CHAPTER TWO

Airway

It has been said that one of the differentiating features between a pediatric and a general radiologist is that a pediatric radiologist remembers to look at the airway. Problems with the airway are much more common in children than in adults. For practical purposes, abnormalities of the airway can be divided into acute upper airway obstruction, lower airway obstruction (extrinsic compression, intrinsic obstruction), obstructive sleep apnea (OSA), and congenital high airway obstruction syndrome (CHAOS).

Clinically, children with acute upper airway obstruction (above the thoracic inlet) tend to present with inspiratory stridor, whereas children with lower airway obstruction (below the thoracic inlet) are more likely to present with expiratory wheezing. However, the categorization of a child with noisy breathing into one of these two groups is commonly more difficult than we are led to believe. The primary imaging evaluation of the pediatric airway for acute conditions should include frontal and lateral high-kilovolt radiography of the airway and frontal and lateral views of the chest.

ACUTE UPPER AIRWAY OBSTRUCTION

Acute stridor in a young child is the most common indication for imaging the pediatric airway. The most common causes of acute upper airway obstruction in children include inflammatory disorders and foreign bodies. Common inflammatory disorders include croup, epiglottitis, exudative tracheitis, and retropharyngeal cellulitis/abscess. Anatomic structures that are especially important to evaluate on radiographs of children with acute upper airway obstruction include the epiglottis, aryepiglottic folds, subglottic trachea, and retropharyngeal soft tissues.

Croup

Croup (acute laryngotracheobronchitis) is the most common cause of acute upper airway obstruction in young children. Croup is a disease of infants and young children; the peak incidence occurs between 6 months and 3 years of age. The mean age at presentation of croup is 1 year of age. In children older than 3 years, other causes of airway obstruction should be suspected. Croup is viral in cause and is usually a benign, self-limited disease. Redundant mucosa in the subglottic region becomes inflamed, swells, and encroaches upon the airway. The children present with a barky ("croupy") cough and intermittent inspiratory stridor. It usually occurs following or during other symptoms of lower respiratory tract infection. Most children with croup are managed supportively as outpatients, and the parents are managed by reassurance. Inhaled corticosteroids are becoming a popular therapy in children with croup. They have been shown to reduce the length and severity of illness.

The purpose of obtaining radiographs in a patient with suspected croup is not to document the diagnosis but rather to exclude other, more serious, causes of upper airway obstruction that require intervention. However, characteristic radiographic findings that indicate croup are best seen on frontal radiographs. With croup, there is loss of the normal shoulders (lateral convexities) of the subglottic trachea secondary to symmetric subglottic edema (Fig. 2-1A, B). Normally, the subglottic trachea appears rounded, with "shoulders" that are convex outward (Fig 2-2). In croup, the subglottic trachea becomes long and thin, with the narrow portion extending more inferiorly than the level of the pyriform sinuses. The appearance has been likened to an inverted V or a church steeple (see Fig. 2-1). I have found the term *church steeple* confusing because some steeples look like croup and some are shaped like the normal subglottic airway (Fig. 2-3). Lateral radiographs may demonstrate a narrowing or loss of definition of the lumen of the subglottic trachea (see Fig. 2-1) or hypopharyngeal overdistention. The epiglottis and aryepiglottic folds appear normal.

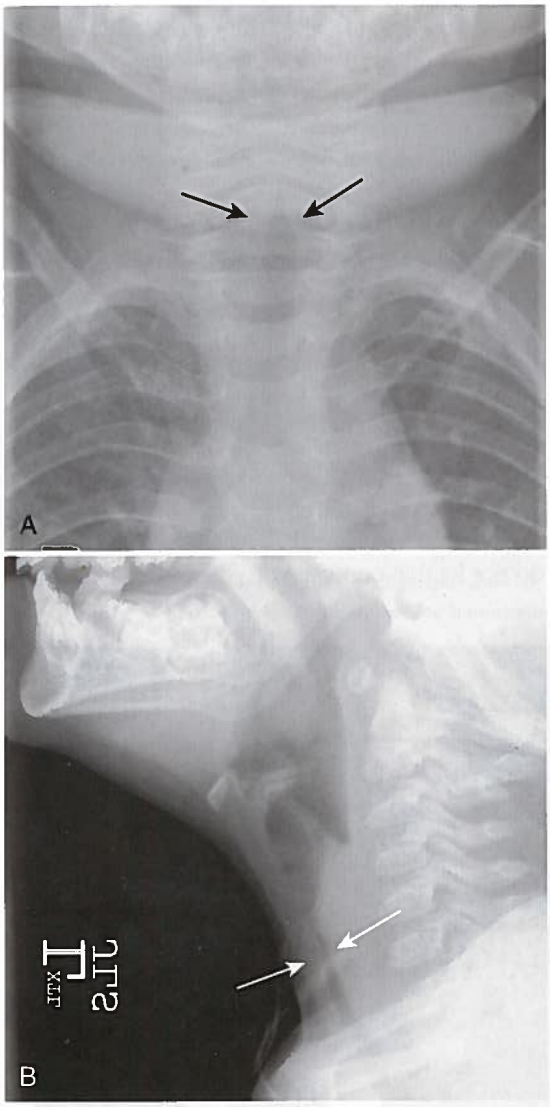

FIGURE 2-1. Croup. A, Frontal radiograph showing symmetric subglottic narrowing *(arrows)* with loss of normal shouldering. The narrowing extends more inferiorly than the piriform sinuses. B, Lateral radiograph showing subglottic narrowing *(arrows)*. Note normal-appearing epiglottis.

Epiglottitis

In contrast to croup, epiglottitis is a life-threatening disease that could potentially require emergent intubation. The possibility that a child with epiglottitis might arrive in a deserted radiology department was once a constant source of anxiety for on-call radiology residents. However, most cases of epiglottitis are caused by *Hemophilus influenzae* and are now preventable by immunization (HiB vaccine), so the incidence of epiglottitis has dramatically decreased. I think caregivers should be more nervous

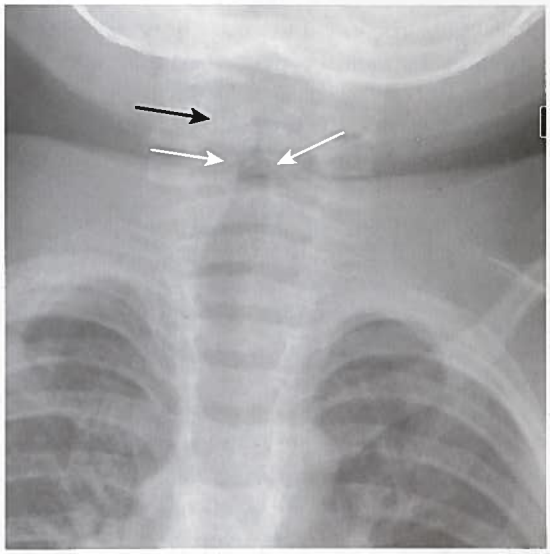

FIGURE 2-2. Normal frontal radiograph of the airway. The subglottic airway demonstrates rounded shoulders *(white arrows)* that are convex outward. Note the appearance and location of the pyriform recess *(black arrow on right pyriform recess)*.

about epiglottitis now because health care workers are less used to dealing with patients with this disorder. Children with epiglottitis are usually toxic appearing and present with an abrupt onset of stridor, dysphagia, fever, restlessness, and an increase in respiratory distress when recumbent. The patients are typically older than those with croup; the classically described peak incidence occurs at age 3.5 years. However, since the introduction of the HiB vaccine, some reports have shown a marked increase in the mean age of presentation to 14.6 years. Because of the risk for complete

FIGURE 2-3. Steeple sign. I find the term *steeple sign* confusing. It is meant to denote the pointed configuration of the subglottic trachea on a frontal radiograph of the airway when subglottic edema has effaced the normally convex lateral shoulders in this region. However, some steeples look like croup *(white arrows)* and some look like a normal subglottic airway *(black arrow)*.

airway obstruction and respiratory failure, no maneuvers should be performed that make the patient uncomfortable. If the diagnosis is not made on physical examination, a single lateral radiograph of the neck should be obtained, usually with the patient erect or in whatever position that allows the patient to breathe comfortably. Children with epiglottitis should never be made to lie supine against their will in order to obtain a radiograph because it can result in acute airway obstruction and, potentially, death.

On the lateral radiograph, there is marked enlargement of epiglottis. The swollen epiglottis has been likened to the appearance of a thumb. There is also thickening of the aryepiglottic folds (Fig. 2-4A-C). The aryepiglottic folds are the soft tissues that extend from the epiglottis anterosuperiorly to the arytenoid cartilage posteroinferiorly and normally are convex downward. When the aryepiglottic folds become abnormally thickened, they appear convex superiorly. An obliquely imaged, or so-called omega-shaped, epiglottis may artifactually appear wide because both the left and right sides of the epiglottis are being imaged adjacent to each other. This should not be confused with a truly enlarged epiglottis. The presence or absence of thickening of the aryepiglottic folds can be helpful in making this differentiation. On lateral view, a normal epiglottis has a very thick appearance. Often both the left and right walls of the epiglottis are visible (Fig. 2-5). Symmetric subglottic narrowing, similar to croup, may be seen on frontal radiography (if obtained); do not let that confuse you.

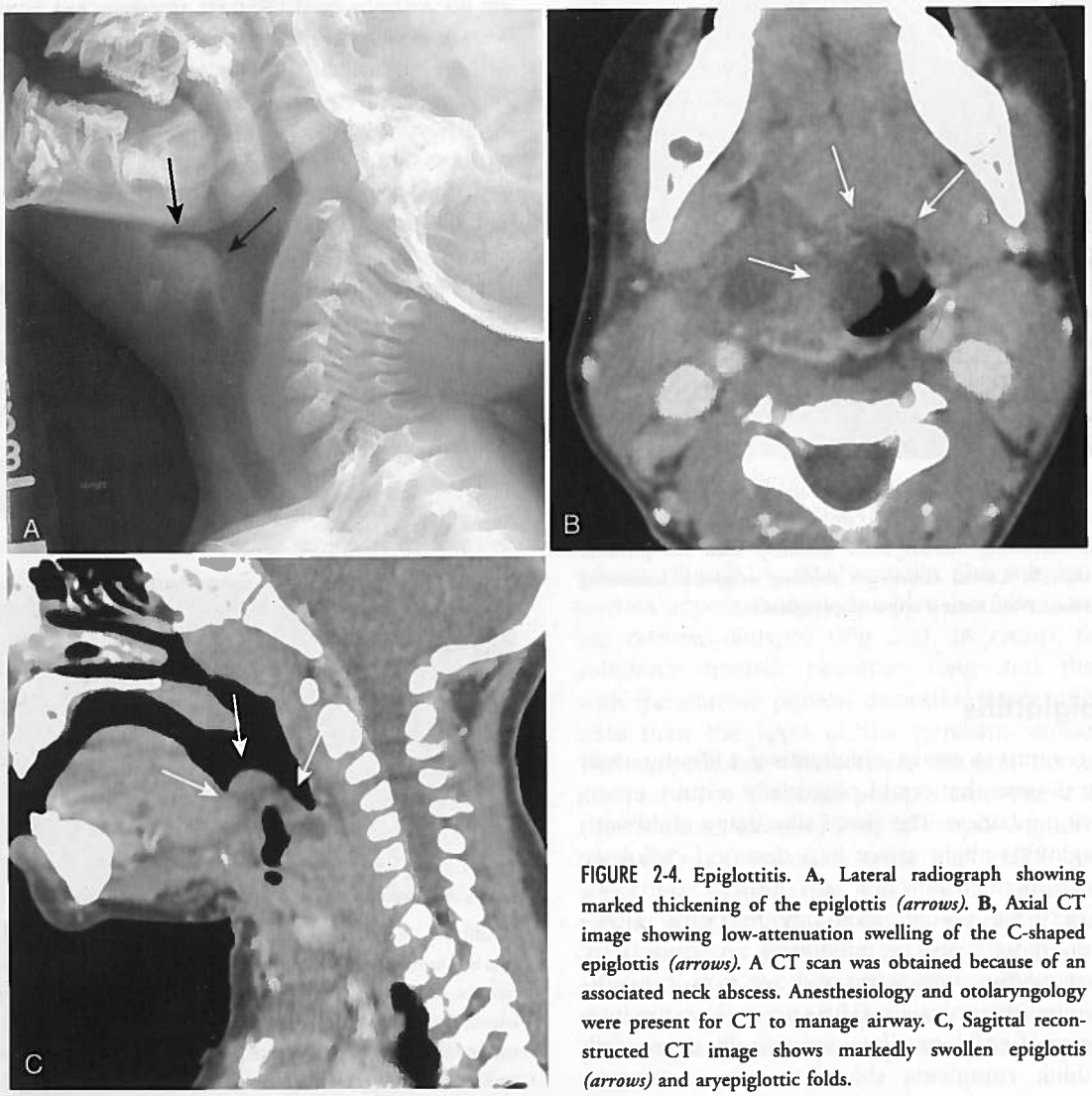

FIGURE 2-4. Epiglottitis. **A,** Lateral radiograph showing marked thickening of the epiglottis *(arrows).* **B,** Axial CT image showing low-attenuation swelling of the C-shaped epiglottis *(arrows).* A CT scan was obtained because of an associated neck abscess. Anesthesiology and otolaryngology were present for CT to manage airway. **C,** Sagittal reconstructed CT image shows markedly swollen epiglottis *(arrows)* and aryepiglottic folds.

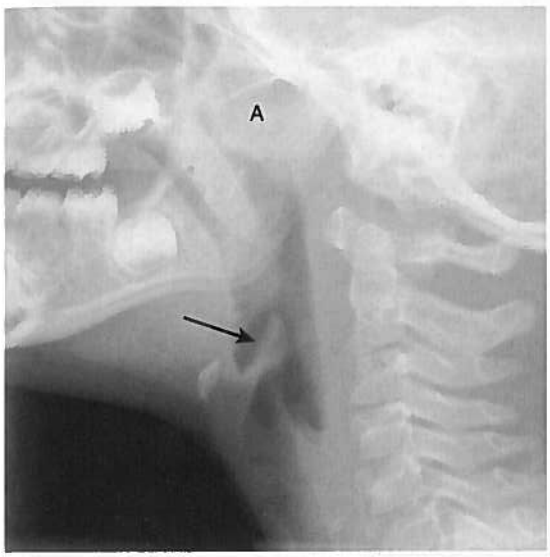

FIGURE 2-5. Normal epiglottis. Lateral radiograph showing thick-appearing epiglottis *(arrow)*. Incidentally, note appearance of enlarged adenoid tonsils *(A)*.

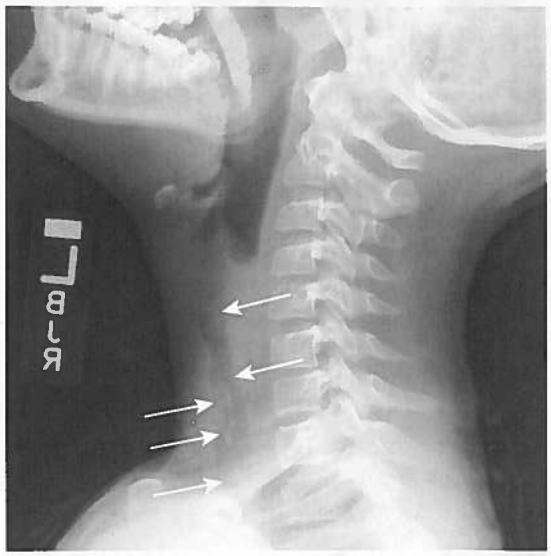

FIGURE 2-6. Exudative tracheitis. Lateral radiograph showing irregular plaquelike filling defects and airway wall irregularities *(arrows)* within trachea. Again, note the normal appearance of the nonthickened epiglottis in this patient.

Exudative Tracheitis

Exudative tracheitis (also know as bacterial tracheitis, membranous croup, or membranous laryngotracheobronchitis) is another uncommon but potentially life-threatening cause of acute upper airway obstruction. The disorder is characterized by a purulent infection of the trachea in which exudative plaques form along the tracheal walls (much like those seen in diphtheria). Affected children are usually older and more ill than those with standard croup; typically their ages range from 6 to 10 years. Although initial reports described most cases to be secondary to infection by *Staphylococcus aureus*, other reports have noted multimicrobial infections. It is unclear whether the disease is a primary bacterial infection or a secondary bacterial infection that occurs following damage to the respiratory mucosa by a viral infection. A linear soft tissue filling defect (a membrane) seen within the airway on radiography is the most characteristic finding. A plaquelike irregularity of the tracheal wall is also highly suspicious (Fig. 2-6). Nonadherent mucus may mimic a membrane radiographically. In cooperative patients, having them cough and then repeating the film may help to differentiate mucus from a membrane. Other findings include symmetric or asymmetric subglottic narrowing in a child too old typically to have croup and irregularity or loss of definition of the tracheal wall. Membranes and tracheal wall irregularities may be seen on frontal or lateral radiographs, and often seen on one but not the other, so it is therefore important to get both views.

If one of these exudative "membranes" is sloughed into the lumen, it can lead to airway occlusion and respiratory arrest. Therefore, children who are suspected to have exudative tracheitis should be evaluated endoscopically, the exudative membranes stripped, and elective endotracheal intubation performed.

A number of controversies regarding exudative tracheitis exist. First, it is seen with great frequency at some institutions and not at all at others. Second, although it is considered a life-threatening condition, to my knowledge, no patient has ever died at home of this disease. Both of these points raise the question of the validity of this diagnosis. My take is that there are definitive cases of this disease, but it is probably overdiagnosed and overtreated at some institutions.

Retropharyngeal Cellulitis and Abscess

Retropharyngeal cellulitis is a pyogenic infection of the retropharyngeal space that usually follows a recent pharyngitis or upper respiratory tract infection. Children present with sudden onset

of fever, stiff neck, dysphagia, and occasionally stridor. Most affected children are young, with more than half of the cases occurring between 6 and 12 months of age. On lateral radiography, there is thickening of the retropharyngeal soft tissues (Figs. 2-7A, B, 2-8A-C). In an infant or young child, the soft tissues between the posterior aspect of the aerated pharynx and the anterior aspect of the vertebral column should not exceed the anterior to posterior diameter of the cervical vertebral bodies. However, in infants, who have short necks, it is common to see pseudothickening of the retropharyngeal soft tissues when the lateral radiograph is obtained without the neck's being well-extended (Fig. 2-9A, B). Apex anterior convexity of the retropharyngeal soft tissues provides supportive evidence that there is true widening of the retropharyngeal soft tissues (see Fig. 2-7). If it is unclear on the initial lateral radiograph whether the soft tissues are truly versus artifactually widened, it is best to repeat the lateral radiograph with the neck placed in full extension (see Fig. 2-9). The only radiographic feature that can differentiate abscess from cellulitis is the identification of gas within the retropharyngeal soft tissues. Computed tomography (CT) is commonly performed to define the extent of disease and to help predict cases in which a drainable fluid collection is present (see Figs. 2-7, 2-8). On CT, a low-attenuation, well-defined area with an enhancing rim is suspicious for a drainable fluid collection (see Fig. 2-7). Cellulitis without abscess (see Fig. 2-8) is actually more common than a drainable abscess.

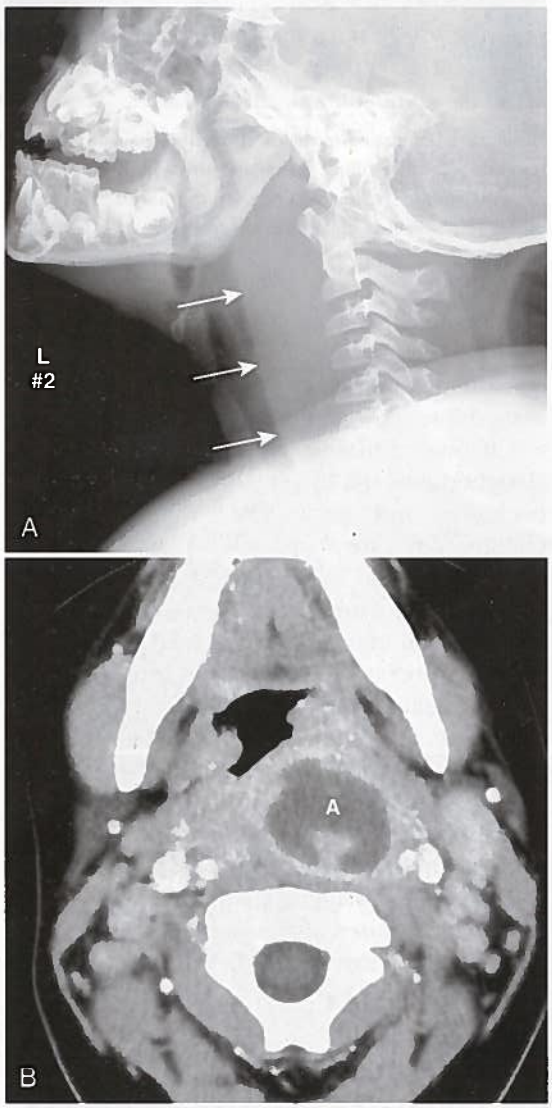

FIGURE 2-7. Retropharyngeal abscess. **A,** Lateral radiograph showing marked thickening of the retropharyngeal soft tissues *(arrows),* which are wider than the adjacent vertebral bodies. Note the anterior convexity of soft tissues. **B,** Contrast-enhanced CT shows a low attenuation region with enhancing rim *(A),* suggestive of a drainable abscess.

LOWER AIRWAY OBSTRUCTION

The most common cause of wheezing in children is small airway inflammation such as is caused by asthma and viral illness (bronchiolitis). When the wheezing persists, presents at an atypical age for asthma, or is refractory to treatment, other reasons for lower airway obstruction are entertained. Other causes of lower airway obstruction can be divided into those that are intrinsic to the airway (such as bronchial foreign body, tracheomalacia, or intrinsic masses) and those that cause extrinsic compression of the trachea (such as vascular rings). The initial radiologic screening procedure for wheezing is frontal and lateral radiography of the airway and chest. Radiographs are used to exclude acute causes of upper airway obstruction, to evaluate for other processes that can cause wheezing such as cardiac disease, and to help categorize the abnormality as being more likely to be an intrinsic or an extrinsic airway process. Important findings to look for on the radiographs include evidence of tracheal narrowing, position of the aortic arch, asymmetric lung aeration, radiopaque foreign body, and lung consolidation. When tracheal compression is present on radiography, it is important to note both the superior to inferior level of the

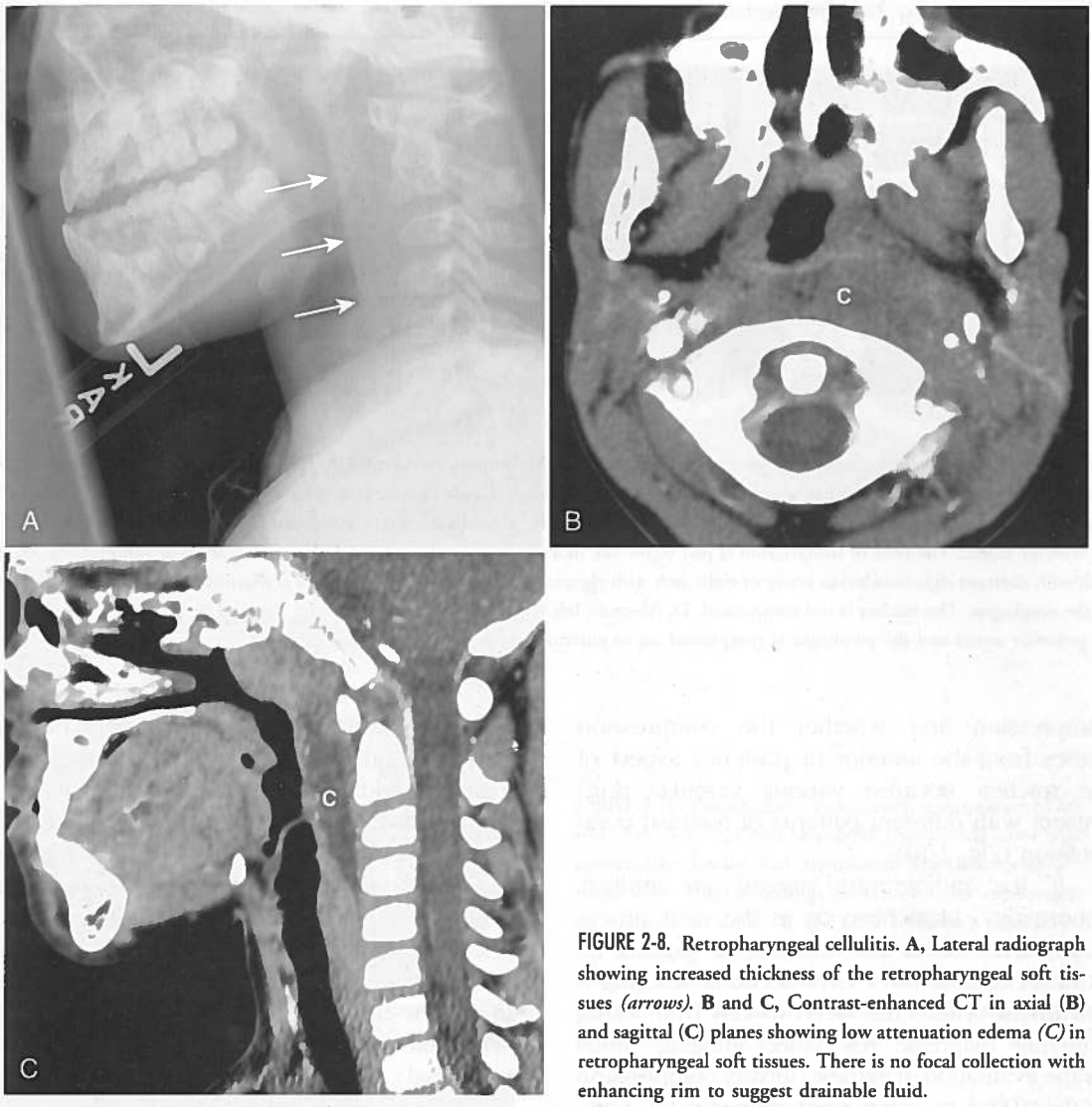

FIGURE 2-8. Retropharyngeal cellulitis. **A**, Lateral radiograph showing increased thickness of the retropharyngeal soft tissues *(arrows)*. **B** and **C**, Contrast-enhanced CT in axial (**B**) and sagittal (**C**) planes showing low attenuation edema *(C)* in retropharyngeal soft tissues. There is no focal collection with enhancing rim to suggest drainable fluid.

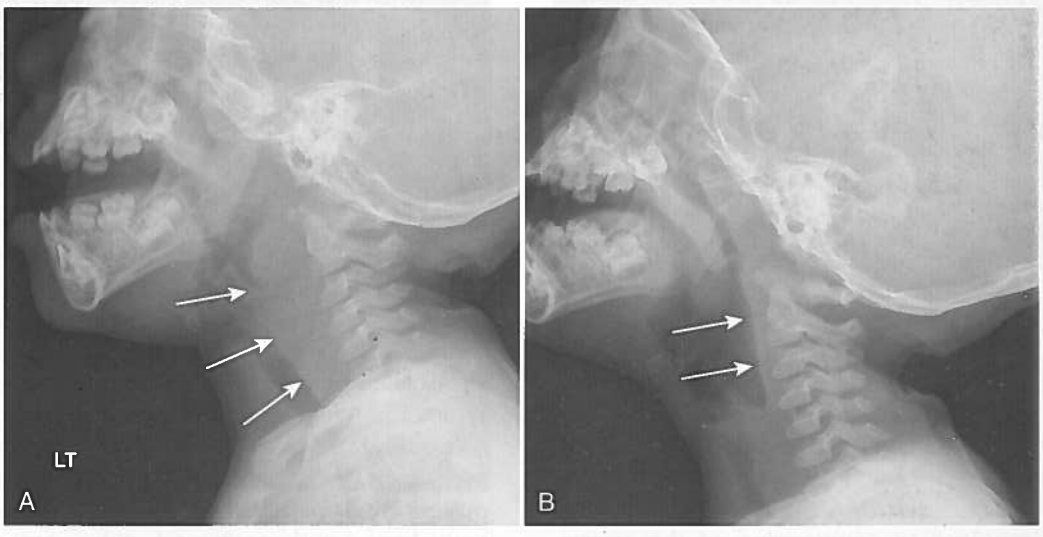

FIGURE 2-9. Pseudoretropharyngeal soft tissue thickening secondary to lack of extended neck positioning. **A**, Initial lateral radiograph showing apparent thickening of retropharyngeal soft tissues mimicking potential retropharyngeal abscess *(arrows)*. **B**, Repeat lateral radiograph with neck extended, showing normal thickness of retropharyngeal soft tissues, much narrower in thickness than adjacent vertebral bodies *(arrows)*.

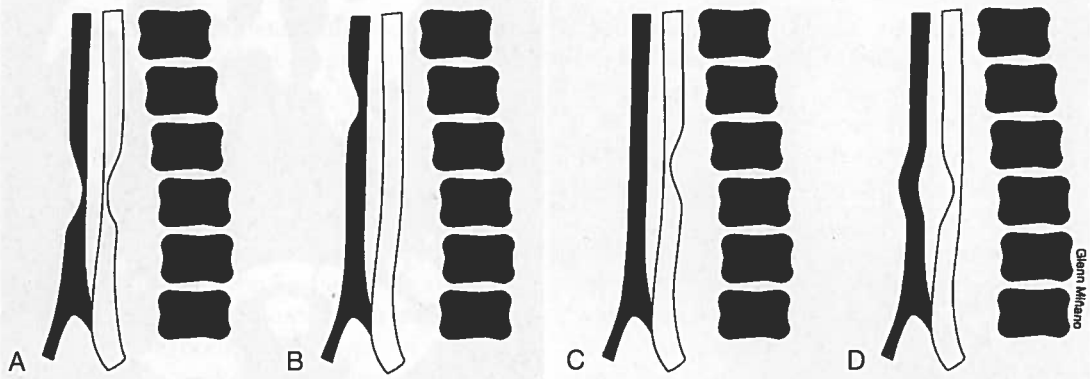

FIGURE 2-10. Patterns of compression of the trachea and esophagus in common vascular rings. The diagrams are comparable to a lateral radiograph of the chest. The trachea is black; the esophagus is white. **A,** Double aortic arch. The trachea is compressed on its anterior aspect, and the esophagus is compressed on its posterior aspect. **B,** Innominate artery compression. The trachea is compressed on its anterior aspect. The level of compression is just below the thoracic inlet, higher than other vascular causes of compression. **C,** Left arch with aberrant right subclavian artery or right arch with aberrant left subclavian artery. There is compression of the posterior aspect of the esophagus. The trachea is not compressed. **D,** Aberrant left pulmonary artery (pulmonary sling). The trachea is compressed on its posterior aspect and the esophagus is compressed on its anterior aspect.

compression and whether the compression comes from the anterior or posterior aspect of the trachea because various vascular rings present with different patterns of tracheal compression (Fig. 2-10).

If the radiographs suggest an intrinsic abnormality, bronchoscopy is the next procedure of choice. If the radiographs suggest an extrinsic compression, cross-sectional imaging is performed. There has been a shift from using primarily magnetic resonance imaging (MRI) for the evaluation of extrinsic airway compression in the 1990s to using predominantly CT now. This shift is related to the rapid acquisition times of the newer multidetector CT scanners. The advantages of CT over MRI are that most infants can be scanned without sedation on CT (which is a significant factor in an infant with airway difficulties) and that better evaluation of the lungs is possible. The disadvantages of CT are the radiation exposure and the dependence upon IV contrast.

Extrinsic Lower Airway Compression

Almost any process that causes either a space-occupying mass within the mediastinum or the enlargement or malposition of a vascular structure can lead to compression of the airway. The classically described vascular causes of lower airway compression include double aortic arch, anomalous left pulmonary artery, and innominate artery compression syndrome. However, other causes of airway compression include middle mediastinal masses, such as a bronchogenic cyst (Fig. 2-11A-C) or large anterior mediastinal masses (Fig. 2-12); enlargement of the ascending aorta such as is seen in Marfan syndrome; enlargement of the pulmonary arteries, as in congenital absence of the pulmonary valve; malposition of the descending aorta, as in midline-descending aorta-carina-compression syndrome; enlargement of the left atrium; or abnormal chest wall configuration such as a narrow thoracic inlet. On axial imaging, the trachea is normally rounded in configuration (Fig. 2-13), sometimes with a flattened posterior wall related to the noncartilaginous portion. A normal trachea is never oblong, with a greater left-to-right than anterior-to-posterior diameter (never "pancake-shaped").

Double Aortic Arch

Double aortic arch is a congenital anomaly related to the persistence of both the left and right fourth aortic arches. It is the most common symptomatic vascular ring. Usually an isolated lesion, it typically presents with symptoms early in life (soon after birth). Anatomically, the two arches surround and compress the trachea anteriorly and the esophagus posteriorly. Typically, the right arch is dominant, both larger and positioned more superiorly (Fig. 2-14). In such cases, the left arch is ligated by performing a left thoracotomy. When the left arch is dominant, a right thoracotomy is

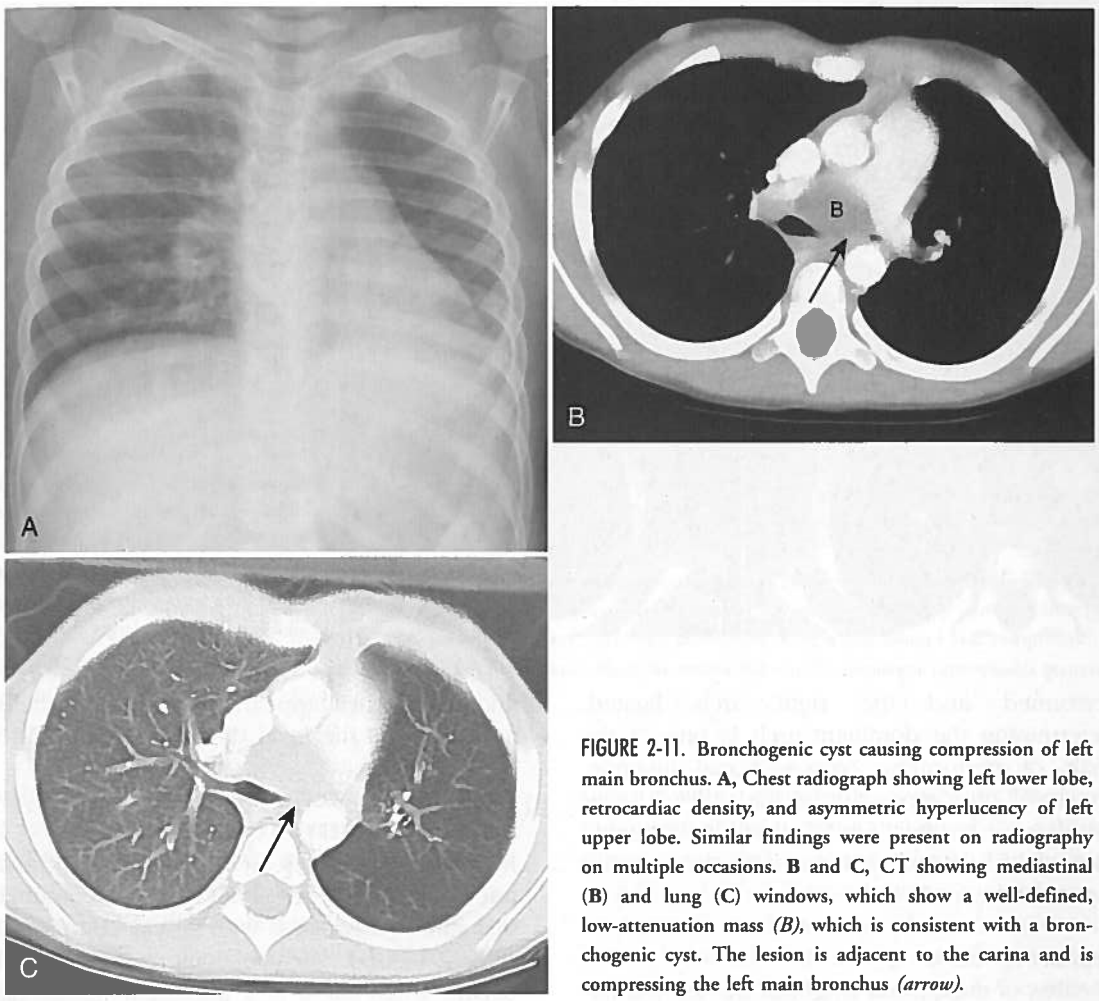

FIGURE 2-11. Bronchogenic cyst causing compression of left main bronchus. **A**, Chest radiograph showing left lower lobe, retrocardiac density, and asymmetric hyperlucency of left upper lobe. Similar findings were present on radiography on multiple occasions. **B** and **C**, CT showing mediastinal (**B**) and lung (**C**) windows, which show a well-defined, low-attenuation mass *(B)*, which is consistent with a bronchogenic cyst. The lesion is adjacent to the carina and is compressing the left main bronchus *(arrow)*.

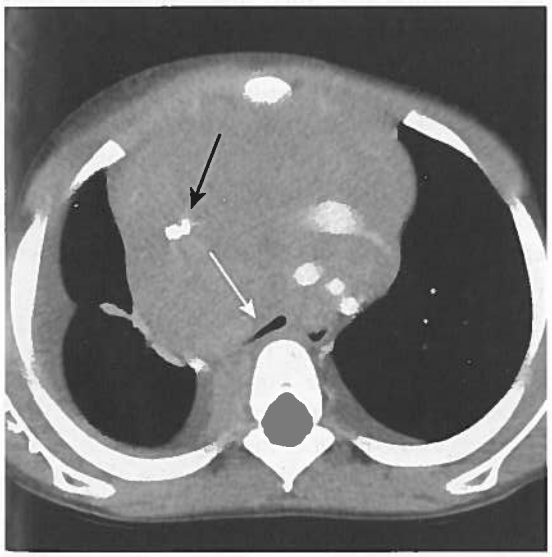

FIGURE 2-12. Lymphoma causing compression of the trachea. CT shows a large anterior mediastinal mass with posterior displacement and severe compression of the trachea *(white arrow)*. The superior vena cava is also compressed *(black arrow)*. There is a small amount of right pleural thickening.

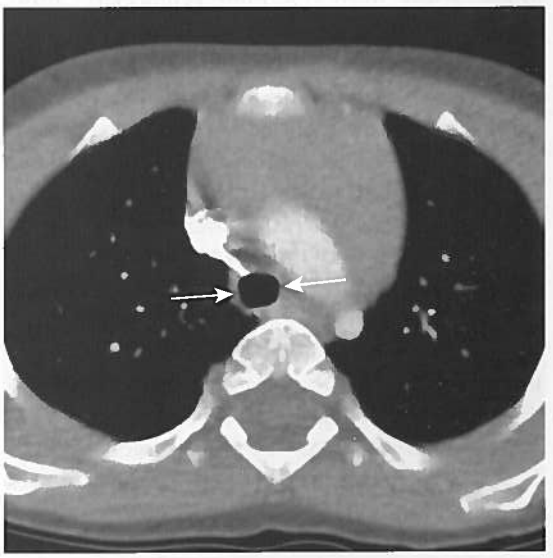

FIGURE 2-13. Normal configuration of trachea on cross-sectional imaging is rounded *(arrows)*. An oval or pancake-shaped intrathoracic trachea is not normal. Note the prominence of the normal thymus in this infant.

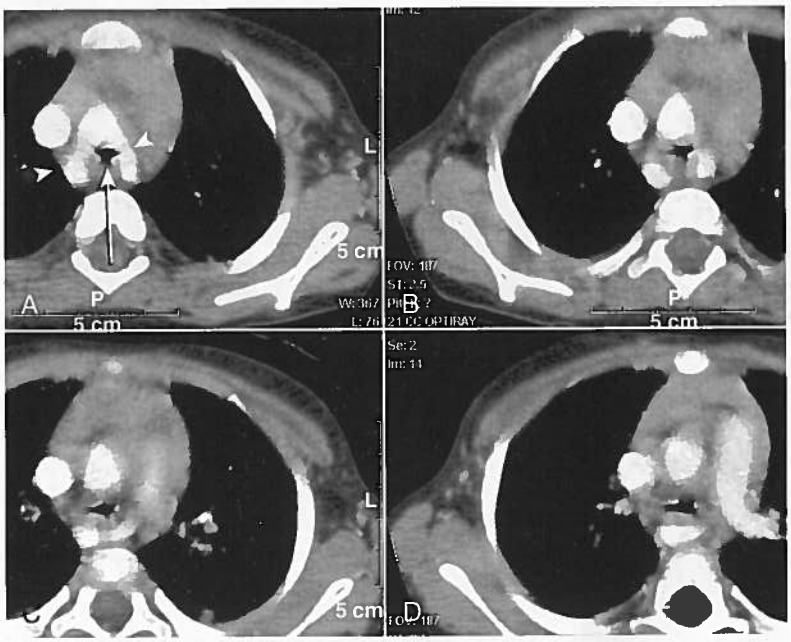

FIGURE 2-14. Double aortic arch. Sequential axial CT images showing right and left arches *(arrowheads)* surrounding a small compressed trachea *(arrow)*. The arches rejoin to form the descending aorta posteriorly. The right arch is only slightly larger than the left.

performed and the right arch ligated. Determining the dominant arch is one of the goals of performing cross-sectional imaging. The level of compression is the mid to lower intrathoracic trachea. On CT, there is symmetric take-off of four great arteries from the superior aspect of the arches.

Pulmonary Sling

In cases of anomalous origin of the left pulmonary artery (pulmonary sling), the left pulmonary artery arises from the right pulmonary artery rather than from the main pulmonary artery and passes between the trachea and esophagus as it courses toward the left lung. The resultant sling compresses the trachea. Pulmonary sling is the only vascular anomaly to course between the trachea and esophagus (Fig. 2-15A, B). Therefore, compression of the posterior aspect of the trachea and the anterior aspect of the esophagus on lateral imaging is characteristic. It is the only vascular cause of airway compression that is associated with asymmetric lung inflation on chest radiographs (see Fig 2-15). Pulmonary sling can be associated with congenital heart disease, complete tracheal rings (Fig. 2-16) (an additional cause of airway problems), and anomalous origin of the right bronchus. On CT, the trachea is compressed at the level of the sling and appears flattened in the anterior to posterior direction—like a pancake. If complete tracheal rings are present, the rings are typically superior to the pulmonary sling, and the trachea appears very small in caliber and round at the level of the rings (Fig. 2-16).

Right Aortic Arch with Aberrant Left Subclavian Artery

Right aortic arch with an aberrant left subclavian artery (RAA-ALSCA) is another arch anomaly that can be associated with airway compression (Fig. 2-17A-D). Airway compression typically occurs when there is a persistent ductus ligament completing the ring. However, you cannot see or know whether this is the case by imaging. There are several mechanisms by which RAA-ALSCA contributes to airway compression in addition to compression by the completed ring. Often, there is dilatation of the subclavian artery at the origin from the right aorta (called a Kommerell diverticulum), which can contribute to airway compression. In addition, the descending aorta may lie in the midline, immediately anterior to the vertebral bodies, if the descending aorta passes from right to left as it descends (see Fig. 2-17). This midline descending aorta can contribute to airway compression as the result of the abnormal stacking of anatomic structures in the limited space between the sternum and vertebral bodies.

Innominate Artery Compression Syndrome

The innominate artery passes immediately anterior to the trachea just inferior to the level of the thoracic inlet. In infants, in whom the innominate artery arises more to the left than in adults

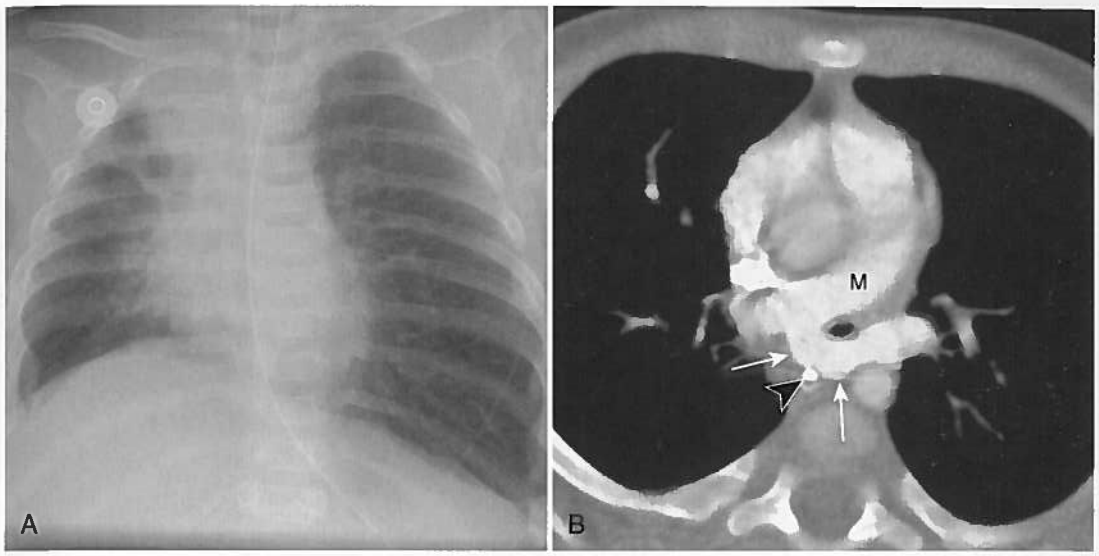

FIGURE 2-15. Pulmonary sling. A, Frontal radiograph showing asymmetric aeration of the lungs, often seen in pulmonary sling but rarely in other causes of extrinsic tracheal compression. B, CT showing anomalous origin of left pulmonary artery *(arrows)* from the right pulmonary artery rather than from the main pulmonary artery *(M)*. The pulmonary sling wraps around and compresses the trachea (small low-attenuation area) as it passes into the left hemithorax. Note the enteric tube in the esophagus *(arrowhead)*, posterior to the sling.

and in whom the mediastinum is crowded by the relatively large thymus, there can be narrowing of the trachea at this level. There is a spectrum from normal to severe narrowing; the term *syndrome* is reserved for cases that are symptomatic. The compression and resultant symptoms decrease with time as the child grows, and surgical therapy is reserved for cases in which symptoms are severe. On lateral radiography, there is indentation of the anterior aspect of the trachea at or just below the thoracic inlet (Fig. 2-18). CT demonstrates the abnormality as anterior compression of the trachea at the level of the crossing of the innominate artery and also excludes other causes of the airway compression.

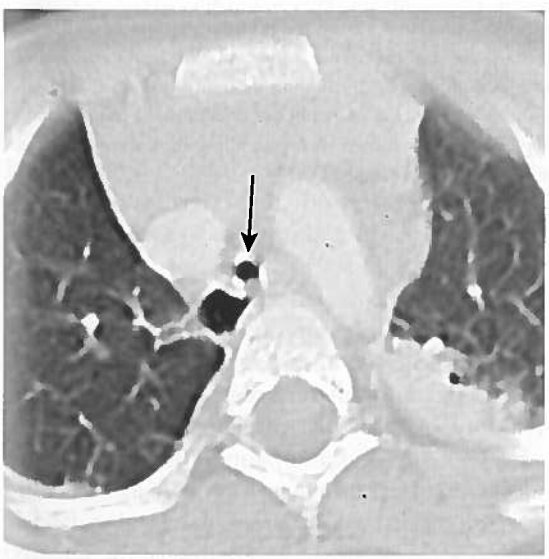

FIGURE 2-16. Complete tracheal rings. CT shows the very small caliber and rounded appearance *(arrow)* of the midtrachea.

Intrinsic Lower Airway Obstruction

Intrinsic abnormalities of the lower airway include dynamic processes, such as tracheomalacia, tracheal stenosis, foreign bodies, and focal masses. Tracheomalacia is tracheal wall softening related to abnormality of the cartilaginous rings of the trachea. It can be a primary or secondary condition and results in intermittent collapse of the trachea. The diagnosis cannot be made on a single static radiograph. However, lateral fluoroscopy or endoscopy can demonstrate dynamic changes in the caliber of the trachea, and they are diagnostic.

The most common soft tissue masses in the trachea are hemangiomas, which most commonly occur in the subglottic region, are often associated with facial hemangiomas in a beard distribution, and appear on frontal radiographs with asymmetric subglottic narrowing.

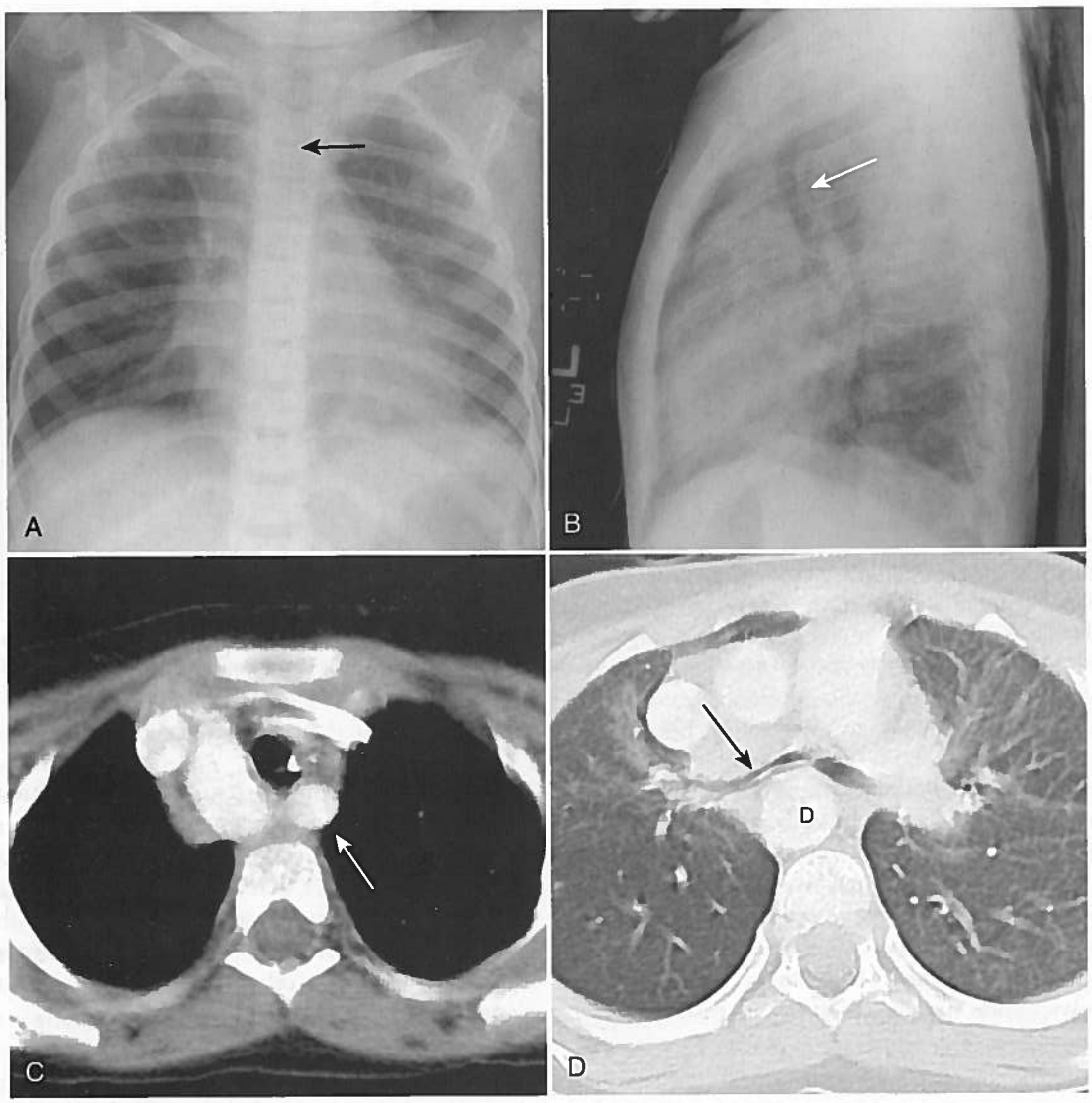

FIGURE 2-17. Right-sided aortic arch with aberrant left subclavian artery and associated airway compression. **A,** Frontal radiograph showing trachea deviated leftward, with soft tissue impression in the rightward aspect of the trachea, consistent with right aortic arch. **B,** Lateral radiograph showing trachea *(arrow)* to be bowed anteriorly and to be compressed. **C,** CT showing right-sided aortic arch with aberrant left subclavian artery *(arrow).* The trachea is not compressed at this level. **D,** CT at more inferior level showing compression of right main bronchus *(arrow)* secondary to midline position of descending aorta *(D),* associated with descending aorta starting on right superiorly and crossing over to left more inferiorly. Abnormal stacking leads to airway compression.

Other tracheal masses include tracheal papilloma and tracheal granuloma.

Airway Foreign Body

Infants and toddlers explore their environments with their mouths and will put almost anything into them. When such foreign bodies are aspirated, the bronchus is the most common site of lodgment. The aspiration commonly is not witnessed, and symptoms may be indolent, leading to an occult presentation. Radiographic findings of bronchial foreign bodies include asymmetric lung aeration, hyperinflation, oligemia, atelectasis, lung consolidation, pneumothorax, and pneumomediastinum. The vast majority of bronchial foreign bodies (as much as 97%) are nonradiopaque. Inspiratory films alone can be normal in as much as one third of patients in whom bronchial foreign bodies are present. Because the volume of the affected lung segments can be normal, increased, or decreased, the key radiographic feature is the

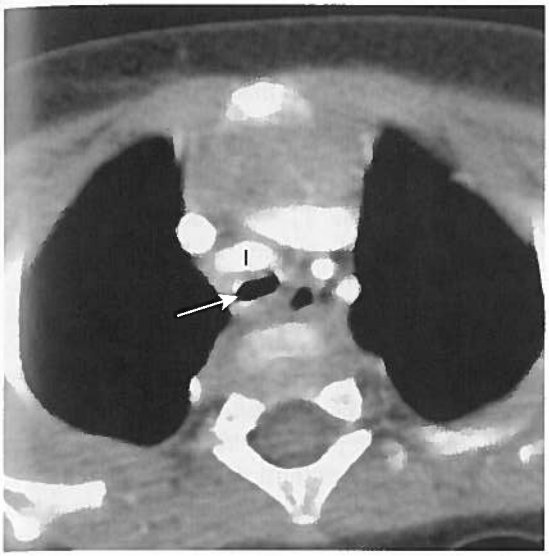

FIGURE 2-18. Innominate artery compression syndrome. CT shows innominate artery *(I)* compressing the trachea *(arrow)*. The trachea is oblong. Normally, the trachea is round at this level.

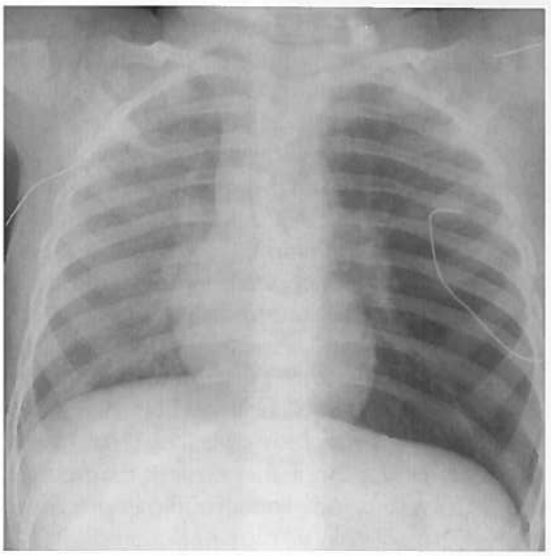

FIGURE 2-19. Bronchial foreign body. Radiograph showing slight asymmetry in lung volumes, with the left being larger and more lucent. Decubitus films documented left air-trapping.

lack of change in lung volume demonstrated at different phases of the respiratory cycle (Fig. 2-19). Evaluation at varying phases of the respiratory cycle is easily accomplished in cooperative children by taking expiratory and inspiratory films. In infants and uncooperative children, the population most at risk for foreign body aspiration, air trapping can be detected in bilateral decubitus views of the chest or by fluoroscopy. Some articles propose non-contrast-enhanced CT for the diagnosis of bronchial foreign bodies, but it is not a widespread practice at this time. The differential diagnoses for an asymmetric lucent lung include bronchial foreign body, Swyer-James syndrome, and pulmonary hypoplasia.

Laryngeal or tracheal foreign bodies are far less common than bronchial foreign bodies and usually present with abrupt stridor or respiratory distress. Radiographic findings include a radiopaque foreign body, soft tissue density within the airway, and loss of visualization (silhouetting) of the airway wall contours. Foreign bodies lodged within the proximal esophagus may also present with airway compression.

Obstructive Sleep Apnea (OSA)

One of the most common clinical problems involving the pediatric airway is the presence of OSA. This disorder affects 3% of children (millions in the United States alone) and is increasingly being associated with significant morbidities, such as poor performance in school, attention deficit disorder, excessive daytime sleepiness, and failure to thrive. Most children with OSA are otherwise healthy children in whom there is enlargement of the adenoid and palatine tonsils, causing OSA. When the

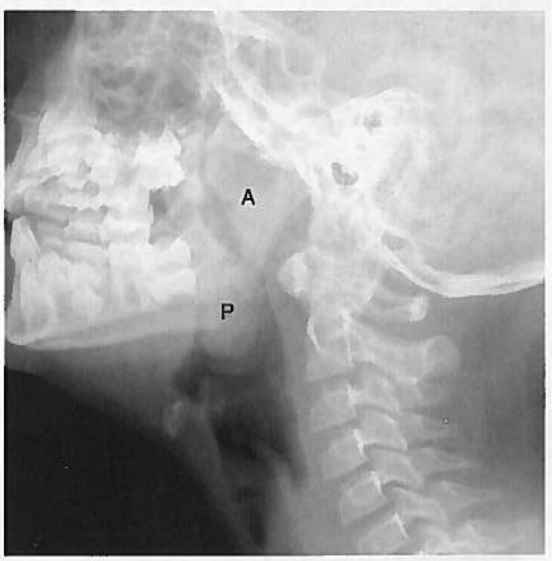

FIGURE 2-20. Enlargement of the adenoid and palatine tonsils. Lateral radiograph showing enlargement of the palatine *(P)* and adenoid *(A)* tonsils, with near obstruction of the nasopharynx.

adenoid and palatine tonsils are removed, the OSA-related symptoms typically resolve. In these children, imaging is limited to a lateral radiograph of the airway preoperatively. The palatine tonsils can be evaluated on physical examination. The lateral radiograph is obtained to evaluate the adenoid tonsils. On radiography, enlarged adenoids appear as a convex soft tissue mass in the posterior nasopharynx and are greater than 12 mm in diameter (Fig. 2-20). Markedly enlarged adenoid tissues may completely obstruct the posterior nasopharynx. Enlarged palatine tonsils can also be seen radiographically; they appear as a large soft tissue mass projecting over the posterior aspect of the soft palate on lateral radiography (see Fig 2-20).

Certain children have more complicated airway issues. In these children, an MR sleep study may be helpful in planning future management. Such studies have been shown to influence management decisions and help to plan surgical interventions in the majority of cases. Sequences performed include T1-weighted (for anatomy) and T2-weighted images with fat-saturation (depicts tonsillar tissue as bright on a dark background), as well as fast-gradient echo images that can be displayed in a cine, or movie, fashion to depict patterns of airway motion and collapse. Indications for MR sleep studies include persistent OSA despite previous airway surgery (most commonly tonsillectomy and adenoidectomy); predisposition to multilevel obstruction such as in Down and other syndromes; OSA and

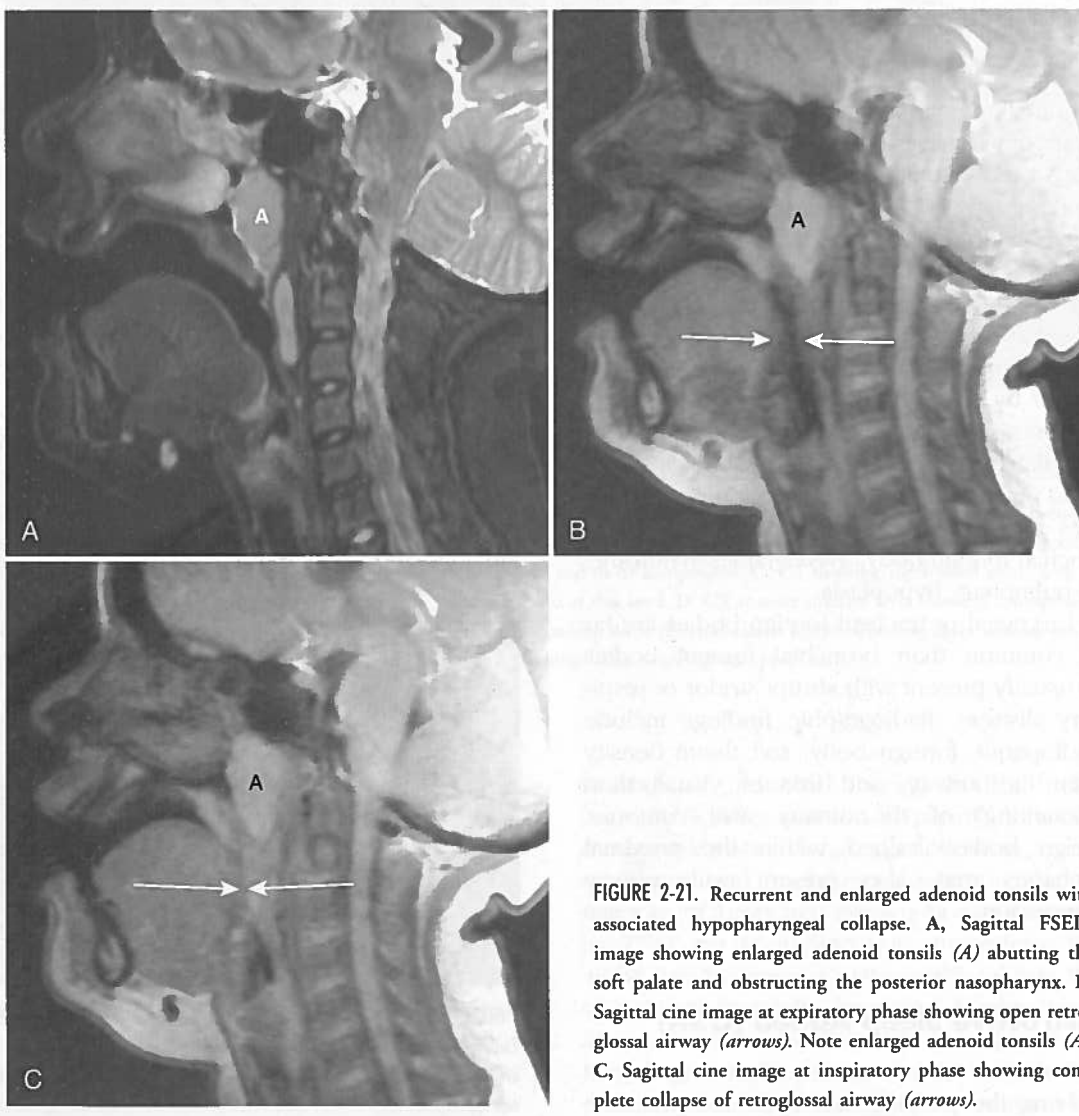

FIGURE 2-21. Recurrent and enlarged adenoid tonsils with associated hypopharyngeal collapse. **A,** Sagittal FSEIR image showing enlarged adenoid tonsils *(A)* abutting the soft palate and obstructing the posterior nasopharynx. **B,** Sagittal cine image at expiratory phase showing open retroglossal airway *(arrows)*. Note enlarged adenoid tonsils *(A)*. **C,** Sagittal cine image at inspiratory phase showing complete collapse of retroglossal airway *(arrows)*.

severe obesity; and preoperative evaluation prior to complex airway surgery. Commonly encountered diagnoses include recurrent enlarged adenoid tonsils, enlarged palatine tonsils, enlarged lingual tonsils, glossoptosis, hypopharyngeal collapse, and abnormal soft palate.

Recurrent and Enlarged Adenoid Tonsils

The adenoid tonsils are absent at birth, rapidly proliferate during infancy, and reach their maximal size when children are between 2 and 10 years of age. During the second decade of life, they begin to decrease in size. One of the things I have been surprised by is how commonly the adenoids can grow back. It is one of the most common causes of recurrent OSA after tonsillectomy and adenoidectomy. Adenoid tonsils are considered to be recurrent and enlarged (Fig. 2-21A-C) if they are greater than 12 mm in anterior to posterior diameter and are associated with intermittent collapse of the posterior nasopharynx on cine images. There may also be associated collapse of the hypopharynx because the relatively superior obstruction generates negative pressure in the hypopharynx during inspiration. On axial images, the postsurgical appearance of a V-shaped defect in the midportion of the adenoid tonsil is typically seen (Fig. 2-22).

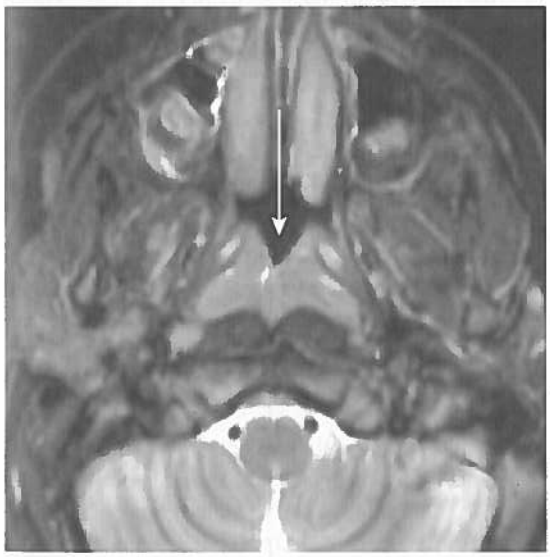

FIGURE 2-22. Recurrent and enlarged adenoid tonsils shown on axial FSEIR MR image. Note wedge-shaped central defect *(arrow)* in adenoid tonsil, typical of postoperative appearance.

Enlarged Palatine Tonsils

Unlike the adenoid tonsils, which commonly grow back after surgical removal, the palatine tonsils do not. Therefore, because most MR sleep studies are performed after tonsillectomy, absence of the palatine tonsils is depicted in most cases. When present and enlarged (Fig. 2-23), the palatine tonsils appear as round, high T2-signal structures in the palatine fossa, and they bob inferiorly and centrally, intermittently obstructing the airway. There is no published range of normal size for palatine tonsils on imaging.

Enlarged Lingual Tonsils

Enlargement of the lingual tonsils is being recognized as a common cause of persistent OSA following previous tonsillectomy and adenoidectomy. In such patients, the lingual tonsils can become quite large and obstruct the retroglossal airway. Enlarged lingual tonsils appear as high-signal masses (Fig. 2-24A, B) that are

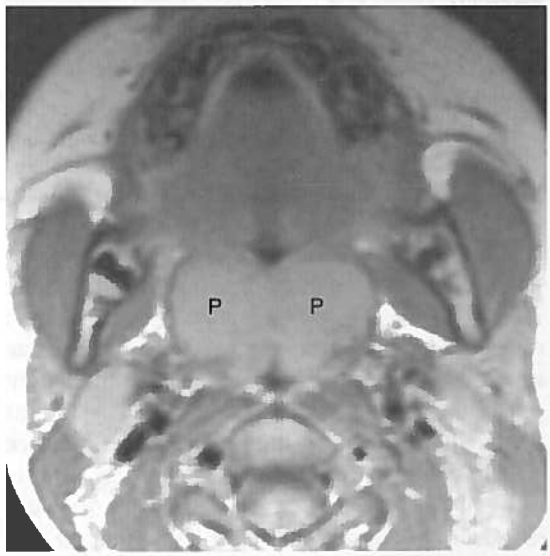

FIGURE 2-23. Massively enlarged "kissing" bilateral palatine tonsils. Axial proton-density image showing bilateral markedly enlarged palatine tonsils *(P)* touching in the midline and obstructing airway.

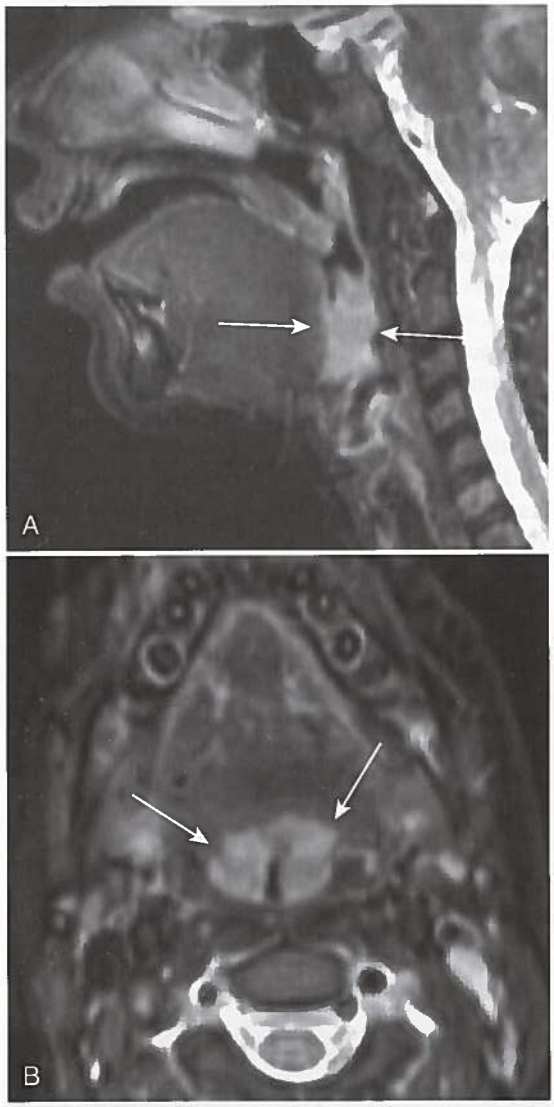

FIGURE 2-24. Enlarged lingual tonsils. **A,** Sagittal FSEIR image showing enlarged lingual tonsils *(arrows)* completely obstructing the retroglossal pharynx. **B,** Axial FSEIR showing enlarged bilateral lingual tonsils *(arrows)* as a dumbbell-shaped area of high signal intensity posterior to tongue.

round or that have grown together and appear as a single dumbbell-shaped mass immediately posterior to the tongue. It is an important diagnosis to make on imaging because it is not readily seen on physical examination and is one of the more easily surgically curable causes of persistent OSA. Enlargement of the lingual tonsils appears to be particularly common after tonsillectomy and adenoidectomy in obese children and in children with Down syndrome.

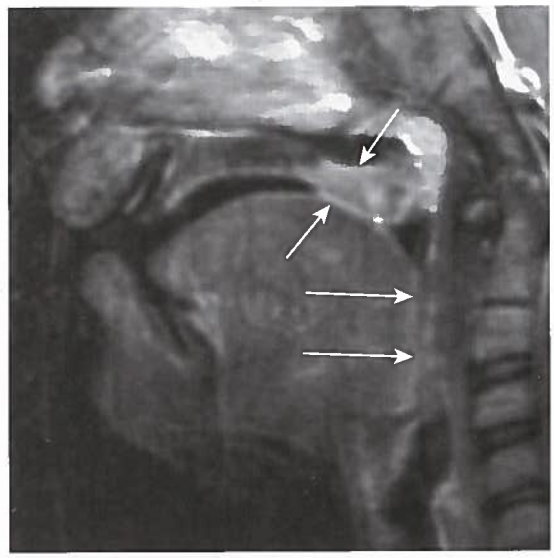

FIGURE 2-25. Glossoptosis and edematous soft palate. Sagittal FSEIR showing large tongue with posterior aspect of tongue *(large arrows)* abutting the posterior pharyngeal wall and obstructing the retroglossal airway. Note the high signal and thickening of soft palate *(small arrows)*, consistent with edematous soft palate, a sign of significant OSA. Normally, the soft palate produces the same signal intensity as the musculature of the tongue.

Glossoptosis

Glossoptosis is defined as posterior motion of the tongue during sleep. The posterior aspect of the tongue intermittently falls posteriorly and abuts the posterior pharyngeal wall, obstructing the retroglossal airway (Fig. 2-25). It is associated with large tongues (macroglossia), small jaws (micrognathia), and decreased muscular tone. It is most commonly seen in children with Down syndrome, Pierre-Robin sequence, and neuromuscular disorders such as cerebral palsy. On imaging, intermittent posterior motion of the tongue in the anterior to posterior direction is depicted on cine images.

Hypopharyngeal (Retroglossal) Collapse

Hypopharyngeal collapse can be a primary phenomenon caused by decreased muscle tone, or it may occur secondary to negative pressure generated by a more superior obstruction (typically enlarged adenoid tonsils). With hypopharyngeal collapse, there is cylindrical collapse of the retroglossal airway, with the anterior,

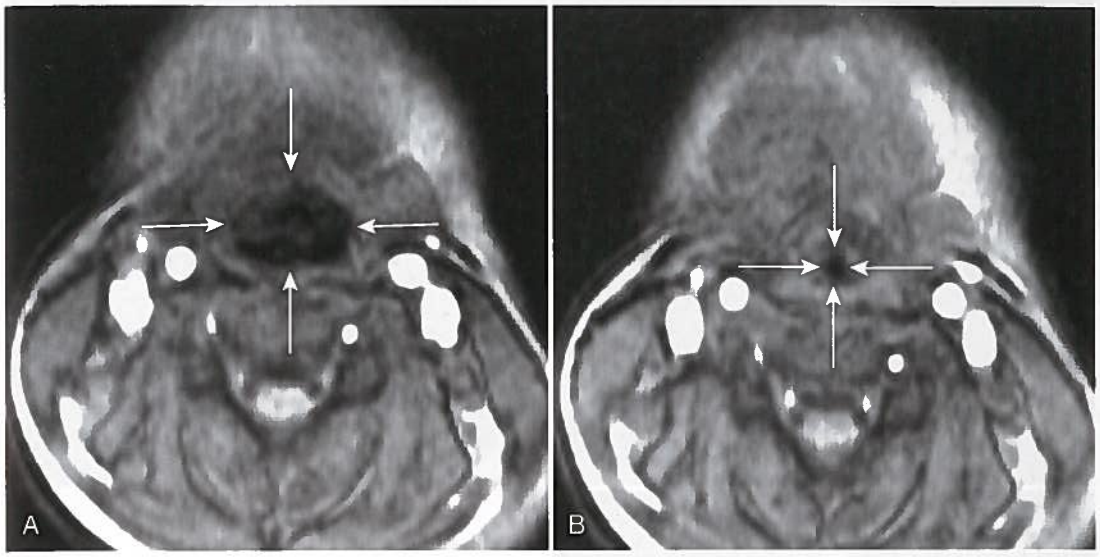

FIGURE 2-26. Hypopharyngeal (retroglossal) collapse. A, Axial cine image during expiration showing open retroglossal airway *(arrows)*. B, Axial cine image during inspiration showing complete collapse of the retroglossal airway *(arrows)*. Note that lateral left and right, anterior, and posterior walls all collapse cylindrically to the center of airway, in contrast to tongue moving posteriorly, as seen in glossoptosis.

posterior, left, and right walls of the airway all collapsing centrally (Fig. 2-26A, B). In contrast, with glossoptosis, the tongue moves anteriorly and posteriorly, and the lateral diameter of the airway remains unchanged. This differentiation is easiest to observe on axial cine images at the level of the midportion of the tongue, from superior to inferior. It is important to characterize the pattern of collapse of the retroglossal airway as hypopharyngeal collapse or glossoptosis because the surgical options for the two groups of patients are quite different.

Abnormal Soft Palate

A prominent soft palate is one of the contributing factors in some cases of OSA, and there are surgical procedures that decrease the size of the soft palate. As you can imagine, there are no published criteria for abnormal soft palate enlargement. If the soft palate is prominent in size, is draped over the tongue and hangs more inferiorly than the midportion of the tongue, and is associated with intermittent collapse of the posterior nasopharynx or retroglossal airway, we consider it enlarged.

The soft palate can be edematous as seen on physical examination in patients with significant OSA. This is thought to be related to the repeated trauma of snoring. On T2-weighted MR sequences, the edema is depicted as an increased signal throughout the soft palate (see Fig. 2-25); in patients without OSA, the soft palate is similar in signal to that of the musculature of the tongue.

CONGENITAL AIRWAY OBSTRUCTION

With the increase in fetal surgery centers and associated fetal ultrasound and MRI, pediatric radiologists are beginning to see an increasing number of cases of congenital obstruction of the airway, although it remains a rare entity. Congenital high airway obstruction syndrome (CHAOS) is the term given to a constellation of findings resulting from this form of airway obstruction. Causes of the airway obstruction include in utero laryngeal atresia, subglottic stenosis, and head and neck masses obstructing the upper airway, most commonly lymphatic malformations or teratomas. Fetal imaging findings in CHAOS (Fig. 2-27A-C) include massive increases in lung volumes, flattened or everted hemidiaphragms, hydrops, and polyhydramnios. Infants with airway obstruction secondary to masses (Fig. 2-28A, B) or other causes, with or without associated CHAOS findings, may be delivered via an ex utero intrapartum treatment (EXIT). In an EXIT, the head of the infant is delivered via a cesarean section, and the airway is established by tracheotomy or intubation prior to the child's

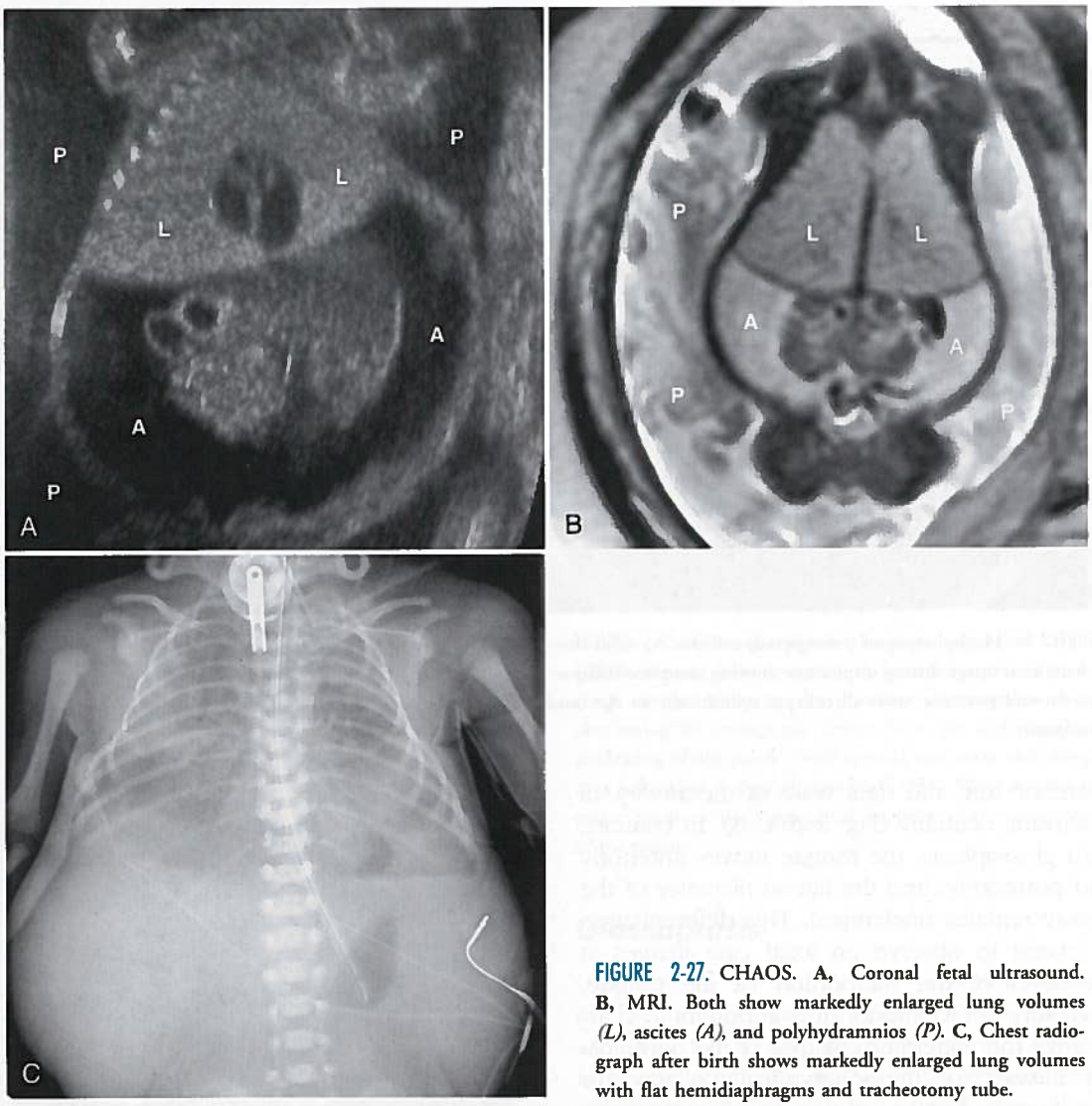

FIGURE 2-27. CHAOS. **A,** Coronal fetal ultrasound. **B,** MRI. Both show markedly enlarged lung volumes *(L)*, ascites *(A)*, and polyhydramnios *(P)*. **C,** Chest radiograph after birth shows markedly enlarged lung volumes with flat hemidiaphragms and tracheotomy tube.

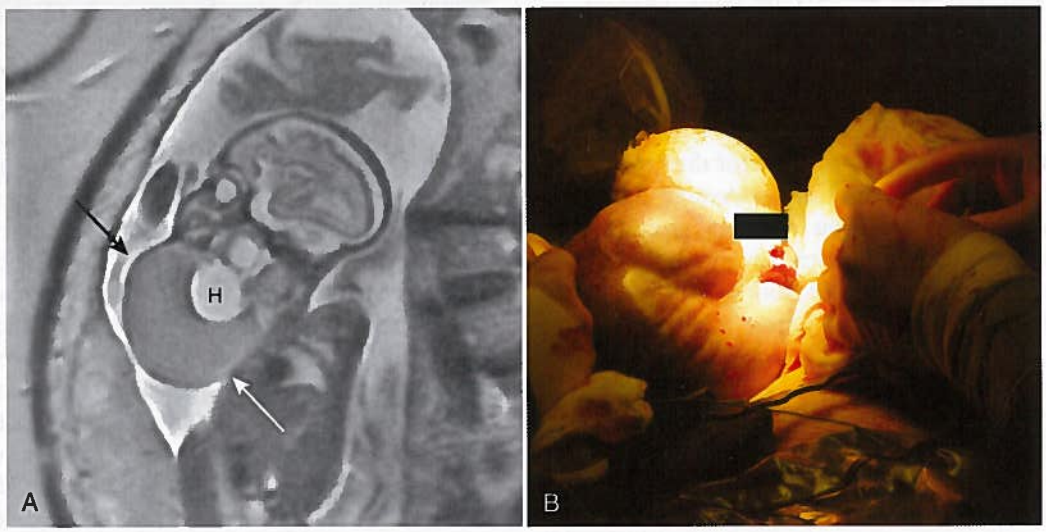

FIGURE 2-28. Teratoma of the neck. **A,** Fetal MRI sagittal to fetal head and neck showing large mass *(arrows)* in the region of the neck. Note the well-defined area of increased signal centrally in lesion *(H)*, consistent with proteinacious fluid. **B,** Photograph during EXIT procedure: head of baby is delivered via cesarean section and airway is established while baby is still on placental blood supply. Note the large mass adjacent to the baby's head.

being taken off placental circulation. Once the airway has been established, the child can be completely delivered.

Suggested Readings

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