Imaging of the Large Airways

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Learning Objectives

- Describe the CT techniques for imaging the large airways.
- Demonstrate CT findings of focal and diffuse tracheobronchial disease.
- Reveal the utility of advanced airway imaging techniques for diagnosis and intervention planning.
Outcomes

- A range of neoplastic, inflammatory and congenital diseases may affect the trachea and main stem bronchi.
- The anatomy of the central airways and different pathologic conditions will be reviewed.
- The appearance and differential diagnosis of the most common disorders affecting the large airways will be discussed.
Anatomy of the central airways

Tracheal cartilage – horseshoe shaped, forms the anterior and lateral wall

- The trachea consists of 4 layers: an inner mucosal layer, a submucosal layer, cartilage and muscle, and an outer adventitial layer. The anterior trachea is composed of 16 to 22 C-shaped, cartilaginous rings linked by annular ligaments of fibroconnective tissue.

- The posterior tracheal wall lacks cartilaginous support, which is provided only by the thin band of the trachealis muscle. The posterior aspect of the trachea is also known as the membranous portion.

- The trachea is approximately 10-12 cm in craniocaudal length, extending from the inferior aspect of the cricoid cartilage to the carina. The normal coronal diameter is 13-25 mm in men and 10-21 mm in women. The normal sagittal diameter is 13-27 mm in men and 10-23 mm in women. On CT, the normal tracheal wall is 1-3 mm thick, delineated by luminal air and the mediastinal fat or lungs. Calcification of the cartilage can be associated with senescent changes, particularly in older women.
CT techniques for imaging the large airways

- Conventionally, CT image interpretation in airway lesions should begin with axial images.
- Once an abnormality is detected it can be better demonstrated on multiplanar reformations, curved MPR, maximum and minimum intensity projections, volume and surface rendered images, virtual tracheobronchoscopy, on a case by case basis.
- A few subtle abnormalities may be seen only on virtual bronchograms and they can be further assessed by focused examination of the axial data. These can provide accurate measurements of the length, luminal narrowing, and distance from the carina to plan bronchoscopic intervention or surgery.
• MDCT supplements bronchoscopy in pre-procedural planning and follow-up of numerous bronchoscopic and surgical procedures including transbronchial biopsies particularly for the submucosal and mediastinal lesion that are occult on bronchoscopy.

• Virtual bronchoscopy provides simulation training for interventional pulmonologists.

• Recent technical advances, including the routine use of CT thin sections and techniques such as 2D minimum-intensity-projection and 3D volume images, have increased our ability to detect large airways diseases. Furthermore, dedicated CT protocols allow the evaluation of dynamic airway dysfunction.

• With evolving techniques like modern multi-detector scanners, PET-CT, virtual bronchoscopy, and newer post processing techniques, we are able to achieve physiologic and metabolic information in addition to the intricate anatomical detail.

• Many of the lesions that were previously seen only on surgery can be seen with current imaging preoperatively and prepare the surgeon and interventionist to handle them.
Classification of tracheal disorders

Intrinsic
- Congenital
- Infectious
- Inflammatory/Infiltrative
- Non-inflammatory
- Iatrogenic
- Neoplastic

Extrinsic
- Extrinsic compression
- Fibrosing mediastinitis
Congenital abnormalities

- Tracheal bronchus
- Cardiac bronchus
- Bronchial atresia
Tracheal bronchus

An anatomical variant where an accessory bronchus originates directly from the supracarinal trachea. The term pig bronchus is often given when the entire upper lobe (usually right side) is supplied by this bronchus. Incidence is estimated at ~1% and there is a marked right sided predilection. Often incidentally discovered and most patients are asymptomatic. Occasionally patients may have a recurrent upper lobe pneumonia.
Cardiac bronchus

A rare variant of the tracheobronchial tree, arising from the medial aspect of the bronchus intermedius. This anomaly is rare and is reported in ~0.3% of individuals. It is almost always an incidental finding of CT examination of the chest. It appears as a continuation of the lumen of the right main bronchus, projecting medially and directly inferiorly towards the posterior aspect of the heart. No treatment is required. In rare instances where recurrent infections can be attributed to a cardiac bronchus then surgical resection may be carried out.
Bronchial atresia is a developmental anomaly characterized by focal obliteration of the proximal segment of a bronchus. Bronchial atresia is usually asymptomatic, and may be found incidentally. If symptomatic, it may cause shortness of breath, cough or rarely infection. It has been suggested that atresia is probably secondary to a traumatic event during fetal life rather than a result of abnormal growth and development. The bronchi distal to the atresia become filled with mucus and may form a mucocele/bronchocele. The lung distal to the atretic bronchus develops normally but is overinflated due to collateral air drift with air trapping.
Bronchial atresia

It is typically at the segmental or subsegmental level. It can involve any lobe but most commonly occurs at the apico-posterior segment of the left upper lobe, followed by right upper lobe.

**CT:**
Atretic bronchial stump(s) often become(s) mucus plugged and can give a finger in glove appearance. Distal lung parenchyma supplied by the atretic segment can be hyperlucent due to oligemia and air trapping with air entering through pores of Kohn.

**Differential diagnosis:**
Congenital lobar emphysema
Allergic bronchopulmonary aspergillosis.
Infection

- Viral – Croup
- Bacterial – including TB
- Fungal
Croup

AP radiographs of the neck/chest and CT neck demonstrates uniform narrowing of the subglottic airway
Croup or Acute laryngotracheobronchitis

- Due to viral infection of the upper airway by para-influenza virus or respiratory syncytial virus.
- Croup can happen in children as young as 6 months age up to 15 years but most commonly between 6 months to 3 years.
- Clinically it presents with protracted barking cough and inspiratory stridor due to mucosal edema resulting in tracheal narrowing.
- Plain radiograph: Steeple sign: seen on AP radiographs of the neck or chest and neck demonstrates uniform narrowing of the subglottic airway.
Inflammatory and Infiltrative diseases

Amyloidosis
Wegener’s granulomatosis
Sarcoidosis
Relapsing polychondritis
Rheumatoid arthritis

Non-inflammatory

Tracheobronchomalacia
Tracheobronchomegaly
Tracheopathia osteochondroplastica
Wegener's is characterized by necrotizing granulomatous inflammation that mainly involves the upper airway, lungs and the kidneys.

Although the disease affects males and females equally, more than 90% of patients with tracheal stenosis are females.

Subglottic stenosis is more frequent in patients with early age of onset.

Approximately, ninety percent of patients have elevated anti-neutrophilic cytoplasmic antibodies (c-ANCA).
Tracheomalacia in a 16 yr old girl with Pompe’s disease
A. 3-D reformatted image
B. Virtual bronchoscopy image
C. Radiograph demonstrating tracheal narrowing and scoliosis

Images – Courtesy of Dr. L. Averill, duPont Hospital for Children, Delaware
Tracheomalacia

- Tracheobronchomalacia is characterized by increased compliance and excessive collapsibility of trachea or bronchi. Increase in compliance is due to loss of structural integrity of components in the tracheal wall and may be congenital or acquired. The causes of congenital tracheomalacia include cartilage deficiency, generalized tracheomalacia, and congenital tracheoesophageal fistula. Acquired tracheomalacia is associated with endotracheal tubes and tracheostomy, closed chest trauma, lung resection, radical neck dissection, radiation therapy, chronic obstructive pulmonary disease, relapsing polychondritis, paratracheal vascular abnormality, and chronic or recurrent infection.

- Paired inspiratory–expiratory CT is recommended if patients present with dyspnea without chest pain and known cause of tracheomalacia, such as prior intubation, chronic obstructive pulmonary disease, or asthma.

- The most common CT finding during dynamic expiration was tracheal collapse with crescentic bowing of the posterior membranous trachea.
Mounier Kuhn/
Tracheobronchomegaly

Most frequently seen in middle age men before the age of 50.
The anatomical and physiological changes present in the airways predispose to stagnation within enlarged portions of the bronchial tree. Therefore, chronic productive cough or recurrent pulmonary infections are common.
The underlying abnormality is an absence or marked atrophy of the elastic fibres and smooth muscle within the wall of the trachea and main bronchi.
To consider the diagnosis, the diameter of the trachea should be greater than 3 cm.
Treatment is usually conservative with physiotherapy and postural drainage. Acute exacerbations are treated with antibiotics. In rare instances, tracheal stenting has been used.

Images courtesy of Dr. M. Kumaran, Brigham and Women’s Hospital, MA
Iatrogenic or Traumatic

- Post intubation stenosis
- Traumatic injury
- Foreign body aspiration
Post intubation stenosis

The main cause of stenosis at the cuff site is due to the pressure exerted on the tracheal mucosa by the cuff. A cuff pressure greater than about 30 mm Hg exceeds the mucosal capillary perfusion pressure, causing mucosal ischemia, which may lead to ulceration and chondritis of the tracheal cartilages. These circumferential lesions heal by fibrosis, leading to a progressive tracheal stenosis.
Foreign body aspiration

Aspirated chicken bone in the right lower lobe bronchus – Coronal image and MIP image
Foreign body aspiration

- Children under the age of four years are at increased risk of foreign body (FB) aspiration.
- Most (70-90%) foreign bodies are organic, most commonly seeds and nuts. Inorganic foreign bodies vary dramatically and can include teeth, coins, pins, pens/crayons, etc.
- Aspirated foreign bodies have a predominance for the right tracheobronchial tree.
- Plain radiograph: Chest x-ray will be normal in ~35%. Unilateral emphysema or atelectasis are the most common findings; only uncommonly will a radio-opaque foreign body be demonstrated.
- CT: Can be useful in assessment of missed or retained foreign body after initial bronchoscopy.
- Bronchoscopy is considered the gold-standard in the diagnosis of tracheobronchial foreign bodies with the added benefit of being able to potentially retrieve the foreign body.
Neoplasms

- Benign
- Malignant (primary, metastasis)
Tracheal neoplasms

- Tracheal neoplasms occur infrequently, accounting for fewer than 0.4% of all body tumors and less than 1% of all thoracic malignancies.
- The most common benign tumors are hamartomas and squamous cell papillomas. However, other minor tumors such as leiomyoma, neurogenic tumor, lipoma, or mucous gland adenoma may also arise in the tracheobronchial tree. Benign tumors tend to be well demarcated, round, and less than 2 cm in diameter. Because these tumors originate in the submucosa, the overlying epithelium is usually intact, resulting in a smooth appearance of the tumor surface in the airway lumen.
90% of tracheobronchial tumors in adults are malignant. Approximately 2/3rds of primary malignant tumors are carcinomas originating from the surface epithelium (most commonly squamous cell cancer) or the salivary glands (most commonly adenoid cystic carcinoma). Other primary malignancies such as mucoepidermoid carcinoma, carcinoid tumor, lymphoma, plasmacytoma, sarcoma, and adenocarcinoma can occur in the tracheobronchial tree but are very rare.

Tracheal or endobronchial metastases from distant primary malignancies are rare. Renal, breast, thyroid and colon cancers are the most common malignancies associated with tracheobronchial metastases.
Laryngotracheal papillomatosis

A. CT axial image showing polyps within the trachea with irregular borders
B. Virtual bronchoscopy showing multiple polypoid papillomas in the lower trachea

Images – Courtesy of Dr. L. Averill, duPont Hospital for Children, Delaware
Laryngotracheal papillomatosis

- Tracheobronchial papillomatosis is usually seen in young people, particularly children. This neoplasm is caused by the human papillomavirus, which is usually acquired at birth from an infected mother. The larynx is most commonly affected; however, extension into the trachea and proximal bronchi does occasionally occur. Rarely, the infection spreads into the lung parenchyma.

- The radiologic manifestations consist of multiple small nodules projecting into the airway lumen or diffuse nodular thickening of the airway wall. Endobronchial papillomas can result in obstructive pneumonia or atelectasis. Involvement of the distal airways and parenchyma can result in multiple nodules, which can measure up to several centimeters in diameter and frequently cavitate.
Tracheal metastasis
Tracheal metastasis

- Tracheal or endobronchial metastases from distant primary malignancies are rare. Renal, breast, thyroid and colon cancers are the most common malignancies associated with tracheobronchial metastases.
Summary of Content

- Although bronchoscopy remains the gold standard in the diagnosis of tracheal pathology, the proper utilization of radiologic imaging with Multidetector computed tomography permits improved patient care. Recent technical advances, including routine use of multiplanar reformations, 3-D volume rendered images, and virtual bronchoscopy can provide additional information.
References


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