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Imaging Acute Airway Obstruction in Infants and Children[1]

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SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- Discuss the unique anatomic features that predispose infants and children to respiratory distress.
- Describe the imaging recommendations for infants and children presenting with acute airway obstruction.
- Recognize the radiographic features of common causes of acute upper and lower airway obstruction.

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Acute airway obstruction is much more common in infants and children than in adults because of their unique anatomic and physiologic features. Even in young patients with partial airway occlusion, symptoms can be severe and potentially life-threatening. Factors that predispose children to airway compromise include the orientation of their larynx, the narrow caliber of their trachea, and their weak intercostal muscles. Because the clinical manifestations of acute airway obstruction are often nonspecific, clinicians often rely on the findings at imaging to establish a diagnosis. Several key anatomic features of the pediatric airway make it particularly susceptible to respiratory distress, and the imaging recommendations for children suspected of having acute airway obstruction are presented. Although cross-sectional imaging may be helpful, the diagnosis can often be established by using radiographs alone. Radiographs of the chest and upper airway should be routinely acquired; however, for the child who is in severe distress, a single lateral radiographic view may be all that is necessary. The purpose of this article is to provide an imaging approach to acquired causes of acute airway obstruction in children, including *(a)* abnormalities affecting the upper portion of the airway, such as croup, acute epiglottitis, retropharyngeal infection, and foreign bodies, and *(b)* abnormalities affecting the lower portion of the airway, such as asthma, bronchiolitis, and foreign bodies. It is essential that the radiologist recognize key imaging findings and understand the pathophysiologic features of acute airway obstruction because in most cases, when the cause is identified, the condition responds well to prompt management.

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Introduction

Respiratory distress, which accounts for 10% of visits to the pediatric emergency department, is more common in children than in adults because of their unique anatomic and physiologic features (1). Even with partial airway occlusion, symptoms can be severe. Patients typically present with tachypnea, stridor, and grunting, although infants with complete obstruction may have apnea, and their condition can deteriorate quickly to cardiopulmonary arrest (2). The findings from the history and physical examination are often nonspecific, leaving clinicians to rely on imaging findings to identify the cause for acute obstruction. It is important for every radiologist working at a hospital where children are treated to be able to recognize imaging findings of airway obstruction. Although the causes of acute airway obstruction can be life-threatening, with appropriate recognition they are often treatable.

TEACHING POINTS

- In acute upper airway obstruction, upright soft-tissue lateral and frontal radiographs of the neck are recommended. If the patient's condition is unstable, a single upright soft-tissue lateral radiograph is usually sufficient to make the diagnosis.
- Several anatomic factors predispose children to acute respiratory distress, even with only partial airway obstruction.
- Although it is possible, viral croup is unlikely to occur in children older than 3 years of age. If there are radiographic findings of croup outside the expected age range, membranous croup and foreign-body aspiration should be considered.
- It is essential to recognize disk batteries lodged in the esophagus because serious complications, including perforation, can occur within hours as a result of the current generated by the battery and the potential leakage of caustic material. After retrieval of the battery from the esophagus, an upper gastrointestinal examination should always follow, to evaluate for esophageal strictures, erosions, tracheoesophageal fistulas, or even aortoesophageal fistulas.
- In the setting of partial airway occlusion, expiratory views have been shown to increase the diagnostic accuracy and should be obtained when possible.

Figure 1. Pseudothickening of the retropharyngeal soft tissues. Lateral neck radiograph shows that when the patient's neck is flexed, the retropharyngeal soft tissues (arrowhead) appear falsely thickened.

The differential diagnosis for acute airway obstruction in infants and children can be divided anatomically into conditions affecting the upper portion of the respiratory tract and those affecting the lower portion of the respiratory tract (3). The purpose of this article is to review the acquired causes of pediatric acute airway obstruction, including the clinical and imaging features that are helpful in distinguishing between these two groups of entities. First, the imaging recommendations are presented, followed by the anatomic considerations. Then the abnormalities of acute upper airway obstruction are covered, including the specific upper airway conditions of croup, acute epiglottitis, retropharyngeal infection, and upper airway foreign bodies. Finally, the abnormalities of acute lower airway obstruction are discussed, including the specific lower airway conditions of asthma, bronchiolitis, lower respiratory tract inflammation, and bronchial foreign bodies.

Imaging Recommendations

Radiographs are an integral part of the algorithm for evaluating children suspected of having airway obstruction. Additional imaging modalities such as computed tomography (CT) or magnetic resonance (MR) imaging may also be helpful but are often not required to make the diagnosis. It is important to minimize patient anxiety while the radiographs are being obtained because crying can exacerbate respiratory distress. When possible, caregivers should accompany children to the radiology department. In children suspected of having epiglottitis, intubation equipment should be nearby because acute deterioration may occur.

In acute upper airway obstruction, upright soft-tissue lateral and frontal radiographs of the neck are recommended. If the patient's condition is unstable, a single upright soft-tissue lateral radiograph is usually sufficient to make the diagnosis. The lateral views should be obtained with the patient upright with the head in neutral position (or slight extension) to avoid "pseudothickening" of the retropharyngeal tissues (Fig 1). Pseudothickening can occur because of the flexed position, young age, and expiration. Note that flexion will also exacerbate the patient's respiratory distress.

In acute lower airway obstruction, upright frontal chest radiographs should be acquired during inspiration and possibly also during expiration. An upright lateral soft-tissue radiograph of the neck should also be obtained. A good-quality inspiratory chest radiograph should be obtained in which at least six anterior ribs are depicted at the level of the mid hemidiaphragm. At our institution, expiratory chest radiographs to assess for airtrapping are obtained only when there is clinical concern about possible aspiration of a foreign body (4,5).

Anatomic Considerations

Several anatomic factors predispose children to acute respiratory distress, even with only partial airway obstruction (6). In children, the nasopharynx is narrower and the trachea is shorter than in adults (7). Also, the pediatric larynx is more anteriorly and superiorly located. The pediatric larynx is at the level of the third and fourth cervical

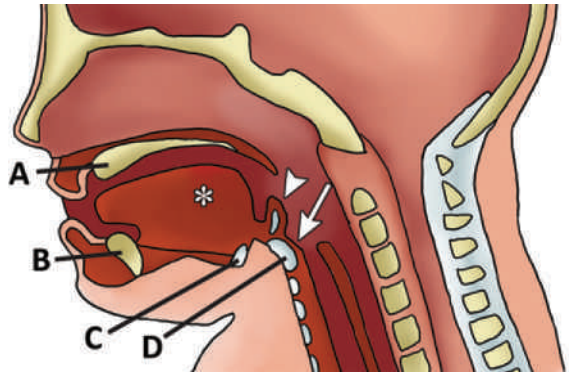


Figure 2. Drawing showing the features of the pediatric upper airway. In children, the larynx (arrow) is more cranially located, the epiglottis (arrowhead) is broader, and the tongue (*) is larger than in adults. *A* = hard palate, *B* = mandible, *C* = hyoid cartilage, *D* = thyroid cartilage.

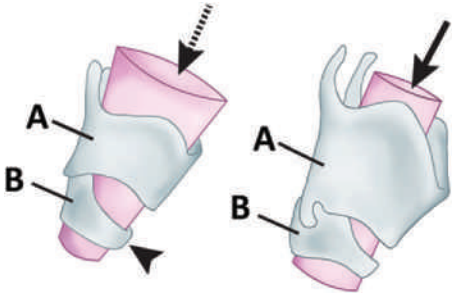


Figure 3. Drawings comparing the pediatric (left) and adult (right) upper airways. The pediatric cricoid cartilage (arrowhead) is the narrowest part of the airway, producing a funnel-shaped airway (dashed arrow). In comparison, the adult upper airway is cylindrical (solid arrow), with no narrowing at the level of the cricoid cartilage *(B)*. It is important to note, however, that the laryngeal cartilages are not seen on pediatric radiographs because these cartilages do not begin to calcify until adulthood. *A* = thyroid cartilage, *B* = cricoid cartilage.

vertebral bodies (C3 and C4), compared with the adult larynx, which is located at the level of the fifth and sixth cervical vertebral bodies (C5 and C6) (Fig 2). The cricoid cartilage is the narrowest part of the pediatric airway (Fig 3) (6), and the narrowest part of the adult upper airway is the glottis opening. In children, the conus elasticus (the elastic membrane extending between the cricoid cartilage and vocal ligaments located approximately 1 cm below the glottis) is particularly susceptible to edema because of its loose mucosal attachment (8). The vocal cords are more anteriorly angled, the epiglottis is broader and longer, and the tongue is larger, making it more difficult for children to move air past areas of obstruction or stenosis. Children also have weaker intercostal and diaphragmatic muscles and a lower cardiopulmonary reserve, making it difficult for them to compensate for airflow obstruction.

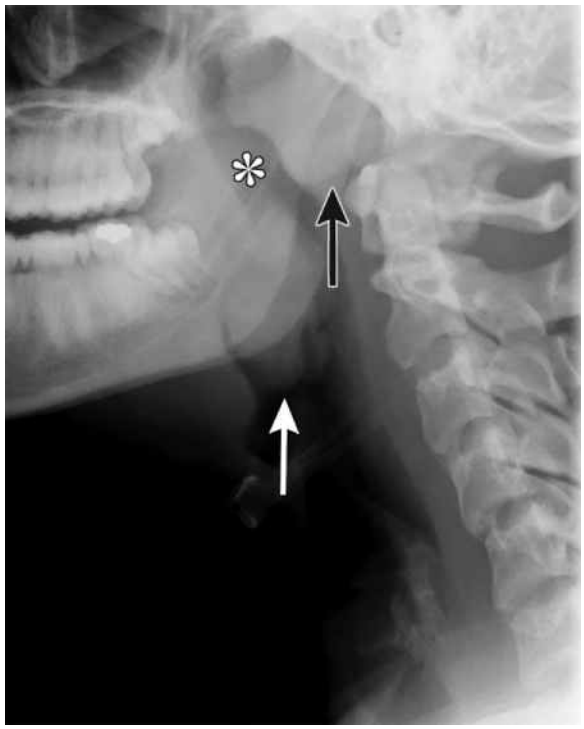


Figure 4. Abnormal tonsils in a 16-year-old girl with mononucleosis. Lateral neck radiograph shows enlarged lingual tonsils (white arrow) and pharyngeal tonsils (black arrow), which are more commonly referred to as adenoids. Note that the normal air column through the nasopharynx is narrowed (*).

Children have more prominent tonsils than adults. The size of the lingual tonsils and pharyngeal tonsils (also known as the adenoids, located in the posterior nasopharynx) vary with age. After 3 months of age, the tonsils become progressively larger and reach maximum size at 2–10 years of age. The tonsils are best depicted on a lateral radiograph obtained with the patient's mouth closed and the patient in deep inspiration without swallowing. The tonsils may enlarge as a result of infection and gastroesophageal reflux. Increased soft tissue in this region can result in obstructive sleep apnea and chronic ear and sinus infections. There are no clear measurements to determine healthy tonsils. The lingual tonsils are considered enlarged if they occupy greater than 50% of the oropharynx, and the pharyngeal tonsils are considered abnormal if they narrow the nasopharynx (Fig 4).

Acute Upper Airway Obstruction

The upper portion of the airway, by definition, lies above the thoracic inlet. Upper airway obstruction can be divided into inflammatory, neoplastic, and iatrogenic causes. Inflammatory processes such as croup, acute epiglottitis, exudative tracheitis, and retropharyngeal cellulitis and abscess are more common, whereas neoplasms, which may be

Figure 5. Frontal neck radiograph showing the normal appearance of the subglottic airway in the frontal projection.

intrinsic or extrinsic, are less common. Classically, obstruction of the upper airway produces stridor, and the type of stridor is defined by the level of obstruction (9). Inspiratory stridor is caused by narrowing of the epiglottic, glottic, and subglottic regions (9). Biphasic stridor may be caused by narrowing of the glottic or subglottic regions, and expiratory stridor is caused by narrowing of the trachea (9).

Croup

Clinical Features.—Croup, or laryngotracheobronchitis, occurs because of subglottic inflammation, most commonly a result of infection with parainfluenza virus, and typically occurs in children between 6 months and 3 years of age (10). Croup is the most common cause of airway obstruction in young children (11). Younger patients have a characteristic "barking" cough that is worse at night and when crying. Treatment is supportive because the symptoms are usually self-limited (11); however, symptoms can occasionally be severe and require aggressive therapy.

Imaging Features.—When imaging is indicated, a frontal radiograph of the neck is considered the most helpful image. Normally, in this view, the subglottic larynx should have smooth lateral convex shoulders (Fig 5). However, when subglottic inflammation and elevation of the mucosa occur, there is loss of these lateral convexities, leading to narrowing of the tracheal air column and producing the steeple sign (also called the inverted *V* sign), which resembles a church steeple (Fig 6a) (12). Recall that the clonus elasticus is particularly susceptible to edema because of its loose mucosal attachment, which explains why even though the entire larynx, trachea, and bronchi are inflamed, it is the subglottic region that is most narrowed. It is important to note that the steeple sign denotes only subglottic edema, and this sign can be absent in croup and present in other inflammatory conditions of the upper airway. Therefore, the clinical context is essential to confidently make the diagnosis. On the lateral soft-tissue neck radiograph, signs of croup include subglottic narrowing and increased density of the subglottic region (Fig 6b). Always identify the normal epiglottis on every lateral radiograph, because this identification will exclude epiglottitis, a more sinister diagnosis, from the differential diagnosis. Hypopharyngeal overdistention commonly occurs with acute obstruction of the upper airway; however, it also occurs at the end inspiratory phase of breathing in a crying child, a finding that is a common diagnostic pitfall. In these cases, look carefully for indistinctness of the laryngeal soft tissues, and scrutinize the frontal projection.

Diagnostic Pearls.—Although it is possible, viral croup is unlikely to occur in children older than 3 years of age. If there are radiographic findings of croup outside the expected patient age range, membranous croup (Fig 7) and foreign-body aspiration should be considered. Also consider these alternate diagnoses if symptoms do not resolve within a few days (11).

Acute Epiglottitis

Clinical Features.—Acute epiglottitis is a potentially life-threatening cause of acute upper airway obstruction, which is due to cellulitis of the epiglottis and frequently the surrounding soft tissues including the aryepiglottic folds and subglottic region (12). Acute epiglottitis may result from infectious causes (most commonly, *Haemophilus influenzae* type b) or noninfectious causes (eg, angioedema, trauma, ingestion of a caustic agent, and anaphylaxis). Prior to the availability of the vaccine for *H influenzae* type b, the average age at diagnosis of epiglottitis in children was 3.5 years; however, widespread vaccination has dramatically reduced the incidence of epiglottitis in children, and the average age at diagnosis is now 14.6 years (13). Patients present with abrupt onset of stridor, dysphagia, fever, and sore throat. Typically, emergent intubation is required to protect the airway, and a referral to an otolaryngologist is recommended.

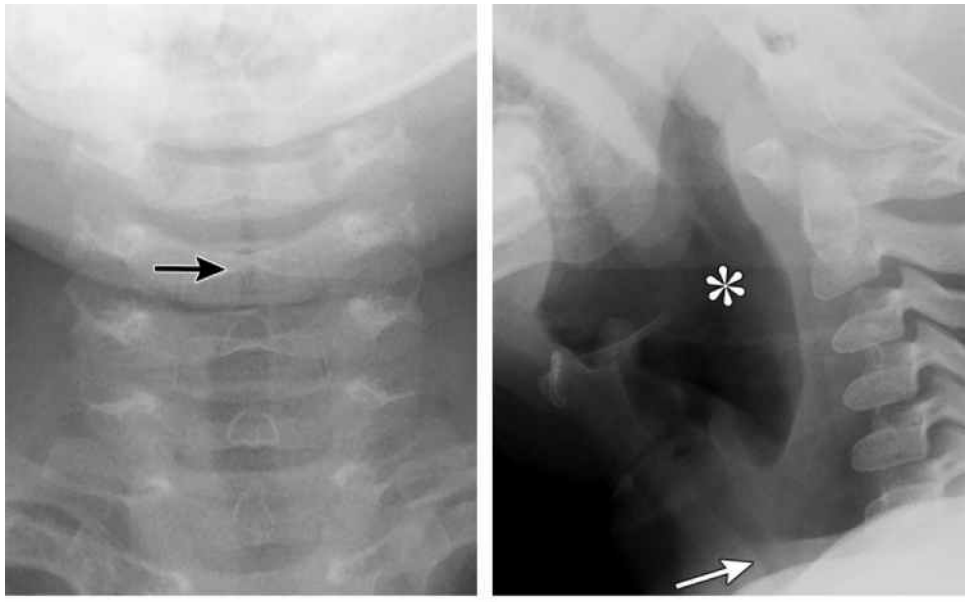


Figure 6. Croup in a 4-year-old boy. **(a)** Frontal neck radiograph shows subglottic narrowing with a loss of the normal convex shoulders at the transition to the larynx, a finding termed the steeple sign (arrow). **(b)** Lateral neck radiograph shows indistinctness and narrowing of the subglottic region (arrow) and overdistention of the hypopharynx (*). In cases in which overdistention is caused by crying, indistinctness of the laryngeal soft tissues will not be seen.

Imaging Features.—Imaging may not be necessary; however, if it is pursued, a single upright lateral neck radiograph is the image of choice because the patient's condition is potentially unstable. Normally, the epiglottis should have well-defined thin margins, and the aryepiglottic folds should be thin and convex inferiorly. The swelling and submucosal edema of the epiglottis in acute epiglottitis produce the characteristic thumb sign on the lateral radiograph, and the aryepiglottic folds are thickened (Fig 8) (12). As the infection progresses, the supraglottic larynx demonstrates additional swelling, which is sometimes termed *supraglottitis*.

Diagnostic Pearls.—When the patient cannot tolerate upright neck radiography, images can be acquired with the patient in the supine position. At our institution, supine anteroposterior or cross-table lateral projections are obtained in patients who weigh less than 19 lb (8.6 kg) or who have poor head control (eg, immaturity or hypotonia). Care is taken to bolster the patient's back so that the chin is not flexed against the chest.

Figure 7. Bacterial tracheitis in an 8-year-old girl. Lateral neck radiograph shows indistinctness and increased density of the subglottic region (arrowhead), as well as narrowing of the subglottic airway (arrow).

Retropharyngeal Infection

Clinical Features.—Approximately 50% of retropharyngeal infections are preceded by an upper respiratory tract infection (14). The most common cause of retropharyngeal abscess is rupture of suppurative lymph nodes into this space (14). In prepubertal children, two lymph node chains within the retropharyngeal space drain the nasopharynx and middle ear, and these lymph node chains atrophy at puberty (15). Other

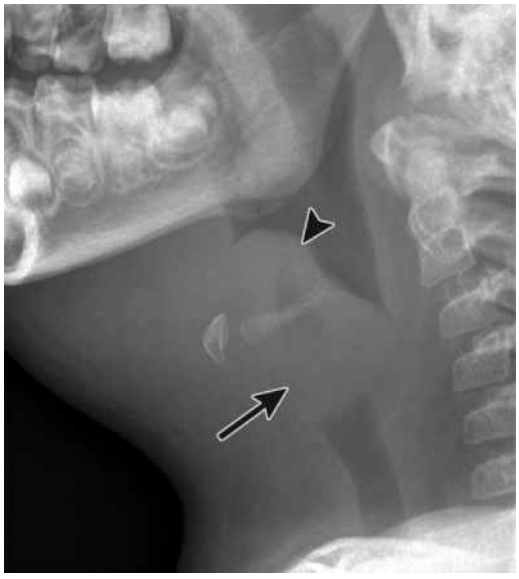
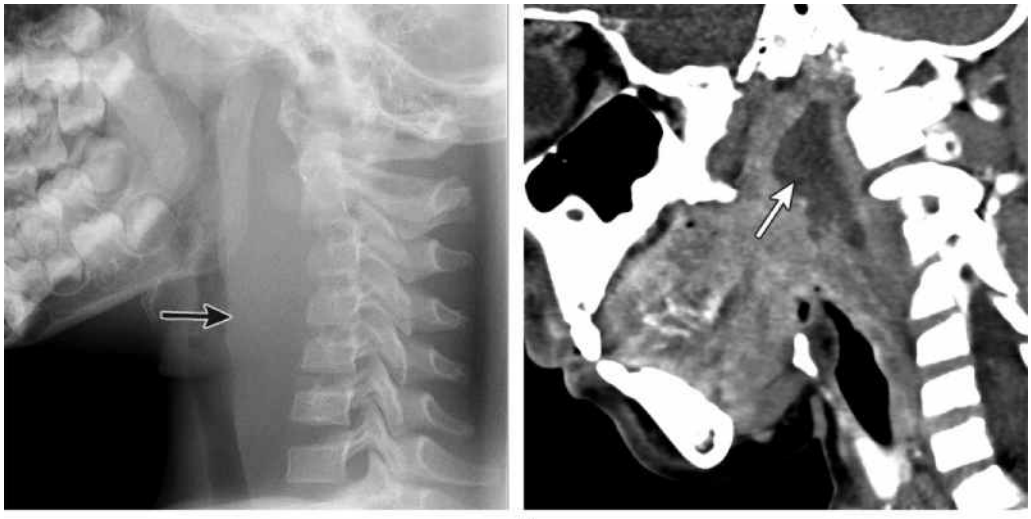


Figure 8. Acute epiglottitis in a 4-year-old boy. Lateral soft-tissue radiograph shows marked swelling of the epiglottis (arrowhead), a finding termed the thumb sign. In addition, thickening of the aryepiglottic folds and increased opacity of the larynx and vocal cords (arrow) are depicted.



a. **b.**

Figure 9. Retropharyngeal infection in a 12-year-old boy. **(a)** Lateral neck radiograph shows thickening of the retropharyngeal soft tissues (arrow). **(b)** Sagittal contrast material–enhanced CT image obtained with reconstruction from a CT examination performed 5 days later shows a rim-enhancing hypoattenuating collection consistent with a retropharyngeal abscess (arrow).

causes include *(a)* ventral spread from diskitis or osteomyelitis, *(b)* spread from a mediastinal infection, and *(c)* a penetrating foreign body (16). The infections are typically polymicrobial, with organisms including *Staphylococcus aureus*, *H influenzae*, and *Streptococcus pneumoniae* (15). Retropharyngeal cellulitis is more common than retropharyngeal abscesses. Although most patients are between 2 and 4 years old, neonates can also be affected (16). Patients are usually unwell, with signs of sepsis (16).

Imaging Features.—If the patient is properly positioned, the anteroposterior width of the retropharyngeal soft tissues should be less than the anteroposterior width of a cervical vertebral body. When thickened, the retropharyngeal soft tissues bow anteriorly and displace the airway (Fig 9a). It is important to look for locules of gas within the thickened tissues, a finding that may be subtle and indicate an abscess. It is also important to evaluate carefully for a possible ingested foreign body that may be the cause of the infection. All patients for whom there is a strong clinical suspicion of retropharyngeal abscess (eg, high fever) and all patients for whom there is radiographic concern for an abscess should undergo a CT examination with intravenous contrast material (17). CT is the reference standard for the diagnosis of a retropharyngeal abscess and is best able to delineate the extent of the abscess and to allow

evaluation for complications. Imaging features include a hypoattenuating ovoid fluid collection distending the retropharyngeal space (Fig 9b). In the early stages, the findings are subtle and may include only soft-tissue swelling or slight peripheral rim enhancement. However, in the later stages, the collection will have irregular enhancing walls. It is important to look carefully for complications, including jugular vein thrombosis (Lemierre syndrome), spread of infection, and arterial abnormalities, including pseudoaneurysms.

Diagnostic Pearls.—If the patient requires cross-sectional imaging, ensure that at least part of the mediastinum has been imaged to exclude descending mediastinitis (18).

Upper Airway Foreign Bodies

Clinical Features.—Aspirated and ingested foreign bodies are a common cause of death in children younger than 2 years old (19). Only 3% of aspirated foreign bodies lodge in the larynx, and these are usually bulky, irregularly shaped, or sharp (ie, penetrating) (20–23). In most cases, infants and young children aspirate food items, whereas older children aspirate nonfood items. The event is often unwitnessed (20,24–26). Ingested foreign bodies lodged in the esophagus are more common and may also contribute to respiratory compromise (27,28). The ingestion of dishwasher and laundry detergent "pods," which occurs more often in infants and toddlers, can result in airway compromise caused by severe caustic injury to the esophagus and the surrounding tissues (29,30).

Imaging Features.—In the setting of a suspicion of upper airway foreign body aspiration or ingestion, frontal and lateral radiographs of both the upper airway and chest are extremely helpful. When possible, it is important to identify the type and number of foreign bodies. However, this identification is often difficult because most foreign bodies are not radiopaque (eg, organic materials) (Fig 10). In these cases, indirect signs of airway obstruction can be detected, including overdistention of the hypopharynx and prevertebral soft-tissue swelling. Because there is usually a delay in the time to clinical manifestation (on average, 24 hours), look carefully for complications (31) (Fig 11). CT is usually indicated only to assess for a residual foreign body after bronchoscopy or when there is a suspicion of serious complications, such as aortic perforation (32). Esophageal foreign bodies may also cause airway obstruction because of mass effect and inflammation (Fig 12).

Figure 10. Upper airway foreign body in a 5-year-old boy with dysphagia. Lateral neck radiograph shows a vertically oriented slender fish bone (arrow) impacted into the epiglottis. It is important to scrutinize the upper airway at radiography because the appearance of foreign bodies may be subtle.

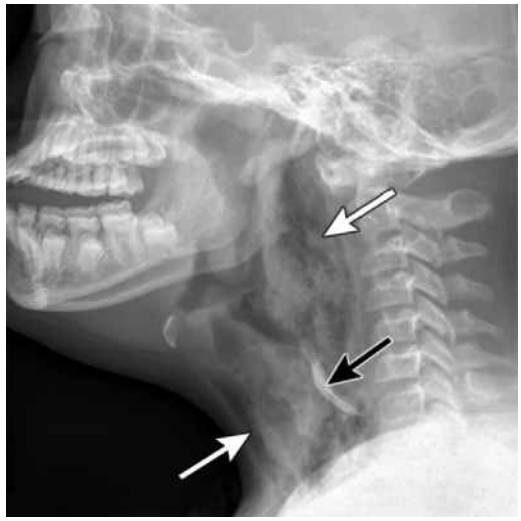


Figure 11. Upper airway foreign body in a 5-year-old boy with Down syndrome who presented with difficulty breathing and drooling. Lateral neck radiograph shows a radiopaque foreign body (black arrow) that proved to be a bone from soup he had recently eaten. Note the extensive subcutaneous emphysema (white arrows) from tracheal and esophageal perforation. Children with Down syndrome are more susceptible to respiratory distress because of their relatively larger head and poor tone.

Diagnostic Pearls.—It is essential to recognize disk batteries lodged in the esophagus because serious complications, including perforation, can occur within hours as a result of the current generated by the battery and the potential leakage of caustic material (Fig 13) (33). After retrieval of the battery from the esophagus, an upper gastrointestinal examina-

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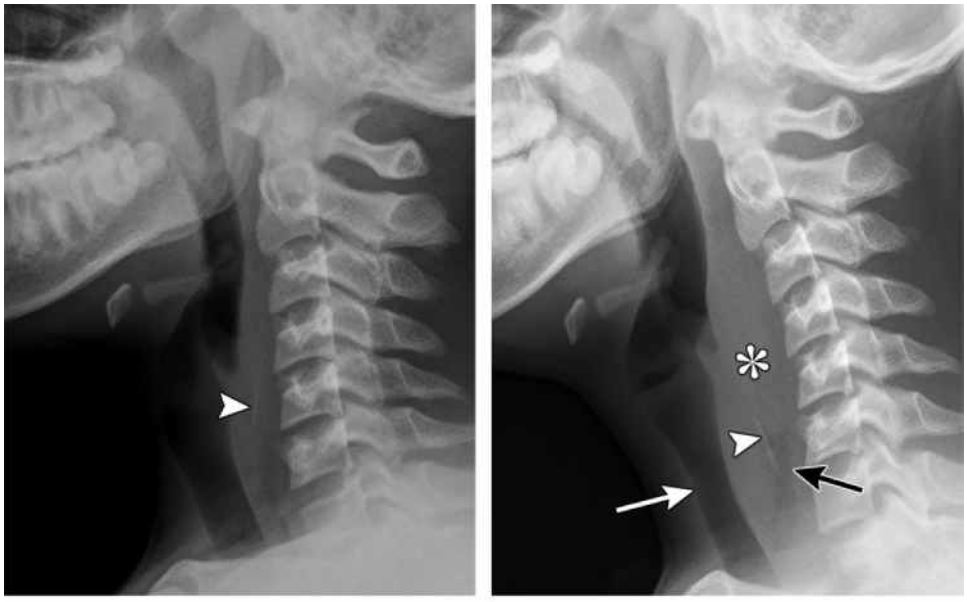
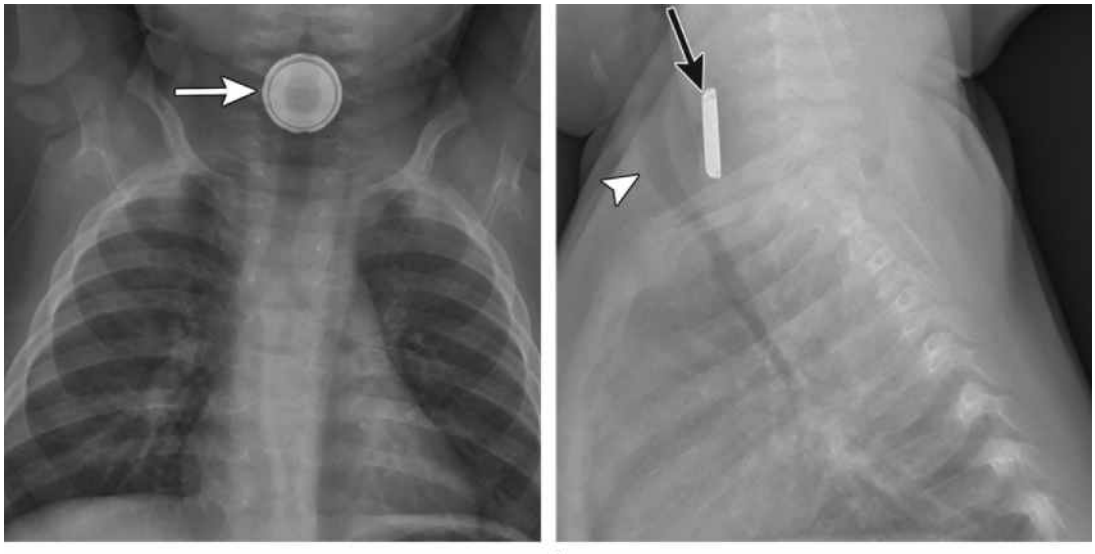


a. b.

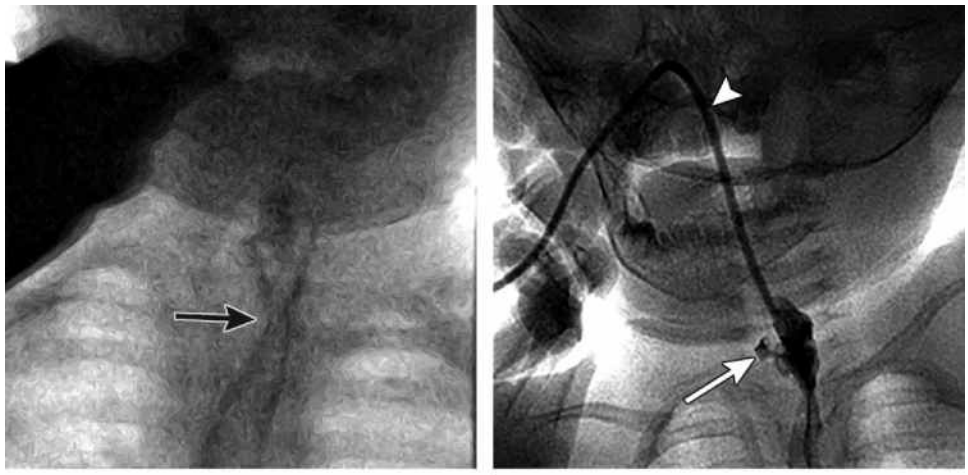
Figure 12. Esophageal foreign body, which proved to be a fish bone at endoscopic removal, in a 6-year-old boy. **(a)** Lateral neck radiograph shows a linear opacity (arrowhead), which was initially overlooked in the emergency department, and also mild thickening of the retropharyngeal soft tissues. **(b)** Lateral neck radiograph acquired 4 days later, when the patient returned to the hospital, again shows the foreign body (white arrowhead). Note the substantial progression of the retropharyngeal soft-tissue thickening (*), as well as the development of locules of gas, in keeping with a retropharyngeal abscess (black arrow). The retropharyngeal soft-tissue thickening pushes the trachea anteriorly, and the convex posterior wall narrows the air column (white arrow). The normal cervical lordosis is also reversed because of the adjacent inflammation.



a. b.

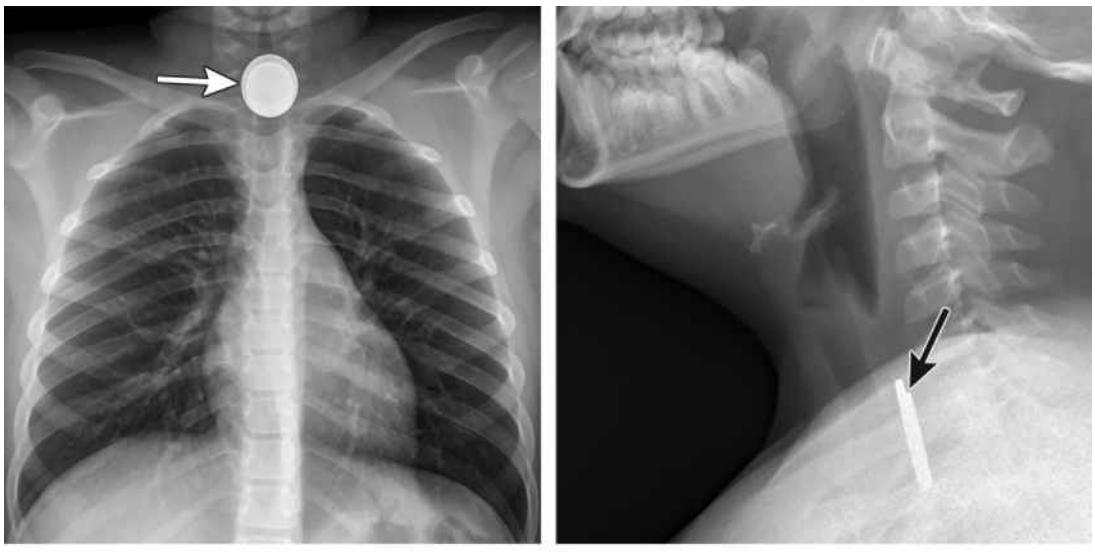
Figure 13. Ingestion of a disk battery in a 2-year-old boy. **(a)** Frontal chest radiograph shows the disk battery (arrow) lodged in the upper part of the esophagus. In the frontal projection, esophageal foreign bodies lie transversely, and tracheal foreign bodies have a sagittal orientation because of the lack of cartilage in the posterior aspect of the trachea. Note the uniform bilaminar appearance, which creates a peripheral ring of increased lucency. **(b)** Lateral chest radiograph shows confirmation of the bilaminar appearance, which in profile produces shouldering (arrow), a finding that is characteristic of a disk battery. Note the focal soft-tissue swelling, which has resulted in a convex anterior trachea (arrowhead).

tion should always follow, to evaluate for esophageal strictures, erosions, tracheoesophageal fistulas, or even aortoesophageal fistulas (Fig 14) (34). On the frontal radiograph, stacked coins may mimic disk batteries (Fig 15a), and a lateral projection is often helpful in differentiating these objects (Fig 15b). If the patient is asymptomatic, ingested coins usually do not require immediate intervention (35).



a. b.

Figure 14. Ingestion of a disk battery in an 18-month-old girl, a finding that was not immediately recognized. After endoscopic removal of the battery, the patient underwent an upper gastrointestinal study, which is routine at our institution. **(a)** Fluoroscopic image shows a focal esophageal stricture (arrow) where the battery was lodged. **(b)** Subsequent fluoroscopic image shows a nasogastric tube (arrowhead) that was inserted at the site of the esophageal narrowing and injected with contrast material to reveal an esophageal ulceration (arrow).



a. b.

Figure 15. Ingestion of two coins of different sizes in a 6-year-old boy. **(a)** Frontal chest radiograph shows that the two coins lodged in the esophagus (arrow) are superimposed, giving the appearance of a disk battery. **(b)** Lateral neck radiograph shows that there is a "step-off" (arrow) between the two coins, a finding that helps confirm their identity.

Neoplasms

Clinical Features.—Occasionally, chronic processes such as tracheal or laryngeal neoplasms may manifest with acute respiratory distress. For these entities to manifest acutely, there is usually a sudden change in either the mass (eg, hemorrhage) or the already compromised airway (eg, superimposed viral infection). Neoplastic masses may be divided into endoluminal masses, which result in partial occlusion, or extraluminal masses, which result in extrinsic compression. The most common endoluminal masses in children are recurrent respiratory papillomatosis, laryngoceles, and subglottic hemangiomas. Extraluminal masses arising from any adjacent structure may compress the airway; such masses include bronchogenic cysts, lymphadenopathy, and neuroblastoma.

Imaging Features.—The frontal radiograph often demonstrates narrowing of the trachea, which may be concentric or eccentric. In the case of subglottic hemangiomas, there will be posterolateral subglottic airway narrowing, which is best appreciated on the frontal radiograph (36). When only a

RadioGraphics

Figure 16. Biphasic stridor in a 10-day-old male infant. Lateral neck radiograph shows a subtle soft-tissue density (arrow) projecting off the posterior wall of the trachea and severely narrowing the subglottic trachea, a finding that is characteristic of a subglottic hemangioma. Note that the infant also has a nasogastric tube (arrowhead) in situ.

lateral radiograph has been obtained, evaluate the subglottic airway carefully for a subtle endoluminal mass (Fig 16). Although radiography is helpful in diagnosis of a neoplasm, intravenous contrast material–enhanced cross-sectional imaging is usually required to delineate the full extent of the mass (Fig 17). Although MR imaging is often preferred because of its lack of ionizing radiation, CT provides better spatial resolution and may not require patient sedation. If the mass is malignant, additional imaging will be required for staging.

Diagnostic Pearls.—It is essential to evaluate the trachea on every lateral neck and chest radiograph because the trachea is often a blind spot. Normally, the trachea should be uniform in caliber and course just to the right of midline in the thorax (because of the left-sided aortic arch) on the frontal projection and should be straight or convex slightly posteriorly on the lateral projection.

Acute Lower Airway Obstruction

The lower portion of the airway includes the intrathoracic trachea and bronchi. Acute processes affecting these structures can be divided into *(a)* infectious and inflammatory causes, such as bronchiolitis, lower respiratory tract inflammation, and reactive airways disease, and *(b)* other causes, such as aspirated foreign bodies. In the lower airway, neoplasms do not typically result in acute manifestations. The differential diagnosis for the infectious and inflammatory category can be further divided on the basis of the child's age (Fig 18) (3).

Reactive Airways Disease and Asthma

Clinical Features.—Asthma is characterized by chronic reversible hyperresponsiveness of the airways, which leads to airflow obstruction. Acute exacerbations are due to inflammatory infiltration and edema in response to environmental or emotional triggers. Most children with asthma (80%) develop symptoms before 5 years of age; however, the diagnosis of asthma is often not established until later in childhood, once the laboratory and clinical parameters have been taken into account (37). At our institution, the term *reactive airways disease* is used if the clinical diagnosis of asthma has not yet been established, usually in children between 2 and 6 years old.

Imaging Features.—Imaging is usually helpful only to identify complications, such as barotrauma and pneumonia, or rule out other causes of respiratory distress (38). Chest radiography is usually indicated only when the patient's condition does not respond to standard therapy or there is clinical concern for superimposed pneumonia. In many cases, the radiograph may be normal or show subtle findings of hyperinflation, including increased anteroposterior chest diameter, increased retrosternal airspace, and flattening of the hemidiaphragms (Fig 19). In more severe cases, bronchial wall thickening, atelectasis, and peripheral oligemia may be present. It is important to assess for entities that mimic asthma, such as an aspirated foreign body. CT is not indicated unless the clinical picture is confusing (39).

Diagnostic Pearls.—The complications of asthma, specifically barotrauma, are often overlooked on radiographs. Because of raised intrathoracic pressures, the alveoli may rupture, and gas will track along the interstitium to the mediastinum. In patients who are suspected of having asthma or reactive airways disease, evaluate carefully for evidence of pneumothorax, pneumomediastinum, or subcutaneous emphysema on radiographs of both the neck and the chest (Fig 20).

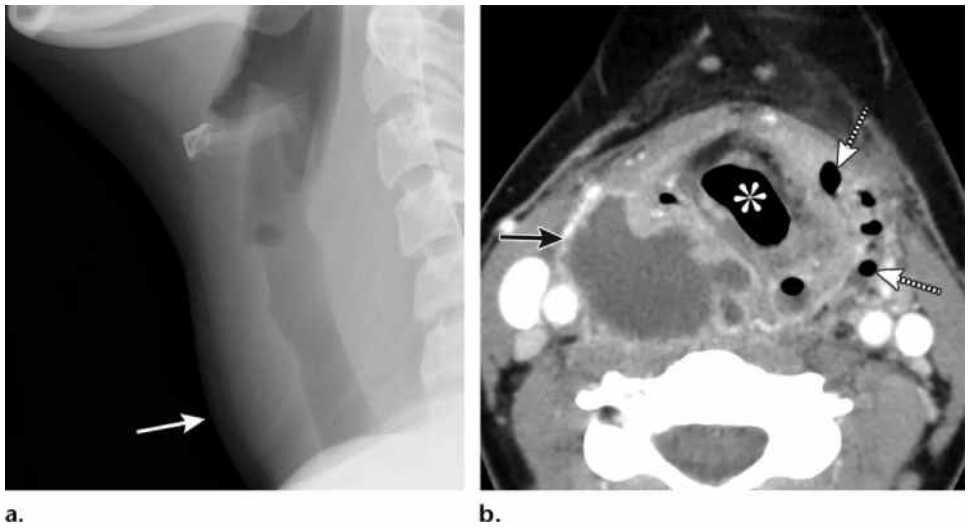


Figure 17. Acute suppurative thyroiditis in a 14-year-old girl who presented with shortness of breath and odynophagia. **(a)** Lateral neck radiograph shows soft-tissue swelling (arrow) at the expected level of the thyroid gland. **(b)** Axial contrast-enhanced CT image shows multiple rim-enhancing collections (black solid arrow) and gas (white dashed arrows) within the thyroid gland, findings consistent with abscesses. Note the narrowing and displacement of the subglottic trachea (*) caused by the adjacent soft-tissue swelling.

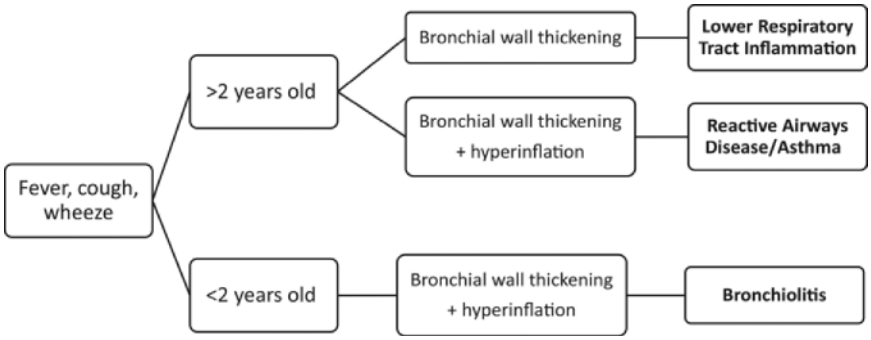


Figure 18. Diagram of the approach to acute lower airway obstruction in children. All three of these conditions (lower respiratory tract inflammation, reactive airways disease/asthma, and bronchiolitis) can be complicated by a focal airspace opacity, which may indicate pneumonia or atelectasis. It is important to raise the possibility of pneumonia because antibiotic therapy may be indicated.

Bronchiolitis and Lower Respiratory Tract Inflammation

Clinical Features.—Bronchiolitis and lower respiratory tract inflammation are both caused by inflammation of the small airways that is due to a viral antigen, usually respiratory syncytial virus or rhinovirus (40). The virus infects the terminal bronchioles, which leads to edema. The term *bronchiolitis* is used when the patient is younger than 2 years of age, and the term *lower respiratory tract inflammation* is used for children older than 2 years of age. In children older than 2 years, respiratory syncytial virus is not as common (41). Many children with virus-induced wheezing, whether bronchiolitis or lower respiratory tract inflammation, will go on to develop asthma later in life (42).

Imaging Features.—As in the setting of asthma and reactive airways disease, radiographs are obtained only when there is a clinical suspicion of pneumonia or other complications. In bronchiolitis, the airways are small, and bronchial wall edema leads to hyperinflation (Fig 21). Signs of hyperinflation include more than six anterior rib ends depicted on the frontal projection, downward sloping and flattening of the hemidiaphragms, and increased retrosternal airspace. In these small children, lung tissue may be seen herniating through the intercostal spaces. The inflammation and the edema of the airways result in perihilar bronchial wall thickening. Normally, the bronchi should be pencil thin when viewed en face. Bronchial wall thickening is also present in lower respiratory tract inflammation; however, because the patient is older (>2 years of age), the

RadioGraphics

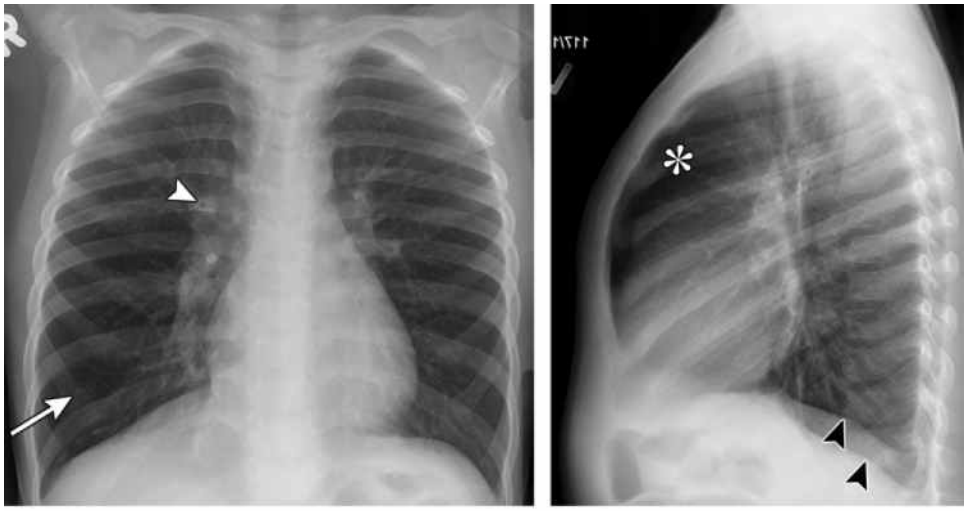


Figure 19. Reactive airways disease in a 6-year-old girl who presented with wheeze. **(a)** Frontal chest radiograph shows that the seventh rib (arrow) does not overlap the hemidiaphragm, a finding consistent with hyperinflation. In addition, evidence of bronchial wall thickening (arrowhead) is shown. **(b)** Lateral chest radiograph shows further signs of hyperinflation, including an increased retrosternal airspace (*) and flattening of the hemidiaphragms (arrowheads).

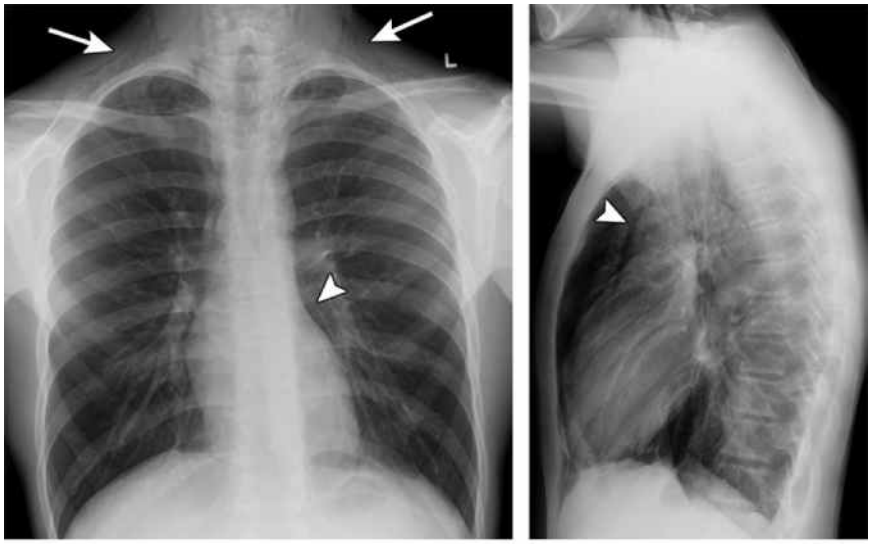


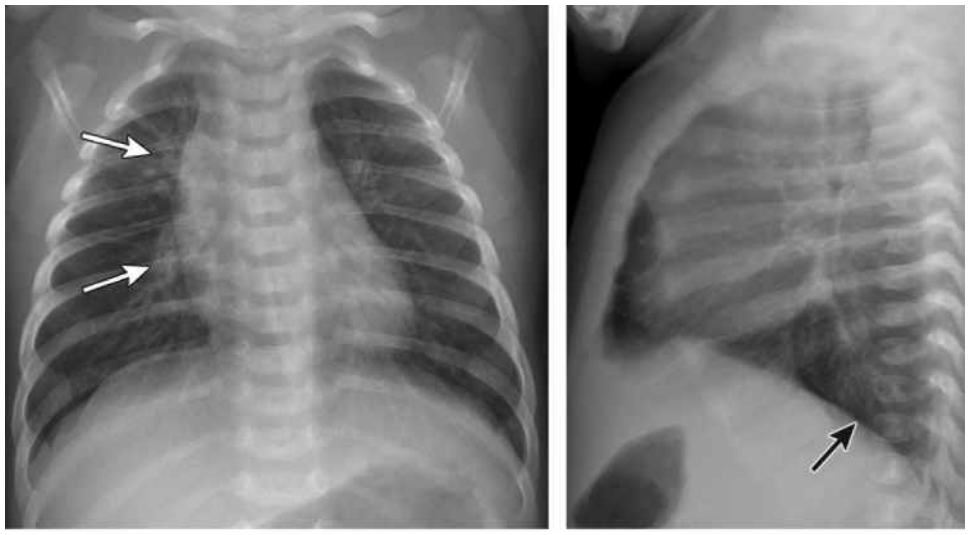
Figure 20. Exacerbation of known asthma complicated by pneumomediastinum in a 12-year-old boy. **(a)** Frontal chest radiograph shows evidence of subcutaneous emphysema (arrows) and air within the mediastinum (arrowhead). **(b)** Lateral chest radiograph also shows the pneumomediastinum (arrowhead).

bronchi are larger, and the inflammatory changes do not necessarily result in narrowing or hyperinflation (Fig 22). It is important in both bronchiolitis and lower respiratory tract inflammation to look for signs of atelectasis and consolidation.

Diagnostic Pearls.—Patchy linear areas of atelectasis are usually seen in the setting of infection with respiratory syncytial virus (Fig 23). The course of respiratory syncytial virus–associated bronchiolitis is usually more severe in patients with risk factors, including prematurity, age younger than 6 weeks, bronchopulmonary dysplasia, congenital heart disease, and immunosuppression (43). If no risk factors are present, there is a 7% chance of respiratory failure, but this chance can increase to as much as 36% if risk factors are present (43). In the findings from one study, the presence of atelectasis on radiographs after intubation correlated with a longer duration of mechanical ventilation (44).

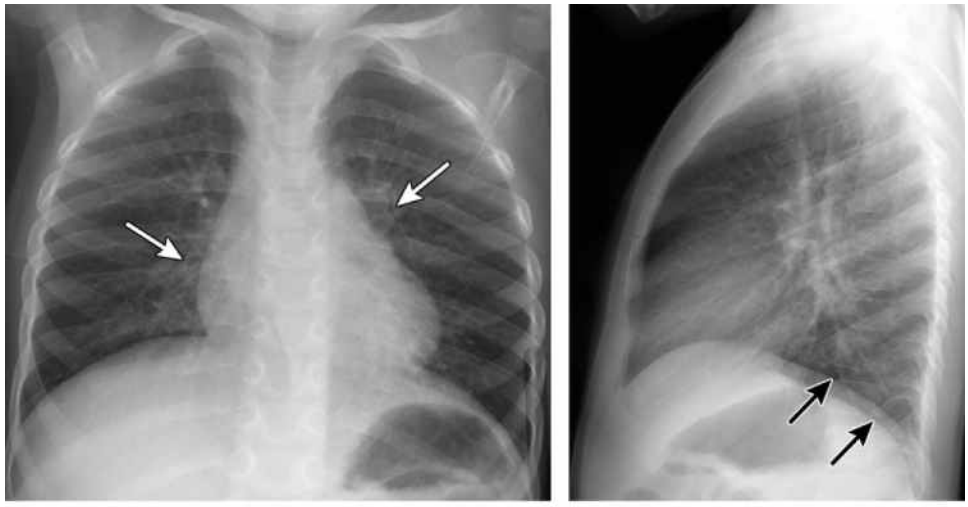
Lower Airway Foreign Bodies

Clinical Features.—Most aspirated foreign bodies (75%) lodge in the lower portion of the airway (20,21). According to the results of one study, 13% of these aspirated foreign bodies lodge in the trachea, 60% in the right lung, and 23% in the left lung (20,21). Only 2% of



a. b.

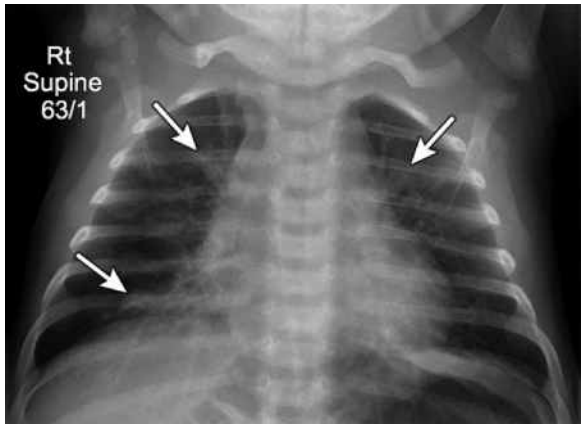
Figure 21. Bronchiolitis in a 20-month-old boy who presented with fever and shortness of breath. **(a)** Frontal chest radiograph shows evidence of bronchial wall thickening (arrows) and hyperinflation, with more than six anterior ribs identified. **(b)** Lateral chest radiograph shows further evidence of hyperinflation, with downward sloping and flattening of the hemidiaphragms (arrow).



a. b.

Figure 22. Lower respiratory tract inflammation in a 4-year-old girl who presented with shortness of breath. **(a)** Frontal chest radiograph shows bronchial wall thickening (arrows) but no evidence of hyperinflation. **(b)** Lateral chest radiograph also shows no signs of hyperinflation but does show a normal configuration of the hemidiaphragms (arrows).

Figure 23. Bronchiolitis associated with respiratory syncytial virus infection in a 14-month-old boy. Supine chest radiograph shows that the lungs are hyperinflated, with more than six anterior ribs depicted, and there are patchy areas of atelectasis (arrows), which are characteristic of respiratory syncytial virus–associated bronchiolitis.



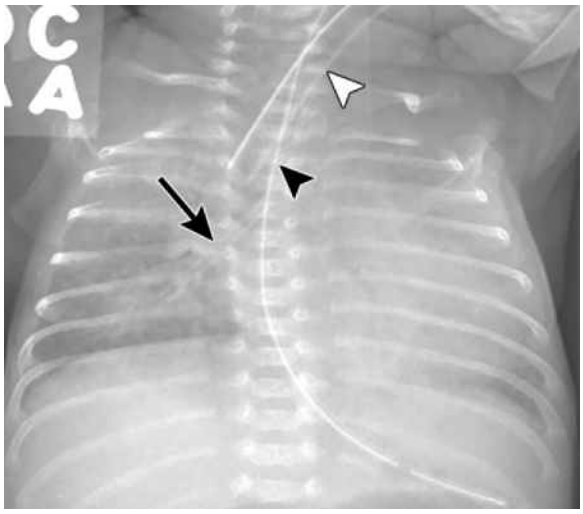


Figure 24. Frontal chest radiograph of a 5-day-old male infant admitted to the neonatal intensive care unit for respiratory distress. The infant is intubated (white arrowhead) and has an enteric tube (black arrowhead) in situ. In addition, a tubular opacity (arrow) is depicted projecting over the right main bronchus, a finding that proved to be the tip of a suction catheter. The tip had become disconnected from the suction unit during routine use.

patients experience bilateral foreign bodies (20,21). Children with bronchial foreign bodies usually have an episode of choking followed by a symptom-free period, which may delay diagnosis (45). In children with a chronic cough or recurrent pneumonia, an aspirated or ingested occult foreign body should be considered (45).

Imaging Features.—As in the case of upper airway foreign bodies, most lower airway foreign bodies are radiolucent because they are composed of organic material (ie, food) (31). In fact, only approximately 10% of aspirated foreign bodies are radiopaque (Fig 24) (31). In most cases, especially if the foreign body is nonocclusive, chest radiographs will be normal (31). Radiographic findings depend on the location of the obstruction and whether it is partial or complete. In partial airway obstruction, which is most common, there may be evidence of unilateral hyperinflation, atelectasis, or mediastinal shift (31,46). In the setting of partial airway occlusion, expiratory views have been shown to increase the diagnostic accuracy and should be obtained when possible (47). In inspiration, when the airway caliber is larger, air rushes into the lung around the foreign body. In expiration, when the airway narrows, air is trapped distal to the foreign body. Because of this ball-and-valve mechanism, the affected lung will remain lucent in expiration (Fig 25). Although lateral decubitus radiographs can be used to try to simulate expiratory radiographs in young patients who are uncooperative, these projections have not been shown to increase the diagnostic accuracy (47,48). Evaluate carefully for complications such as pneumomediastinum and pneumothorax. CT is usually not indicated because it will delay diagnosis, but CT may be a useful problem-solving tool in some situations (Fig 26) (4,5).

Diagnostic Pearls.—Bronchoscopy is the reference standard for diagnosis and management of aspirated foreign bodies, even if radiographs are negative (20,21,49).

Conclusion

The differential diagnosis for acute airway obstruction can be divided anatomically into conditions that affect the upper airway and those that affect the lower airway. Although any process that narrows the airway causes a rise in airway resistance and increased work of breathing, the potentially life-threatening causes of acute airway obstruction include epiglottitis, retropharyngeal abscess, bacterial tracheitis, and foreign-body aspiration. Also keep in mind that "chronic" causes of airway obstruction, such as endoluminal or extrinsic masses, may manifest acutely. It is important to identify subtle airtrapping or radiopaque foreign bodies, even if the history of aspiration or ingestion has not been provided. If the child's condition is clinically unstable, a single lateral radiograph is usually all that is required to aid the diagnosis. It is essential that the radiologist recognize characteristic imaging findings and understand the pathophysiologic features of acute airway obstruction because in most cases, when the cause is identified, the patient's condition responds well to prompt management.

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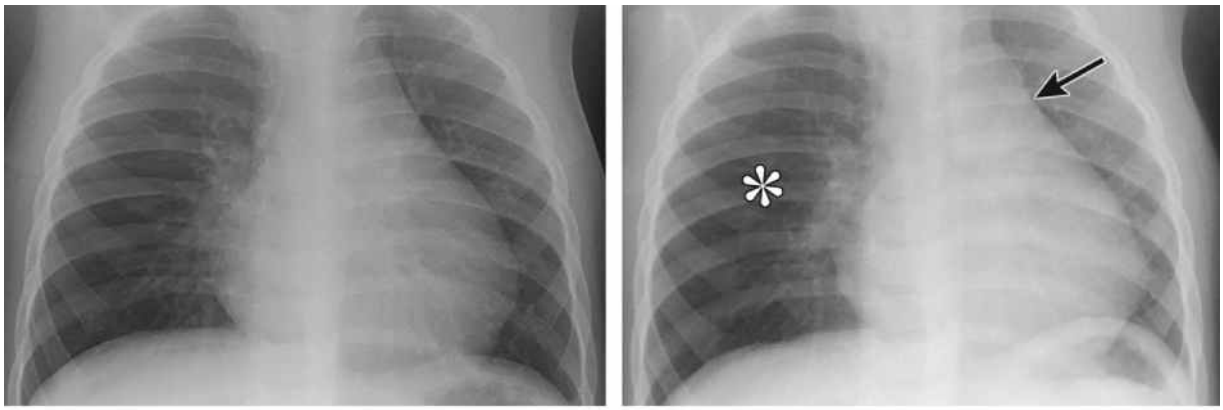
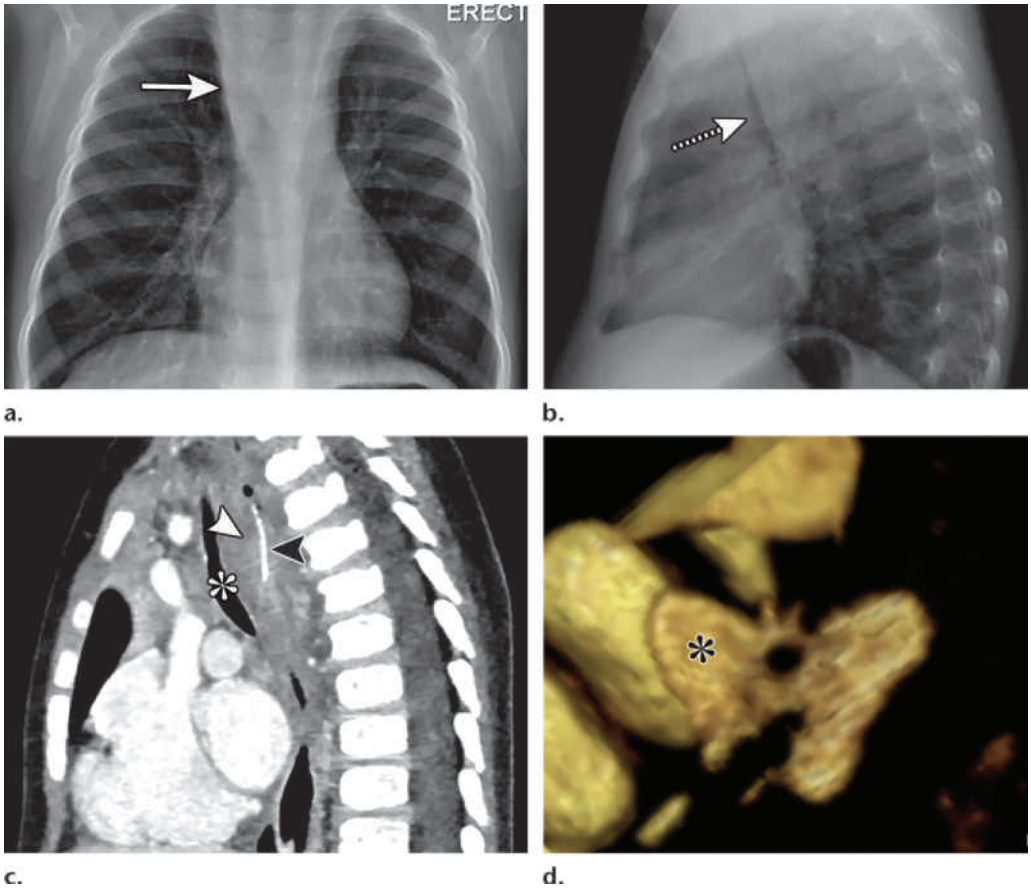


a. b.

Figure 25. Foreign body aspiration in a 24-month-old boy who presented with an episode of choking and wheezing. **(a)** Frontal chest radiograph acquired in inspiration shows subtle asymmetric hyperinflation of the right lung, as demonstrated by increased lucency and mass effect. **(b)** Frontal chest radiograph acquired in expiration shows normal reduction in volume of the left lung. However, persistent airtrapping is depicted in the right lung (*), as well as a more-pronounced mediastinal shift to the left (arrow). At bronchoscopy, a piece of apple was found within the right main bronchus.



a. b.

c. d.

Figure 26. Presumed pneumonia in a 2-year-old boy who presented to his primary care provider on several occasions with a chronic cough and dysphagia and had completed several courses of antibiotic therapy. After more than a year of symptoms, the child developed difficulty breathing and was brought to the emergency department. **(a)** Frontal chest radiograph shows evidence of widening of the mediastinum (arrow). **(b)** Lateral chest radiograph shows narrowing of the trachea, which is bowed slightly anteriorly (arrow). **(c)** Sagittal contrast-enhanced CT image of the chest obtained with reconstruction from an axial CT source image shows a thin linear hyperattenuating structure (black arrowhead) within the esophagus, with surrounding inflammatory changes (white arrowhead), findings consistent with mediastinitis as a result of esophageal perforation. Again depicted is the slight narrowing and bowing of the trachea (*) anteriorly. **(d)** Three-dimensional CT image reconstruction shows that the hyperattenuating object within the esophagus is a butterfly toy (*). Additional questioning disclosed that the child had "misplaced" this toy more than a year ago.

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