

Chapter 122: Diagnostic Imaging of the Trachea

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Examination of the trachea on plain airway and chest radiographs and plain-film tomography may help in identifying a variety of intrinsic and extrinsic abnormalities of the trachea. Computed tomography (CT) and magnetic resonance imaging (MRI) have also proven helpful in demonstrating the extent of tracheal neoplasms and the relationship of extrinsic masses to the trachea (Gamsu and Webb, 1982, 1983; Ross et al, 1986). Since airway symptoms tend to be similar regardless of the etiology, the radiologist can play an important role in providing a specific diagnosis, defining the extent of disease, and supplementing the findings at bronchoscopy.

Methods

The radiologic examination of the distal trachea is essentially the same as that of the proximal airway discussed in Chapter 97. The initial radiographic study in the case of suspected lower airway disease is a conventional plain chest film with frontal and lateral views. High-kilovoltage radiography, a method that improves penetration of the cervical spine, gives somewhat better visualization than conventional films, as also do xeroradiography and plain tomography (Maguire et al, 1965). However, the latter two techniques deliver a high radiation dose and should be used only if conventional or high-kilovoltage films are equivocal (Rosenfield et al, 1979).

Fluoroscopy, expiratory radiographs, and decubitus views are not routinely utilized in the evaluation of suspected airway disease but may be extremely useful in identifying focal air trapping, most commonly in the setting of a suspected endobronchial foreign body (Capitano and Kirkpatrick, 1968, 1972). In wheezing of uncertain etiology, the barium esophagram may reveal vascular rings or slings, occult foreign bodies impacted in the esophagus, or gastroesophageal reflux (Berdon and Baker, 1972; Smith et al, 1974). Positive-contrast tracheography, previously used to demonstrate subtle tracheal abnormalities, has for the most part been replaced by bronchoscopy.

CT and more recently MRI are excellent methods for studying patients with primary tracheal tumors, mediastinal masses, or vascular anomalies (Baron et al, 1981; Gamsu and Webb, 1982; Ross et al, 1986; Spritzer et al, 1989). These studies can demonstrate the extent of the mass and its relationship to normal structures more accurately than conventional radiography.

Anatomy

The tracheal air column including the major bronchi and intermediate bronchus should be visualized on all chest or airway radiographs. Except for slight deviation to the right after entering the thorax, the trachea is essentially a midline structure. Its walls are parallel with the exception of a smooth indentation created by the aorta. Measurements of normal tracheal size are available in adults but are sparse in children (Fearon and Whalen, 1967; Menu and Lallemand, 1981). The upper limits of normal for coronal and sagittal diameters of the adult trachea in men are 25 mm and 27 mm, respectively. In women the corresponding

measurements are 21 mm and 23 mm, respectively. The lower limits of normal for both dimensions are 13 mm in men and 10 mm in women (Breatnach et al, 1984). On expiration the tracheal width is about 10% less; the length is 6% to 12% shorter; and the intratracheal volume decreases by 17% to 23% (Griscom and Wohl, 1982).

On CT the mean cross-sectional area of the normal adult trachea is 272 mm² (standard deviation of 33) in men and 194 mm² (standard deviation of 35) in women. Values less than 190 mm² in men and 120 mm² in women and relative values less than two thirds, compared with other levels, should suggest an abnormality (Vock et al, 1984). A CT study of the pediatric trachea revealed no differences between males and females until 14 years of age. At this time, the female trachea stopped growing. The male trachea continued to enlarge after growth in height stopped (Griscom and Wohl, 1986).

The trachea divides into the two major bronchi at the carina; the angle of bifurcation is variable but generally ranges from 40 to 80 degrees with a mean of 60 degrees (Haskin and Goodman, 1982). The bifurcation angle is not related to age or gender. Small changes (< 20 degrees) normally may be seen on serial measurements.

The trachea is visible on CT scans as a well-defined thin line bordered by mediastinal fat, lung parenchyma, or vessels (Gamsu and Webb, 1982). It is usually circular or slightly oval, but it can be horseshoe shaped or even square. In children the trachea is more uniformly round. Calcification of the tracheal and major bronchial cartilages is usually seen only after 40 years of age (Salzman, 1968).

The radiographic appearance of the trachea in infants, children, and adults is similar, except that the infantile trachea has a marked tendency to bend or buckle to the right on expiration (Fig. 122-1; Swischuk, 1973). The trachea shifts in this direction because it is tethered on the left by the normal aortic arch. If the aortic arch is right sided, deviation occurs to the opposite side. Once recognized, tracheal buckling should pose no problem and can be avoided by performing the chest or airway examination in full inspiration.

Several minor variations in the pattern of tracheobronchial branching can occur (Holinger et al, 1952; Siegel et al, 1979). For example, the right upper lobe bronchus or one of its branches may arise from the lateral wall of the trachea ("tracheal bronchus") (Fig. 122-2; Siegel et al, 1979). This variation as well as "mirror-image" bronchial trees (bronchial isomerism) may be associated with congenital heart disease and cardiac malposition. Distal tracheal stenosis also has been observed in association with a "tracheal bronchus".

Congenital Intrinsic Anomalies of Trachea

Congenital subglottic/tracheal stenosis

Congenital subglottic stenosis is a rare cause of upper airway obstruction in the newborn or young infant. Although symptoms mimic those of croup, the age of onset is earlier. Hypopharyngeal distension, subglottic narrowing, and narrowing of the trachea on inspiration are the primary radiographic findings (Fig. 122-3; Capitano and Kirkpatrick, 1968; Dunbar, 1970). Fluoroscopy will confirm that the subglottic narrowing is fixed and persists on expiration, unlike most cases of croup.

In congenital tracheal stenosis the narrowing may involve a focal segment or the entire trachea may be narrowed. Rarely the tracheal lumen may be fusiform or funnel shaped, tapering distally as it approaches the carina. Congenital narrowing is often associated with abnormally fragmented tracheal rings or cartilaginous rings that completely surround the trachea, leaving no posterior membrane. On occasion, the cartilaginous rings may be totally absent (Wolman, 1961). In most cases, plain-film radiography and fluoroscopy are adequate to demonstrate the length and degree of tracheal stenosis. More recently, ultrafast CT has proven useful in diagnosing tracheal stenosis when conventional studies are inconclusive (Brody et al, 1991).

Tracheomalacia

Tracheomalacia is an abnormal weakness of the tracheal walls and supporting cartilages leading to excessive collapse during normal respiration. Controversy continues as to the amount of tracheal collapse that is normal and the indications for surgical repair. It is fortunate that the natural tendency is for tracheal pliability to decrease in older children and adults, so that most cases can be managed conservatively.

Tracheomalacia may be primary or exist secondary to or in association with other conditions, including vascular anomalies, relapsing polychondritis, Ehlers-Danlos syndrome, and tracheoesophageal fistulas (Baxter and Dunbar, 1963; Gross and Newhauser, 1951; Johner and Szauto, 1970; Wittenborg et al, 1967). Acquired tracheomalacia may follow tracheostomy or prolonged use of an endotracheal tube. The diagnosis can be made fluoroscopically. In the presence of tracheomalacia, the trachea "collapses" during expiration, usually reducing the transluminal diameter by 50% or more (Johnson et al, 1973). Ultrafast CT may provide additional information with regard to the dynamics of airway collapse (Frey et al, 1987; Kao et al, 1990).

Laryngotracheoesophageal cleft

Laryngotracheoesophageal clefts represent fistulous communications between the hypopharynx and proximal respiratory tract (Frates, 1967; Griscom, 1966). The abnormality may vary from a small fistula between the esophagus and larynx to a persistent esophagotrachea in which the wall between the trachea and the esophagus is completely absent. The latter is usually incompatible with life. Plain-film studies of individuals with laryngotracheoesophageal clefts usually demonstrate abnormalities related to the lungs, including infiltrates, atelectasis, and overaeration. Contrast studies performed cautiously can establish the correct nature of the anomaly (Fig. 122-4).

Esophageal atresia and tracheoesophageal fistula

The roentgenographic findings in this condition vary depending on the type of anomaly present (Swischuk, 1973). The most common anomaly is esophageal atresia with fistulous connection between the trachea and distal pouch (82%), although esophageal atresia may exist without a fistula (9%) or with a fistula that may be proximal (1%) or both proximal and distal (2%). A small number of cases (6%) have a tracheoesophageal (H-type) fistula without atresia (Cumming, 1975).

Aspiration pneumonia and disturbances of aeration are often present on plain chest radiographs of infants with esophageal atresia. Anterior bowing of the trachea from the distended proximal esophageal pouch, however, is the characteristic radiographic finding (Fig. 122-5). The diagnosis of esophageal atresia may be confirmed by passing a feeding tube through the nose to the level of the atresia and injecting air if necessary. If esophageal atresia and gas are present within the abdomen, then a distal fistula exists. Skeletal, cardiovascular, gastrointestinal, and genitourinary anomalies frequently coexist with esophageal atresia (Cumming, 1975).

Whether contrast studies for delineation of the proximal esophageal pouch are necessary is controversial. Their use depends to some extent on the plain-film findings and the desires of the surgeon. This type of study confirms the diagnosis of esophageal atresia in equivocal cases and identifies a proximal fistula. If required, the study can be done safely by instilling 0.5 to 1 mL of a non-water soluble material through a radiopaque catheter positioned in the proximal pouch (Cumming, 1982). The distal pouch can be demonstrated by refluxing barium into the distal esophagus after a gastrostomy tube has been placed. As noted earlier, other anomalies should be sought.

Patients with H-type fistulas have recurrent pneumonias. Since no atresia exists, a dilated proximal esophageal pouch will not be seen on chest radiographs. Suspected H-type fistulas should be studied with the child in the prone oblique position. Under fluoroscopic observation, a radiopaque catheter is inserted through the nose into the distal esophagus and barium is injected to distend the esophagus. As the esophagus fills, the tube is gradually withdrawn proximally, with injections of barium every 1 to 2 cm through the entire esophagus. If an H-type fistula is present, barium will follow anterosuperiorly into the trachea (Fig. 122-6).

Frequent respiratory infections or aspiration pneumonia develops in some infants following repair of tracheoesophageal fistula and esophageal atresia. These symptoms result from focal tracheomalacia, distension of the upper esophagus secondary to stenosis at the anastomotic site, or gastroesophageal reflux leading to esophageal dilation and tracheal compression (Cumming, 1975). Barium esophagrams, fluoroscopy, and occasionally CT are helpful in demonstrating these abnormalities (Kao et al, 1990).

Congenital Extrinsic Anomalies of Trachea

A variety of congenital aortic anomalies, most commonly a double aortic arch and vascular ring caused by a right aortic arch with aberrant left subclavian artery and left ligamentum arteriosum, can compress the trachea (Fig. 122-7; Berdon and Baker, 1972). Since some patients, particularly children, may be seen with wheezing and bear the label of "asthma", recognizing the characteristic findings on chest radiographs is important. The diagnosis of an aortic anomaly should be suspected in the presence of a local indentation on the right side of the trachea and absence of the aortic arch on the left. In equivocal cases a barium esophagram confirms the diagnosis by showing impingement on the posterolateral aspect of the esophagus. Depending on the posterolateral aspect of the esophagus. Depending on the surgeon's desires, aortography is sometimes required for clarification or preoperative demonstration of vascular anatomy, although CT with vascular enhancement or MRI may eliminate the need for this procedure (Fletcher and Jacobstein, 1986; Gomes et al, 1987).

An aberrant left pulmonary artery arising from the right pulmonary artery and coursing between the trachea and esophagus to reach the left lung is usually listed with vascular rings as a cause of respiratory distress in infants (Fig. 122-8; Berdon and Baker, 1972). The obstruction in this condition results from either extrinsic compression of the airway by the anomalous vessel or the coexistence of intrinsic tracheal or bronchial stenosis caused by complete cartilaginous rings at sites distant from the position of the anomalous vessel (Berdon et al, 1984; Cohen and Landing, 1976; Siegel et al, 1982). Plain chest radiographs show normal findings, right-sided air trapping from effects of the "sling", or symmetric overaeration if the problem is long-segment tracheal stenosis. Additional findings are a low carina and horizontal equal-length right and left mainstem bronchi. The barium esophagram is a good method of showing the impression of the anomalous vessel on the posterior tracheal and anterior esophageal walls. High-kilovoltage magnification films, fluoroscopy, CT and bronchography are able to identify the tracheal malformations.

Neoplasms

The trachea can be affected by a variety of primary benign and malignant masses, inflammatory masses, or secondary extension from malignant neoplasms arising in adjacent organs. Although most neoplasms are evident on well-penetrated chest radiographs or conventional tomograms, CT scans often can show better the size and extent of the disease process and assess the adequacy of the airway (Gamsu and Webb, 1982, 1983).

Primary benign neoplasms

The majority of benign tracheal neoplasms occur in the pediatric age group, with hemangiomas and papillomas being most common (Fig. 122-9; Felson, 1983). In adults, the most common benign lesions are papillomas, chondromas, chondroblastomas, fibromas, hemangiomas, and granular cell myoblastomas (Felson, 1983). Benign tracheal neoplasms most often appear as smooth, well-circumscribed masses, usually less than 2 cm in diameter (Weber and Grillo, 1978b). They may be sessile or attached to the tracheal wall by a pedicle, but invariably they project into the tracheal lumen. Calcification is frequently seen in the cartilaginous tumors such as chondromas or chondroblastomas. Benign tumors rarely show extratracheal extension into the mediastinum.

Primary malignant neoplasms

Most malignant tracheal tumors are found in adults, with carcinomas predominating, especially squamous cell carcinoma and adenoid cystic carcinoma (Felson, 1983). In children the most common malignant tumors are sarcomas and carcinomas (Gilbert et al, 1953). Most often the tumors are eccentric, sessile, or polypoid masses varying in length from 2 to 10 cm (Weber and Grillo, 1978b). They usually have an irregular surface and produce asymmetric narrowing of the tracheal lumen (Fig. 122-10). Rarely, the tumors are circumferential. Approximately 30% to 40% of malignant tracheal neoplasms extend into the mediastinum (Hajdu et al, 1970). The mediastinal mass can be seen on plain radiographs in some patients, but CT is more accurate in demonstrating extratracheal extension and encasement of adjacent structures, and distant metastases (Fig. 122-11; Gamsu and Webb, 1982, 1983). However, loss of fat planes between tumor and mediastinal structures is not equivalent to definite invasion. CT may underestimate the extent of tumor in the longitudinal plane because of the effect of

partial volume averaging (Spizarny et al, 1986). Although thin-section imaging may alleviate this problem, standard tomography in coronal and sagittal planes may still have a role in assessing longitudinal extent. MRI may prove to be the best imaging study for evaluating these patients since it can image in several planes and also show extraluminal extent of tumor.

Secondary neoplasms

Benign mediastinal masses usually compress the trachea without actually invading the wall. The most common causes of benign extrinsic masses are tortuous extatic great vessels or a goiter in the neck or superior mediastinum (Fig. 122-12). These masses produce a smooth impression on the tracheal lumen and may displace the trachea to the contralateral side. Further, most goiters demonstrate continuity with the cervical thyroid. Lymphangiomas, which most frequently occur before 2 years of age, may demonstrate extension from the neck into the mediastinum and extrinsically compress the trachea.

Malignant mediastinal neoplasms (for example, thyroid gland, esophagus, larynx, lung, lymphoma) can involve the trachea by extrinsic compression or by direct extension (Fig. 122-13; Felson, 1983; Gamsu and Webb, 1983). In some cases the secondary nature of the intratracheal neoplasm will not be suspected before CT or MRI examination. Both studies may show asymmetric tracheal narrowing and contiguous soft tissue masses within the trachea and mediastinum. CT has also demonstrated acquired tracheoesophageal fistulas secondary to neoplasm or radiation therapy (Berkmen and Auh, 1985).

Diffuse Disorders of Trachea

Diffuse disorders of the trachea may be primary or related to underlying respiratory conditions or systemic diseases. In most patients with diffuse tracheal narrowing or widening, the diagnosis is seldom a problem, but the radiologist may add useful information about the extent of disease. Conventional films or plain tomography is usually adequate in showing these disorders, but CT may add additional information about the distribution of the tracheobronchial abnormalities or the degree of airway compromise (Gamsu and Webb, 1983).

Diffuse tracheal narrowing

Mediastinal fibrosis

Progressive fibrosis of caseous mediastinal lymph nodes can result in a fibrotic reaction that infiltrates the entire mediastinum and compresses the tracheobronchial tree as well as adjacent vessels (Schowengerdt et al, 1969). Histoplasmosis and less frequently tuberculosis are the most common causes of this process, with an abnormal immunologic response currently believed to be the mechanism for this extensive fibrosis (Goodwin et al, 1972).

Plain chest radiographs may be normal or show tracheal narrowing and a hilar or mediastinal mass. CT or MRI can be helpful in showing involvement of mediastinal vessels as well as the adjacent airway (Fig. 122-14; Weinstein et al, 1983; Rholl et al, 1985). Calcifications within mediastinal lymph nodes are more easily seen on CT. Obstructive hyperinflation, atelectasis, and recurrent pneumonitis may develop as secondary manifestations

of tracheobronchial involvement.

Relapsing polychondritis

Relapsing polychondritis is an inflammatory disorder that affects the cartilage in many sites, especially the ear, nose, joints, and tracheobronchial tree (McAdam et al, 1976). Although any age group may be affected, most patients are in the third or fourth decade. Airway involvement is the most common cause of death. Radiographs demonstrate long segments of fixed, symmetric tracheal narrowing that may eventually involve the entire tracheobronchial tree (Fig. 122-15; Kilman, 1978). CT findings include diffuse, smooth tracheobronchial wall thickening with narrowing and deformity of the tracheal lumen. In addition, areas of calcium deposition may be seen within the thickened tracheal cartilage (Im et al, 1988).

Saber-sheath trachea

A saber-sheath trachea condition is found almost exclusively in association with chronic obstructive pulmonary disease (Greene, 1978). The trachea is flattened from side to side so that the coronal diameter is less than two thirds the sagittal diameter (Fig. 122-16). Only the intrathoracic trachea is involved so that the trachea abruptly widens above the thoracic inlet. Although the inner margin of the trachea is usually smooth, a nodular contour has been described (Rubenstein et al, 1978). Radiographs obtained during forced expiration may show abnormal invagination of the lateral tracheal walls instead of the usual invagination of the posterior tracheal membrane.

Scleroma

Scleroma is a chronic granulomatous disease caused by *Klebsiella rhinoscleromatis*. The disease primarily affects the nose, paranasal sinuses, and pharynx (Becker et al, 1981). Between 2% and 9% of patients have tracheal involvement with diffuse symmetric subglottic narrowing or multiple nodular masses. The entire trachea and mainstem bronchi may eventually be narrowed by the sclerotic end stage of the infection.

Amyloidosis

Amyloidosis is a disorder characterized by deposition of a protein-polysaccharide complex in the submucosal and muscular layers of the trachea and bronchi (Choplin et al, 1983; Gamsu and Webb, 1983; Wilson et al, 1976). Plain radiographs usually show diffuse or focal narrowing or demonstrate irregular masses encroaching on the tracheal lumen. Concomitant lung disease, including overinflation, atelectasis, or recurrent pneumonias, may secondarily result from the tracheobronchial involvement.

Tracheopathia osteoplastica

Tracheopathia osteoplastica is a degenerative disease characterized by formation of multiple osteocartilaginous nodules in the submucosa of the trachea and bronchi (Young et al, 1980). Typically the radiographs demonstrate multiple sessile and polypoid masses that irregularly narrow the tracheal and bronchial air columns over a long segment. Plain-film

tomography or CT is useful in demonstrating the nodules and rim calcifications or bone formation (Onitsuka et al, 1983). In contrast to the circumferential nodular masses in amyloidosis, the nodules in tracheopathia osteoplastica spare the posterior membranous wall.

Wegener's granulomatosis

Wegener's granulomatosis is characterized by a granulomatous vasculitis of the upper and lower respiratory tract, frequently associated with renal involvement. Tracheal involvement is uncommon and is manifest by diffuse tracheal narrowing. Narrowing of the laryngeal airway may also be seen. CT features include abnormal soft tissue within the tracheal rings and enlarged, abnormally calcified tracheal cartilages (Fig. 122-17; Stein et al, 1986).

Diffuse tracheal widening

Tracheobronchomegaly (Mounier-Kuhn syndrome)

Tracheobronchomegaly is characterized by dilation of the trachea and major bronchi, resulting in a tracheal caliber measuring 35 to 50 mm or more in diameter (Bateson and Woo-Ming, 1973; Choplin et al, 1983). The trachea, in addition to having a widened diameter, also appears irregular and corrugated as the lumen bulges between the cartilaginous rings. Fluoroscopy confirms marked dilation on inspiration and collapse during expiration. Tracheal diverticula and cylindric or saccular bronchiectasis are occasional complications that may require CT, or less commonly, bronchography for clarification (Fig. 122-18; Dunne and Reiner, 1988).

Acquired tracheobronchomegaly

Several inflammatory conditions have been associated with acquired tracheomalacia and diffuse tracheomegaly. These include chronic cigarette smoking, chronic bronchitis, and cystic fibrosis (Griscom et al, 1987). The frequent coughing and prolonged inflammation are postulated to damage the tracheal wall. Tracheomegaly can also be seen in long-standing diffuse pulmonary fibrosis, most likely secondary to increased traction on the tracheal wall (Woodring et al, 1989).

Trauma

Foreign body

Foreign bodies in the airway are a common and serious clinical problem, particularly in young children 1 to 2 years of age. The possibility of an airway foreign body should be considered in a child with wheezing and no obvious pulmonary disease or in an infant with pneumonia unresponsive to treatment. Airway foreign bodies are more common on the right than the left (55% versus 33%; Reed, 1977). Infrequently these are bilateral (7%) or in the trachea (5%). Most foreign bodies are relatively nonopaque vegetable material such as peanuts, sunflower seeds, meat, or eggshells. Only 10% of foreign bodies are opaque; these are usually screws, pins, nails, or tacks.

Chest radiographs are normal in 20% of patients with lower airway foreign bodies (Reed, 1977). If the bronchus is completely obstructed, distal atelectasis or pneumonia results. This occurs in approximately 20% of all lower airway foreign bodies. More commonly a medium-sized foreign body (such as a peanut) is present that partially obstructs or causes no obstruction during inspiration but completely obstructs during expiration (Fig. 122-19). This unilateral hyperinflation can be demonstrated by inspiration-expiration films, fluoroscopy, or decubitus projections. These views will confirm shift of the mediastinum toward the side of obstruction on inspiration and toward the contralateral lung on expiration. Conventional tomograms or CT occasionally can prove helpful in locating nonopaque matter if other studies are equivocal. Contrast studies are rarely required unless plain films show suspicion of a high posterior tracheal mass. A barium esophagram then will disclose the occult esophageal foreign body (Smith et al, 1974).

Cannulation - related problems

In addition to demonstrating the position of endotracheal and tracheostomy tubes, radiologic examination is helpful in demonstrating abnormalities that are the result of airway cannulation (Scott and Kramer, 1978; Slovis et al, 1979; Weber and Grillo, 1978a). Prior tracheal intubation or tracheostomy can result in subglottic or tracheal stenosis, granulomas, and functional disorders. Plain-film radiography and tomography can accurately define the extent of tracheal stenosis or granuloma formation. Fluoroscopy plays an important role in the assessment of secondary tracheomalacia. A barium esophagram may be helpful if an acquired tracheoesophageal fistula is suggested.

Tracheal stenosis usually occurs at the tracheostomy stoma or at the site of the balloon cuff. The degree of narrowing at the site of stenosis is variable but may be severe enough to obliterate the lumen. If patent, the lumen may be fusiform or irregular in configuration (Fig. 122-20). The average length of a stenosis is approximately 1 to 3 cm depending on the degree of tracheal damage. Although CT can also demonstrate tracheal stenosis, conventional radiography usually provides adequate information (Gamsu and Webb, 1982).

Granulomas appear as rounded soft tissue densities projecting into the airway (Fig. 122-21; Scott and Kramer, 1978; Slovis et al, 1979; Weber and Grillo, 1978a). The classic lesions are found at the tracheostomy stoma on the anterior and lateral margins of the trachea, but on occasion granulomas may form at the level of the balloon cuff. Granulomas also may develop in the arytenoid region of the glottis in intubated patients.

Tracheomalacia is usually encountered between the tracheostomy stoma and the area of the balloon cuff, although it may be encountered at the stomal or cuff sites. This is most easily demonstrated with fluoroscopy performed during forced inspiration and expiration or sniffing and coughing. During these maneuvers the trachea collapses completely because of the loss of its cartilaginous support. The degree of narrowing may be focal or diffuse.

Tracheobronchial injury

Although tracheobronchial injury is uncommon, its radiographic and clinical recognition is important in decreasing the mortality and complications associated with these injuries (Greene and Stark, 1978; Wiot, 1983). The radiologic findings after penetrating or

blunt trauma are similar in children and adults. The immediate radiographic sign of penetrating tracheal trauma is subcutaneous emphysema, pneumomediastinum, or mediastinal widening if associated injuries of the heart and great vessels are present. The thorough disruption in the tracheal wall is seen best with bronchoscopy. Delayed effects of penetrating trauma include airway narrowing and stenosis from formation of granulation tissue and scarring.

With blunt tracheal injuries, 80% of the tears occur in a mainstem bronchus within 2 or 3 cm of the carina. The trachea is involved in 15% and the peripheral bronchi in another 5% (Wiot, 1983). Plain radiographic findings include, alone or in combination, pneumothorax, pneumomediastinum, thoracic fractures (particularly one or more of the first three ribs), and subcutaneous emphysema (Fig. 122-22). These findings, however, may be seen in patients with thoracic trauma and an intact airway. Superior displacement of the hyoid bone is a helpful sign indicating transection of the trachea. If the body of the hyoid bone is above the level of the third cervical vertebral body or if the greater cornu is less than 2 cm from the angle of the mandible, tracheal transection is likely (Polansky et al, 1984). Abnormalities of endotracheal tube configuration (for example, balloon cuff overdistension) or position (for example, tip outside of tracheobronchial tree) are also important clues to tracheal disruption (Unger et al, 1989). CT scan also demonstrate these findings and may be helpful in cases in which plain films are inconclusive (Tocino and Miller, 1987; Unger et al, 1989). CT may occasionally show pneumomediastinum not seen on the chest radiograph. Although most patients with pneumomediastinum do not have tracheobronchial (or esophageal) disruption, pneumomediastinum in conjunction with a high clinical suspicion may suggest the need for bronchoscopy, endoscopy, or contrast esophagography (Kerns and Gay, 1990). Approximately 10% of patients with tracheobronchial fractures have no demonstrable radiographic abnormality, presumably because of preservation of the integrity of the peribronchial connective tissue sheath.

A radiographic finding diagnostic of fracture of a mainstem bronchus is the "lung falling away from the hilum" sign (Oh et al, 1969). In the presence of a pneumothorax with an intact main bronchus, the lung will collapse toward the hilum and mediastinum. On the other hand, complete transection of the bronchus will cause the lung to fall toward the most dependent portion of the hemithorax. This finding, however, is relatively rare. Failure of the collapsed lung to expand and continued air leak following tube thoracotomy suction for a pneumothorax are other radiographic findings suggestive of a ruptured bronchus (Fig. 122-22). However, if the tear of the peribronchial sheath is small, early fibrinous closure of the leak may occur and the lung will expand even with total disruption of the bronchus. Formation of scar tissue or eccentric healing at the site of laceration may eventually result in bronchial stenosis with distal atelectasis or air trapping.