuous than a standard MPR (b).
Air Trapping Quantification

• Historically air trapping on expiratory CT has been subjective, more recently attempts have been made to use software to quantify the extent of air trapping and its correlation with pulmonary function testing.

• Air trapping can be identified by comparing mean lung density (MLD) on paired inspiratory/expiratory images and low attenuation areas on expiratory images which are defined by a threshold value (e.g. -850 to -910 HU)$^3$. 
Air Trapping Quantification

Figure: Data processed on *syngo* via (Siemens, UK) workstation. Density mask method with low attenuation areas depicted by threshold values of -850 to -910 HU. (a) The table shows the percentage of lung parenchyma affected within this range as a percent for the left and right lung. (b) Corresponding mask image with the areas of small airways disease coloured green.
Imaging in Asthma – Mixed Large and Small Airways Disease

• Many patients will demonstrate combined large and small airways disease

Figure: Combined large and small airways disease with bronchial wall thickening and mosaic attenuation on the inspiratory images (a) confirmed to be air trapping on the expiratory images (b)
Imaging in Asthma – Acute Complications

- Plain radiographs will often allow rapid evaluation for common complications such as pneumothorax and consolidation.
- There still remains a role for CT in specific patients with atypical clinical presentations.

Figure: Complications of asthma at CT (a) left upper and right lower lobe collapse due to mucus plugs (b) peripheral ground glass opacity on the background of bronchial wall thickening. This is in-keeping with inhalational lung injury in a patient known to smoke illicit drugs and (c) pneumomediastinum with marked central bronchial wall thickening but no associated pneumothorax.
Bronchial Thermoplasty (BT)

- A novel therapy which is indicated in patients with severe asthma refractory to optimal medical therapy.
- Involves applying thermal energy to the airway wall. The aim is to reduce the amount of excessive muscle in the airway and limit its ability to contract and narrow the airway.
- Limited role for imaging provided there is optimal patient selection, other than ensuring no treatable disease association is present.
- Assessment of benefit of BT is largely based on clinical and physiological parameters.
Bronchial Thermoplasty (BT)

Figure: Pre (a) and post (b) bronchial thermoplasty, demonstrating an improvement in bronchial wall thickening in the lower lobes.

CT may have a role following BT to examine airway wall thickness and airway wall density⁴.
Asthma disease associations

Various conditions can be associated with asthma. The imaging features of these should be recognised by the radiologist as these patients may benefit from different treatment strategies.

Such diseases include:

• Eosinophlic lung disease.
• Samter’s triad.
Eosinophilic Lung Disease

• Can complicate Asthma in a minority of patients
• Diagnosis is based on clinical assessment, imaging findings and eosinophilia in peripheral blood or bronchoalveolar lavage (or lung biopsy).
• Spectrum of disease includes
  – pulmonary eosinophilia
  – Eosinophilic Granulomatosis with Polyangiitis (EGPA)
  – Allergic Bronchopulmonary Aspergillosis (ABPA).
## Pulmonary eosinophilia

<table>
<thead>
<tr>
<th>Simple Pulmonary Eosinophilia</th>
<th>Acute Eosinophilic Pneumonia</th>
<th>Chronic Eosinophilic Pneumonia</th>
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<tbody>
<tr>
<td>• Loeffler syndrome</td>
<td>• Acute severe illness</td>
<td>• Homogenous peripheral airspace consolidation lasting more than 6 months</td>
</tr>
<tr>
<td>• Migratory areas of peripheral consolidation</td>
<td>• Elevated BAL eosinophils</td>
<td>• Steroid responsive</td>
</tr>
<tr>
<td>• Blood eosinophilia</td>
<td>• Associated with inhalation injury or drug reaction</td>
<td>• 50% have asthma and therefore maybe difficult to differentiate from EGPA</td>
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<td>• Resolution within 1 month</td>
<td>• Non-specific findings at CT including patchy ground glass opacity and interlobular septal thickening</td>
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18
Acute Eosinophilic Pneumonia

Figure: A 30 year old asthmatic presented with acute respiratory symptoms. Plain radiograph (a) shows a “reverse bag wing” appearance. Coronal MPR (b) and axial (c) CT show a peripheral ground glass opacity.
Eosinophilic Granulomatosis with Polyangiitis (EGPA)

• Previously known as Churg-Strauss Syndrome.
• Triad of asthma (96%-100%), peripheral eosinophilia and vasculitis.
• Other common associations including peripheral neuritis, paranasal sinus disease, skin lesions and cardiac involvement.
• Diagnosis made on clinical and radiological grounds and positive p-(myeloperoxidase) antineurotrophic cytoplasmic antibody (p-ANCA)
Eosinophilic Granulomatosis with Polyangiitis (EGPA)

HRCT Findings

- Peripheral or patchy ground glass opacity or consolidation
- Bronchial wall thickening
- Centrilobular nodules
- Smooth interlobular septal thickening
- Less commonly nodules that may cavitate

Figure: A 30 year old with a diagnosis of mild asthma presented with progressive breathlessness. Initial CT (a) showed mild airway thickening and mosaic attenuation. Progressive symptoms led to further imaging (b) which shows peribronchial patchy ground glass opacity in the right upper lobe. P-ANCA was positive.
Eosinophilic Granulomatosis with Polyangiitis (EGPA)

Figure: CT examinations in two different patients with EGPA showing peripheral ground glass opacity and interlobular thickening (a). The second patient has an atypical airway dominant pattern with diffuse bronchial wall thickening and peripheral centrilobular and tree in bud nodules (b).
Eosinophilic Granulomatosis with Polyangiitis (EGPA) EXTRAPULMONARY MANIFESTATIONS

Figure: Cardiac MRI late gadolinium images in a patient with EGPA shows (a) basal inferoseptal subendocardial and (b) mid septal transmural enhancement. Normal coronary arteries at cardiac catheterisation.

Figure: Coronal MPR (a) and axial (b) CT show evidence of bilateral maxillary sinus mucosal thickening and adjacent hyperostosis. Nasal polyps are also present.
Allergic Bronchopulmonary Aspergillosis (ABPA)

ABPA is a syndrome characterised by hypersensitivity to endobronchial growth of Aspergillus fumigatus.

Characteristic features include homogenous tubular finger in glove opacities on the background of bronchiectasis (more likely to be varicoid or cystic than asthmatics without ABPA).

Figure: Coronal (a) and sagittal (b) MPR CT demonstrate cylindrical and varicose bronchiectasis with marked mucus plugs in the right upper lobe and both lower lobes characteristic of ABPA.
30% of patients with ABPA demonstrate high density mucus plugs.

Can see additional findings of centrilobular nodules or tree in bud reflecting bronchiolar mucoid impaction.

Figure: Axial CT demonstrates bilateral high density mucus plugs.
SAMTERS TRIAD

Triad consisting of:

• Asthma
• Hypersensitivity to aspirin/NSAIDS
• Nasal polyps

Figure: A patient with known aspirin induced asthma. CT thorax (a) shows mixed large and small airways phenotype. CT sinuses (b) shows nasal polyps.
Clinical/Radiological mimics of asthma

• Important to distinguish other conditions which may have similar symptoms/signs as asthma.

• Often clinically unsuspected and the radiologist maybe the first to suggest these diagnoses.
Diffuse idiopathic pulmonary neuroendocrine cell hyperplasia (DIPNECH)

- Rare condition, female predominant
- Non-specific symptoms such as cough and progressive breathlessness
- HRCT findings include marked air trapping, ground glass opacities, bronchial wall thickening and small solid nodules

Figure: A patient referred to the asthma service. Coronal maximal intensity (a) and minimum intensity (b) images show marked mosaic attenuation with small bilateral solid nodules, the presence of nodules should draw the radiologist to the possible diagnosis.
Obliterative Bronchiolitis (OB)

- Can be misinterpreted as asthma due to the dominant air trapping. Important to ascertain clinical history, including risk factors such as underlying collagen vascular disease, lung or bone marrow transplantation or childhood infection (Swyer-James syndrome).
- HRCT findings include patchy air trapping sometimes only evident on the expiratory images, diffuse low attenuation of the lung parenchyma on inspiratory images, bronchiectasis and less commonly areas of consolidation or tree in bud nodularity.

Figure: A patient with known Rheumatoid Arthritis. Inspiratory (a) images show diffuse hypodensity and paucity of vascularity with bronchial wall thickening in the right upper lobe. Severe air trapping confirmed on the expiratory images (b).
Hypersensitivity Pneumonitis (HP)

- Inflammatory reaction due to inhalation of organic or inorganic particles.
- Three phases – acute, subacute and chronic.
- HRCT findings in subacute HP (most commonly encountered at the time of a possible asthma diagnosis) include centrilobular ground glass nodules (<5mm), more diffuse ground glass opacity affecting lobules, air trapping due to bronchiolar inflammation.

Figure: Axial CT demonstrates bilateral centrilobular ground glass nodules with background mosaic attenuation in keeping with subacute HP.
Smoking related interstitial lung disease

The presence of emphysema, diffuse ground glass opacity and reticulation should raise the suspicion of smoking related ILD.

Air trapping is less commonly encountered in these patients than in asthma.

Figure: Axial CT images in a smoker demonstrate paraseptal emphysema and left upper lobe bullae (a) with more diffuse ground glass and fine reticulation in the anterior aspects of both upper lobes (b).
Tracheobronchomalacia

Defined as >50% airway collapse on expiration. Can be quickly assessed at CT using sequential or volumetric expiratory images.

Uncertain association with asthma but should be considered in patients with refractory severe asthma or as an alternative diagnosis.

Figure: Paired inspiratory and expiratory images at two levels showing marked airway collapse.
Summary

• Imaging has an important role in the assessment of patients with asthma, in particular those with severe disease.
• Disease associations/complications should be actively sought out.
• There is a role for quantitative CT in assessment of small airways disease and potentially as a marker of response to novel therapies such as Bronchial Thermoplasty.
• It is important to be mindful of disease mimics which would benefit from entirely different treatment strategies.
References

1) Asthma UK https://www.asthma.org.uk/about/media/facts-and-statistics/

2) Qualitative analysis of high-resolution CT scans in severe asthma. Gupta S et al. Chest 2009.


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