AJR FOCUS ON:

Chest Radiography in the ICU: Part I, Evaluation of Airway, Enteric, and Pleural Tubes

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OBJECTIVE. In this pictorial essay, we discuss and illustrate normal and aberrant positioning of nonvascular support and monitoring devices frequently used in critically ill patients, including endotracheal and tracheostomy tubes, chest tubes, and nasogastric and nasoenteric tubes, as well as their inherent complications.

CONCLUSION. The radiographic evaluation of the support and monitoring devices used in patients in the ICU is important because the potentially serious complications arising from their introduction and use are often not clinically apparent. Familiarity with normal and abnormal radiographic findings is critical for the detection of these complications.

The American College of Radiology recommends daily chest radiography for critically ill patients who have acute cardiopulmonary disease or are receiving mechanical ventilation, as well as immediate imaging for all patients who have undergone placement of endotracheal tubes (ETTs), feeding tubes, vascular catheters, and chest tubes [1]. These recommendations are made because the malpositioning of these devices and the serious complications that may ensue are often not clinically apparent. Radiographic evaluation of these devices is important, albeit challenging, because of the technical limitations of portable chest radiography and the inability of patients to cooperate.

Endotracheal and Tracheostomy Tubes

Endotracheal intubation is performed to maintain airway patency or to provide ventilatory support for patients with hypoventilation or hypoxemia. The most common complication of ETT placement is malpositioning, which is reported in approximately 15% of patients undergoing this procedure [2, 3]. The correct position of the ETT is determined by the distance between the tip of the ETT and the carina. The ideal location of the tip of the ETT is in the mid trachea, approximately 5 cm above the carina if the patient's head is in the neutral position—that is, the inferior border of the mandible is projecting over the lower cervical spine [4, 5]. Flexion of the head and neck causes a 2-cm descent of the tip of the tube, whereas extension of the head and neck causes a 2-cm ascent of the tip [4, 6].

If the ETT is too high (Fig. 1), there is a risk of either inadvertent extubation or hypopharyngeal intubation, which can cause ineffective ventilation and gastric distention. In addition, the ETT's occluding cuff may cause vocal cord injury. The tip of the ETT should be at least 3 cm distal to the vocal cords [7]. If the ETT is too low, selective bronchial intubation may occur, usually in the right main bronchus (Fig. 2). Consequently, segmental or complete collapse of the contralateral lung may occur, along with overinflation of the ipsilateral lung with increased risk of pneumothorax. If the ETT tip reaches the bronchus intermedius, atelectasis of the right upper lobe may develop [5].

Inadvertent esophageal intubation is a potentially fatal complication of endotracheal intubation. In this case, the chest radiograph may show the ETT lateral to the tracheal air column or extending below the carina, the presence of an air column lateral to the trachea, and overdistension of the stomach [5, 8]. A right posterior oblique radiograph can help diagnose this complication because it projects the trachea to the right of the esophagus, allowing visualization of the ETT's position outside the trachea and within the esophagus [8].

The inflated ETT cuff should fill but not expand the tracheal walls. Overinflation of

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the balloon to 1.5 times the diameter of the normal trachea has been shown to cause tracheal injury [9, 10], including acute tracheal rupture or chronic damage, such as tracheomalacia or tracheal stenosis (Fig. 3).

ETT-related tracheal rupture usually involves the membranous posterior wall of the trachea within 7 cm of the carina [5, 11]. Radiographic indications of tracheal rupture include subcutaneous emphysema, pneumomediastinum, pneumothorax, right oblique displacement of the distal portion of the ETT, overdistension of the ETT balloon (> 2.8 cm), and reduced balloon-to-tip distance (i.e., distance < 1.3 cm; the normal balloon-to-tip distance is 2.5 cm) [8, 11, 12] (Fig. 4). If hypopharyngeal perforation occurs, the chest radiograph may show cervical subcutaneous emphysema, pneumomediastinum, and pneumothorax [13].

Positive pressure ventilation may cause barotrauma, resulting in interstitial emphysema, pneumothorax, and pneumomediastinum (Fig. 5). Other complications from ETT placement include the development of aspiration pneumonitis, nosocomial infection, and intratracheal clots or mucus plugging with resultant atelectasis (Fig. 6).

Tracheostomy tubes are placed when long-term intubation is required. The tip of the tracheostomy tube should be located at approximately one-half to two-thirds of the distance from the stoma to the carina [7, 9]. Unlike the ETT's position, the tracheostomy tube's position is not changed by extension or flexion of the patient's head. Although small amounts of subcutaneous emphysema and pneumomediastinum may be seen after an uncomplicated tracheostomy tube placement, significant emphysema should raise suspicion of complication [7, 9]. Tracheal stenosis caused by granulation tissue formation and fibrosis may occur at the site of the stoma [8].

Double-lumen ETTs are used to preferentially ventilate one lung, to avoid spillage or contamination from one lung to the other, to allow unilateral bronchopulmonary lavage, or to control the distribution of ventilation to each lung. They are rarely seen in patients in the ICU, but when present, they should not be mistaken for iatrogenic bronchial intubation (Fig. 7).

Chest Tubes

Tube thoracostomy is a common procedure used to evacuate fluid or air from the pleural space. The proper position of the chest tube depends on whether air or fluid is being removed from the pleural space; the tip of the tube should ideally be aimed apically for a pneumothorax evacuation or basally for fluid drainage [7, 14]. For the drainage of loculated pleural fluid, the chest tube should be placed in the specific location of the loculation.

If a chest tube fails to drain the air or fluid, malposition should be suspected. On radiograph, a radiopaque stripe is seen along the length of the tube and allows identification of the tip and holes. The side hole should be always positioned medial to the inner margin of the ribs. Incomplete insertion of the tube may result in ineffective pleural drainage and accumulation of air or fluid in the chest wall (Fig. 8).

Inadvertent placement of the tube in the extrapleural soft tissues is not rare (Figs. 9 and 10). It should be suspected on the chest radiograph when there is poor visualization of the nonopaque wall of the tube. When the tube is in an appropriate intrapleural position, the nonopaque wall is better seen because there is air both inside and outside of the tube. However, with subcutaneous placement, the nonopaque wall is obscured by the soft tissue [7].

Intrafissural positioning of the tube is suspected on frontal chest radiograph when the tube has a horizontal or oblique upward course and can be confirmed by a lateral view, fluoroscopy, or CT (Fig. 11). Complications of this malposition include inadequate pleural drainage and herniation of the lung parenchyma into the lumen of the tube causing infarction, with radiographic demonstration of a pulmonary opacity in the region of the tube's side or end hole [15]. Inadvertent intraparenchymal positioning is associated with pulmonary laceration, hematoma, infarction, and bronchopleural fistula. It is usually not identified radiographically and first noted on CT but should be suspected when one of the above mentioned complications is present on the radiograph (Fig. 12).

Other causes of ineffective drainage include tube kinking (Fig. 13); intermittent tube blockage resulting from clotted blood, pus, or debris in the tube [14]; or occlusion by juxtaposition of the tip of the tube against the mediastinum [16]. Inadvertent advancement of the chest tube into the mediastinum is uncommon, with rare reports of heart or great vessel injury [14, 17] (Fig. 14). Iatrogenic placement of the chest tube through the diaphragm into the abdomen has been reported to cause laceration of the liver, spleen, and stomach [14] (Fig. 15).

During thoracentesis, an intercostal vein or artery may be torn, causing an extrapleural hematoma. Because the intercostal vessels and nerves run along the inferior margin of each rib, the chest tube should be introduced over the superior margin of the rib to avoid this complication. An extrapleural hematoma usually appears as a focal lobulated area of increased density with a convex margin toward the lung. Unlike free pleural space fluid collections, extrapleural hematomas will not change configuration with changes in patient position. A CT scan can confirm the presence of this complication, showing a hematoma in the extrapleural space causing medial displacement of a fat layer that is just external to the parietal pleura (Fig. 16).

Reexpansion pulmonary edema results from rapid removal of air or fluid from the pleural space, usually after prolonged pulmonary atelectasis [13]. The clinical manifestations of reexpansion pulmonary edema vary from minimal symptoms to severe hypoxia and cardiorespiratory collapse. The symptoms tend to appear within the first 2 hours after lung reexpansion, but occasionally may take up to 48 hours. The process usually lasts 1–2 days, but may take several days to resolve [18]. The main radiographic finding of reexpansion pulmonary edema is a unilateral airspace opacity, which can be seen within a few hours of reexpansion of the lung [19]. CT findings include ground-glass opacities, consolidation, and interlobular and intralobular septal thickening [20] (Fig. 17). The pathogenesis of reexpansion pulmonary edema is not completely known. It is thought to be related to increased pulmonary vascular permeability, surfactant depletion, and increased production of oxygen free radicals [18].

After the removal of a chest tube, a residual thickened pleural or parenchymal line may be seen on the chest radiograph outlining the previous tube tract. This line should not be mistaken for a pneumothorax [7, 21].

Nasogastric and Nasoenteric Tubes

Nasogastric and nasoenteric tubes are used for suction of gastric contents, administration of medication, and feeding. The ideal position of the tip of the nasogastric tube is within the stomach beyond the cardia. When present, the side port of the tube should be located beyond the gastroesophageal junction. Small-bore nasoenteric feeding tubes ideally should be positioned with the tip in the second portion of the duodenum to decrease the risk of aspiration, but positions within the gastric antrum or in the other portions of the duodenum are acceptable [9, 13].

Complications after the placement of nasogastric and nasoenteric tubes are not rare. Ghahremani and Gould [22] reported a complication rate of 7.6% in 340 debilitated or critically ill patients after placement of flexible small-bore feeding tubes. Tube malposition is the most common complication, including incomplete insertion and tube coiling within the esophagus or hypopharynx [13] (Fig. 18). Tube misplacement in the tracheobronchial tree, lung parenchyma, pleural space, or even through the diaphragm may occur, which can result in pulmonary laceration, pulmonary contusion, pneumothorax, and hydropneumothorax [23] (Figs. 19 and 20). A chest radiograph should be obtained after the removal of a misplaced intrapleural feeding tube because a pneumothorax may develop after the removal of the tube [9]. Tracheobronchial tube malpositioning may cause aspiration, pneumonia, lung abscess, and empyema secondary to the infusion of feeding material or medications [7].

Pharyngeal, esophageal, or gastric perforations are rare complications of nasogastric or nasoenteric intubation. Radiographic findings that indicate esophageal perforation include extraesophageal location of the tube (best seen on oblique and lateral views), rapid development of pleural effusion after initiating tube feeding, hydropneumothorax, mediastinal widening, pneumomediastinum, and mediastinal air-fluid levels [13]. Gastric perforation may cause pneumoperitoneum.

Conclusion

A variety of devices is used to monitor and treat critically ill patients. The radiographic evaluation of these devices is important because the potentially serious complications arising from their introduction and use are often not clinically apparent. Familiarity with normal and abnormal radiographic findings is critical for the detection of these complications.

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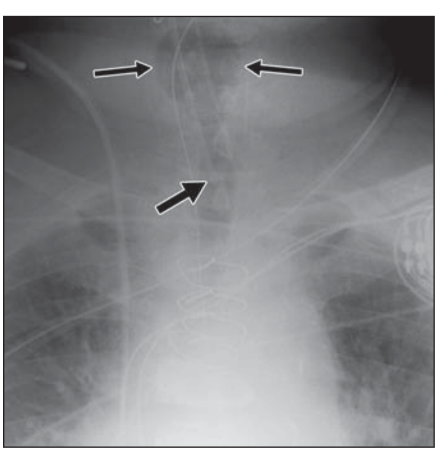


Fig. 1—56-year-old woman with misplaced endotracheal tube. Magnified anteroposterior chest radiograph shows that tip of endotracheal tube (*thick arrow*) is too high, at level of thoracic inlet. Endotracheal tube cuff (*thin arrows*) is overdistended. This abnormal position may cause vocal cord injury. ←

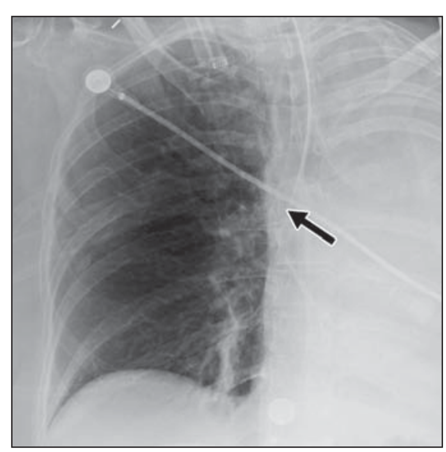


Fig. 2—60-year-old woman with inadvertent right main bronchial intubation. Anteroposterior chest radiograph shows endotracheal tube tip (*arrow*) in right main bronchus, resulting in complete collapse of left lung and leftward shift of mediastinum. →

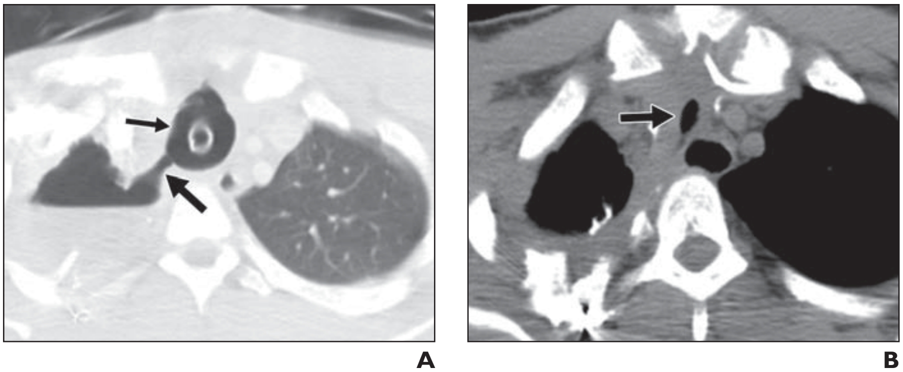


Fig. 3—32-year-old man with tracheal stenosis.
A, CT image shows overdistension of endotracheal tube cuff (*thin arrow*) and tracheopleural fistula (*thick arrow*). Note right hydropneumothorax.
B, CT image obtained few months later shows development of tracheal stenosis (*arrow*).

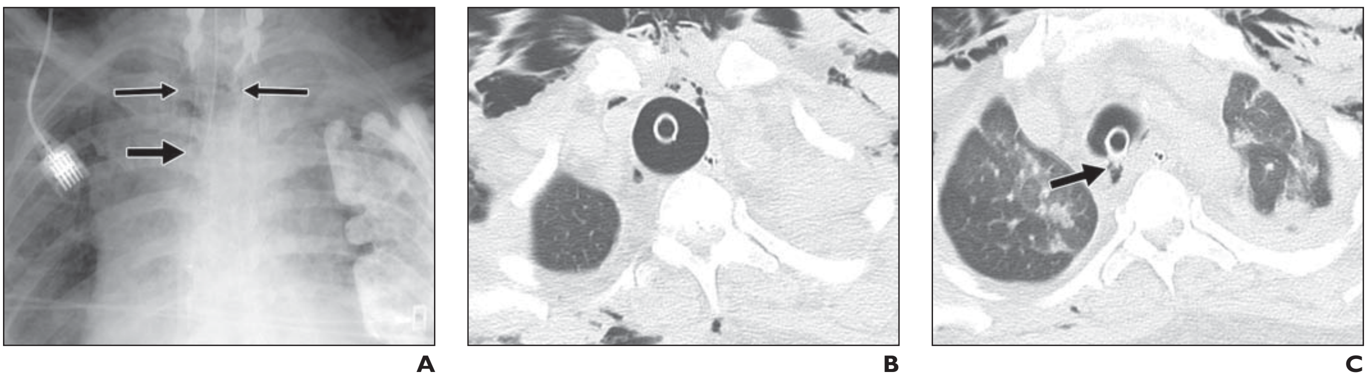


Fig. 4—42-year-old man with tracheal rupture.
A, Magnified anteroposterior chest radiograph shows overdistention of endotracheal tube cuff (*thin arrows*). Note right oblique displacement of distal portion of endotracheal tube (*thick arrow*) and reduced balloon-to-tip distance. Pneumomediastinum and subcutaneous and intramuscular emphysema are present. External pacemaker-defibrillator electrode plate is seen overlying left hemithorax.
B and **C,** Sequential CT images show overdistention of cuff (**B**) and tracheal rupture (*arrow*, **C**).

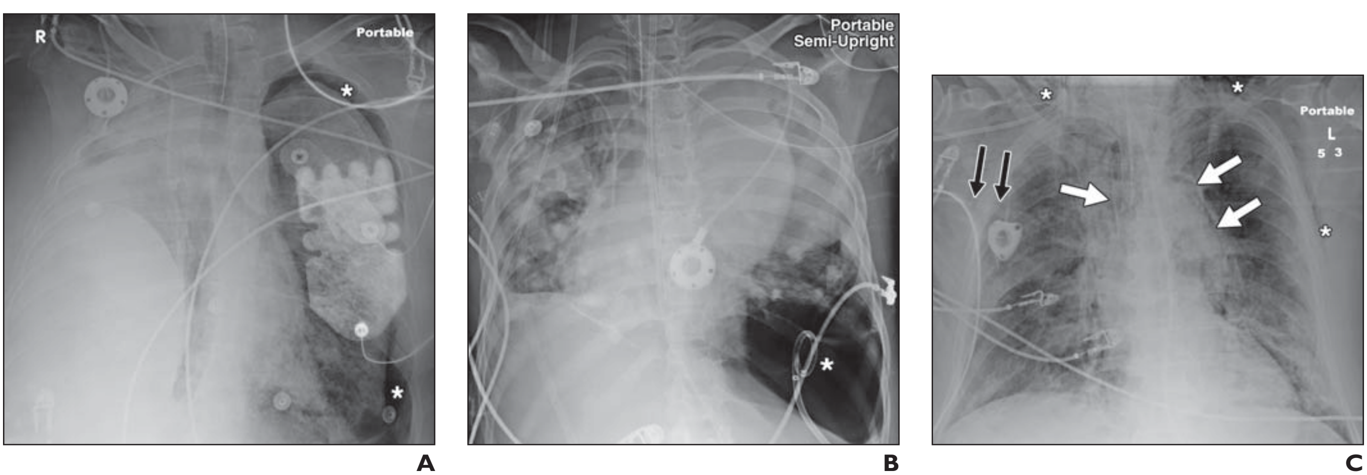


Fig. 5—Barotrauma in three patients.
A, 61-year-old woman with metastatic lung cancer, pneumonia, and large loculated right pleural effusion. Anteroposterior chest radiograph performed after endotracheal intubation shows development of left pneumothorax (*asterisks*). External pacemaker-defibrillator electrode plates are seen overlying left hemithorax.
B, 11-year-old girl with metastatic osteosarcoma. Anteroposterior chest radiograph shows left tension pneumothorax after endotracheal intubation. Intrapleural air is collecting at left lung base (*asterisk*), expanding costophrenic sulcus (deep sulcus sign). There is rightward shift of mediastinum. Bilateral pulmonary nodules and left pleural masses represent metastatic disease, and bilateral diffuse airspace disease corresponds to superimposed pneumonia.
C, 69-year-old man. Anteroposterior chest radiograph shows development of pneumomediastinum (*white arrows*) and extensive subcutaneous (*asterisks*) and intramuscular (*black arrows*) emphysema after endotracheal intubation.

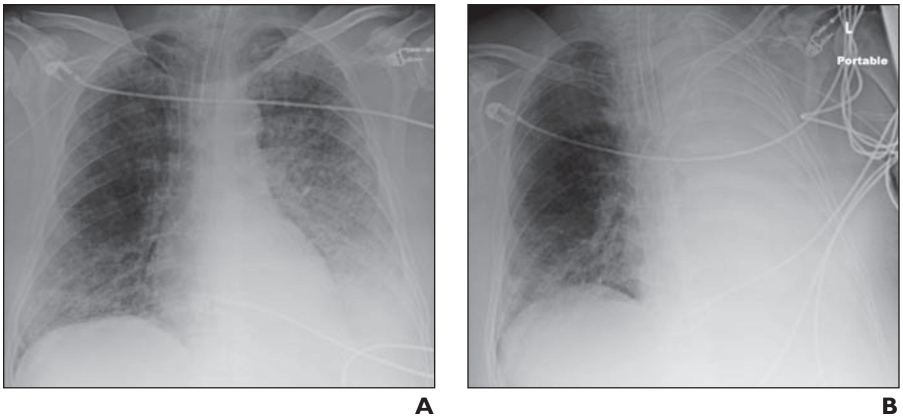


Fig. 6—66-year-old man with pneumonia and ventilator-related left lung collapse.
A, Anteroposterior chest radiograph shows bilateral diffuse airspace disease and left pleural effusion. Endotracheal tube is in proper position.
B, Anteroposterior chest radiograph obtained 12 hours later because of oxygen desaturation shows interval collapse of left lung with leftward shift of mediastinum. Bronchoscopy showed occlusion of left main bronchus caused by mucus plugging.

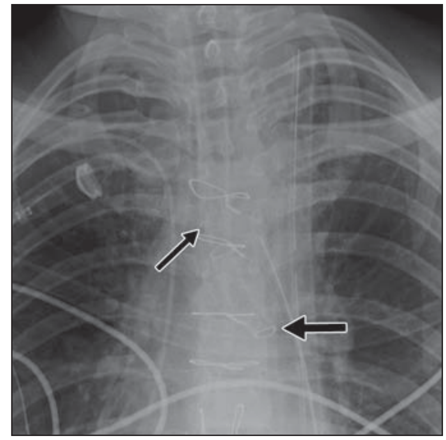


Fig. 7—66-year-old man with left-sided double-lumen endotracheal tube. Magnified anteroposterior chest radiograph shows double-lumen endotracheal tube with its left tip (*thick arrow*) in left main bronchus. Right tip (*thin arrow*) is noted within trachea for ventilation of right lung. Double-lumen endotracheal tube allows control of distribution of ventilation to each lung. It is important to differentiate between double-lumen endotracheal tubes and inadvertent selective bronchial intubation with single-lumen catheters.

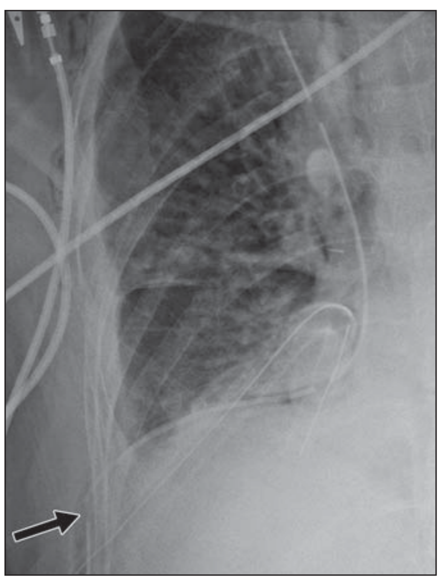


Fig. 8—56-year-old woman with incomplete insertion of chest tube. Magnified anteroposterior chest radiograph shows that side hole of one of right chest tubes (*arrow*) is located in subcutaneous tissue and there is mild subcutaneous emphysema. Side hole should be always positioned medial to inner margin of ribs. Incomplete insertion is associated with ineffective pleural drainage and accumulation of air or fluid in chest wall.

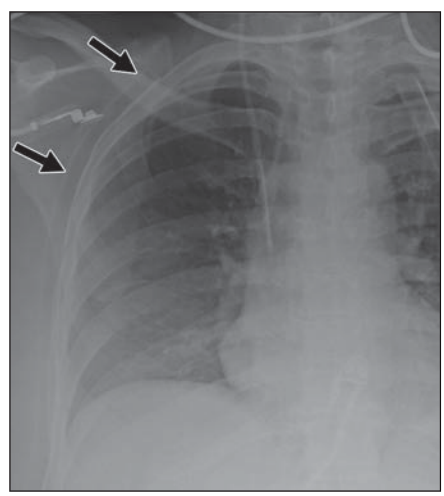
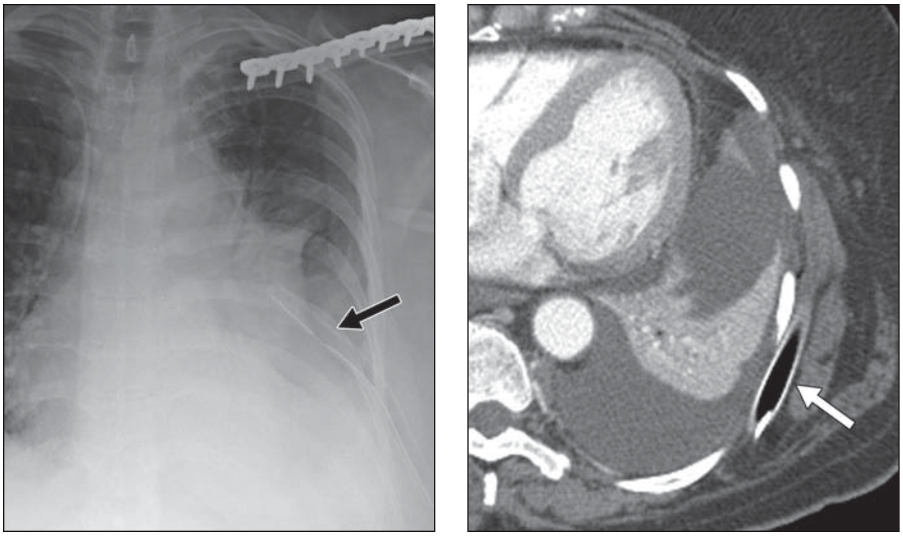
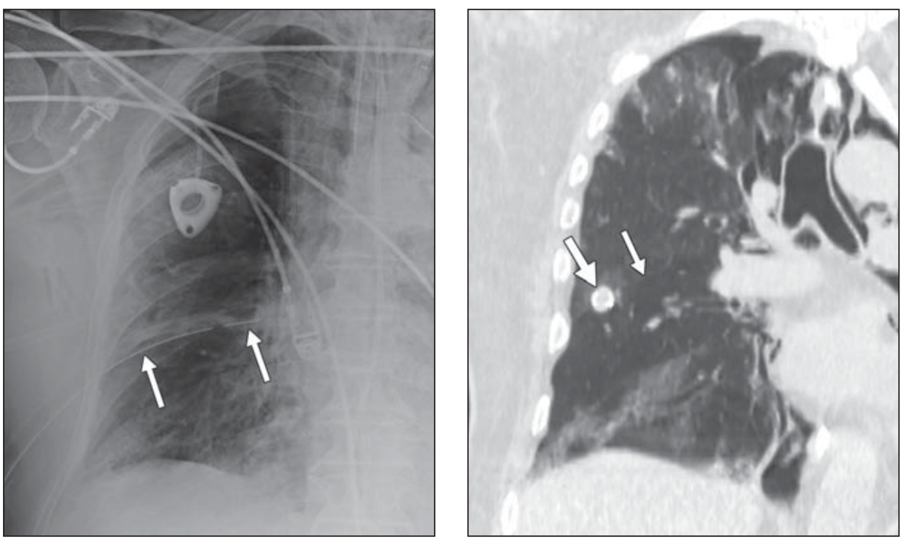


Fig. 9—58-year-old woman with extrapleural placement of chest tube. Magnified anteroposterior chest radiograph shows misplaced chest tube (*arrows*) within right chest wall.



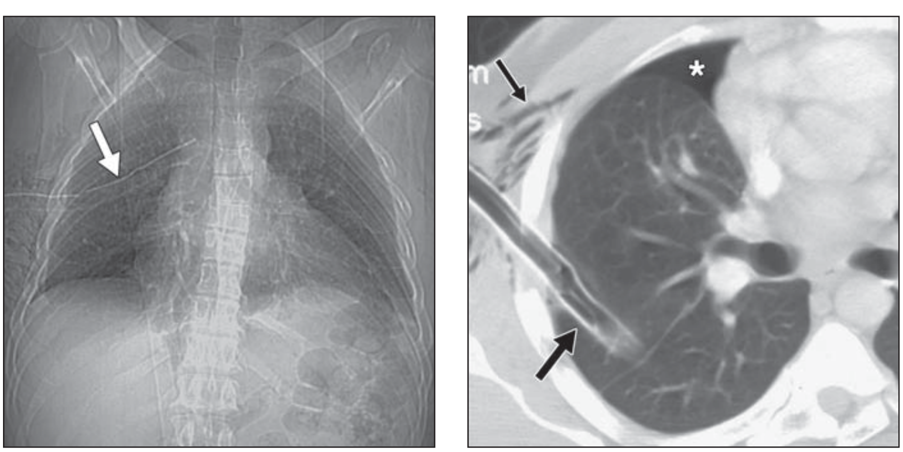
A B

Fig. 10—65-year-old woman with extrapleural placement of chest tube.
A, Magnified anteroposterior chest radiograph shows left chest tube (*arrow*) in apparently adequate position. CT scan was requested to further investigate because of ineffective drainage of left pleural effusion.
B, Magnified axial CT image shows misplacement of chest tube within chest wall (*arrow*).



A B

Fig. 11—69-year-old man with intrafissural placement of chest tube.
A, Magnified anteroposterior chest radiograph shows horizontal course of right chest tube (*arrows*).
B, Magnified coronal CT reformatted image shows misplacement of chest tube (*thick arrow*) within right minor fissure (*thin arrow*).



A B

Fig. 12—49-year-old man with intraparenchymal placement of chest tube.
A, Scout image shows chest tube (*arrow*) projecting over right mid lung field.
B, Magnified CT image shows chest tube (*thick arrow*) coursing through right upper lobe. There is associated small pneumothorax (*asterisk*) and subcutaneous emphysema (*thin arrow*).

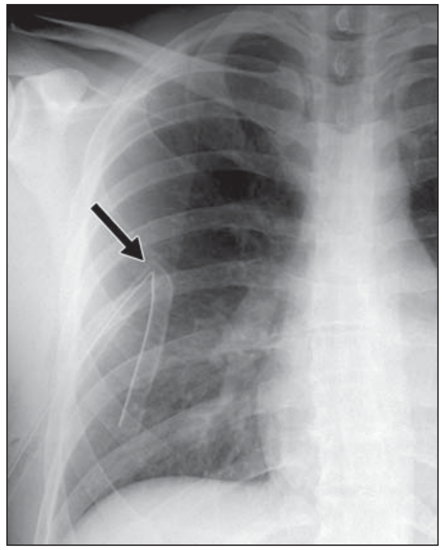
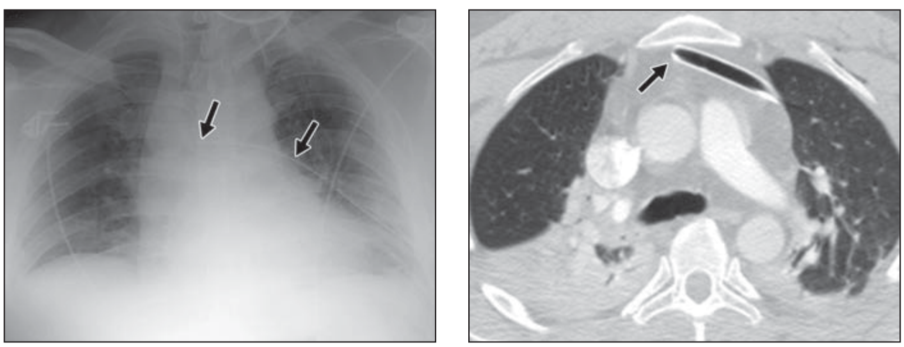
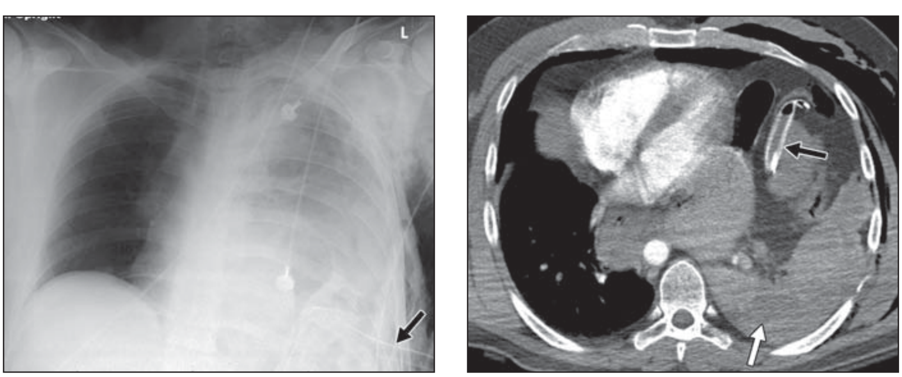


Fig. 13—48-year-old man with chest tube kinking. Magnified posteroanterior chest radiograph performed after chest tube placement shows kinking of chest tube (*arrow*) precluding adequate pleural drainage.



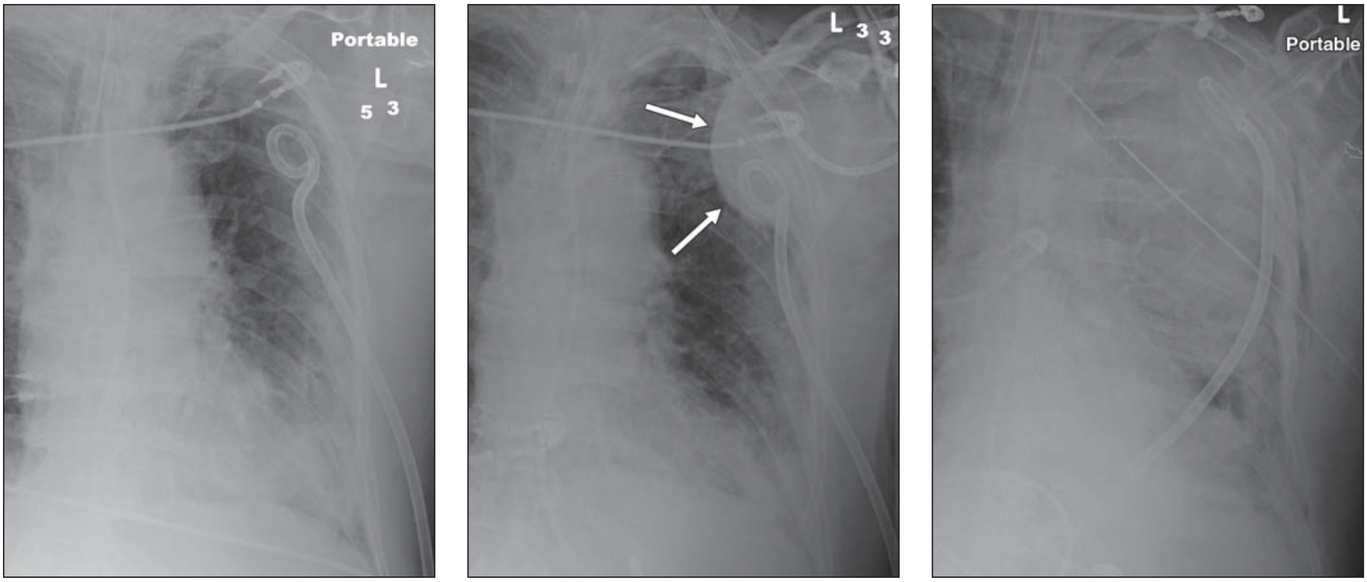
A B

Fig. 14—37-year-old man with mediastinal placement of chest tube.
A, Anteroposterior chest radiograph shows left chest tube (*arrows*) in inappropriate position, directed medially and projecting across mediastinum. There is persistent left pleural effusion.
B, CT image at level of pulmonary artery trunk confirms that tip of chest tube (*arrow*) is in anterior mediastinum.

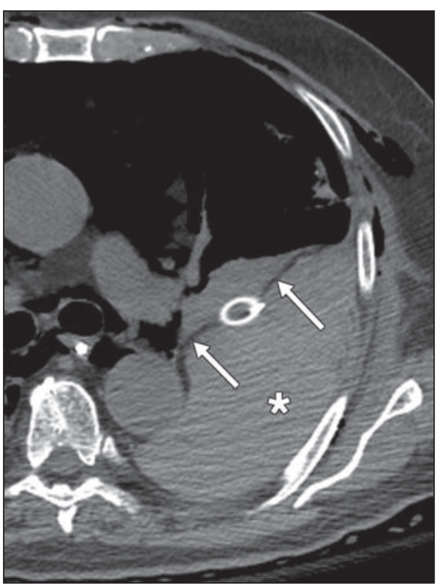


A B

Fig. 15—30-year-old male victim of motor vehicle trauma with abdominal placement of chest tube.
A, Anteroposterior chest radiograph shows horizontally oriented chest tube (*arrow*) in left lower hemithorax. There are several left rib fractures, opacification of left hemithorax, and subcutaneous emphysema.
B, CT image shows traumatic left diaphragmatic rupture with migration of abdominal content to left hemithorax. Chest tube (*black arrow*) is seen within mesenteric fat abutting small bowel loops. Note splenic rupture (*white arrow*) related to trauma.

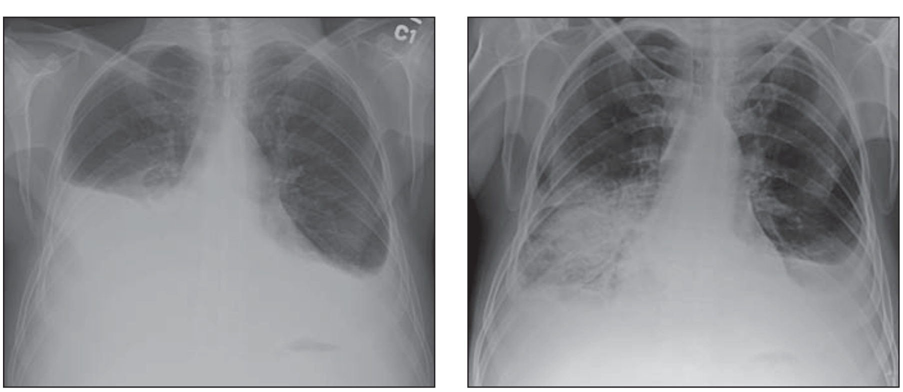


A B C



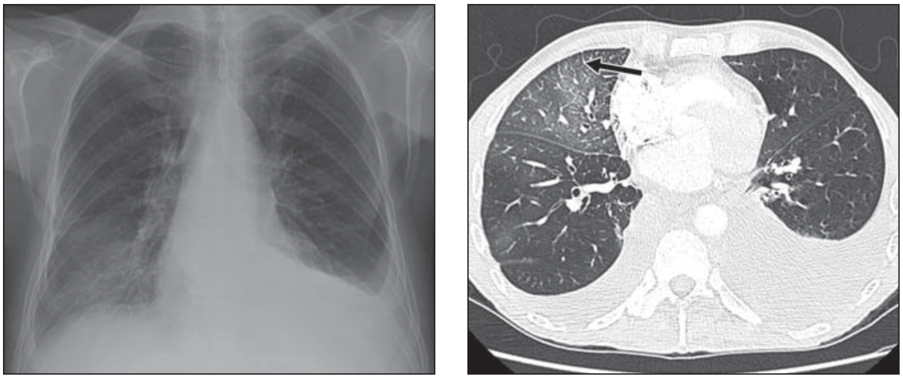
D

Fig. 16—69-year-old man with extrapleural hematoma.
A, Magnified anteroposterior chest radiograph performed immediately after placement of small-bore pleural drainage catheter for evacuation of pneumothorax shows no evidence of complications.
B and **C,** Sequential magnified anteroposterior chest radiographs performed next day show development of extrapleural hematoma (*arrows*, **B**), which increased in size, causing opacification of left hemithorax (**C**). Chest tube was placed.
D, Axial CT image shows large hyperdense extrapleural hematoma (*asterisk*). Note medial displacement of extrapleural fat (*arrows*).



A B

Fig. 17—58-year-old woman with reexpansion pulmonary edema following drainage of chylothorax.
A, Posteroanterior baseline chest radiograph shows bilateral pleural effusions. Patient underwent drainage of right pleural effusion and presented with progressive shortness of breath after procedure.
B, Anteroposterior chest radiograph obtained 2 hours after thoracentesis shows development of airspace opacity in right lower lung, compatible with reexpansion pulmonary edema.
(Fig. 17 continues on next page)



C D

Fig. 17 (continued)—58-year-old woman with reexpansion pulmonary edema following drainage of chylothorax.
C, Posteroanterior chest radiograph obtained few days later shows improvement of edema.
D, CT image shows ground-glass opacities and interlobular septal thickening (*arrow*) in right middle and lower lobes. Patient improved with no additional treatment.

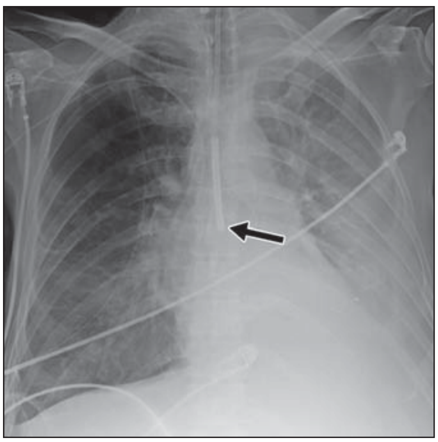


Fig. 18—58-year-old man with incomplete insertion of feeding tube. Anteroposterior chest radiograph shows tip of feeding tube (*arrow*) projecting over mid esophagus. There is risk for aspiration pneumonia if feeding material is administered.

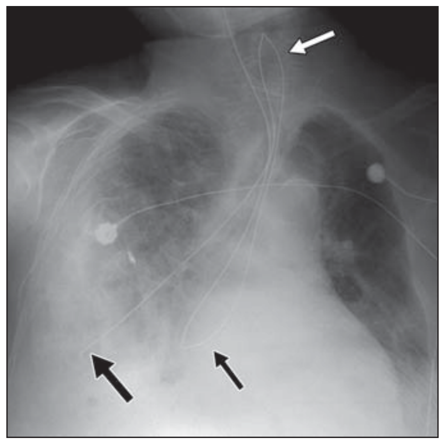


Fig. 19—60-year-old woman with malpositioned nasogastric tube. Anteroposterior chest radiograph shows looped nasogastric tube (*thin black arrow*) projecting in mid esophagus. After second looping in neck (*thin white arrow*), tube has entered bronchial tree, and its tip (*thick black arrow*) projects over right lower lobe. Note increased right lower lobe airspace opacities due to pulmonary contusion or pneumonia and right pleural effusion.

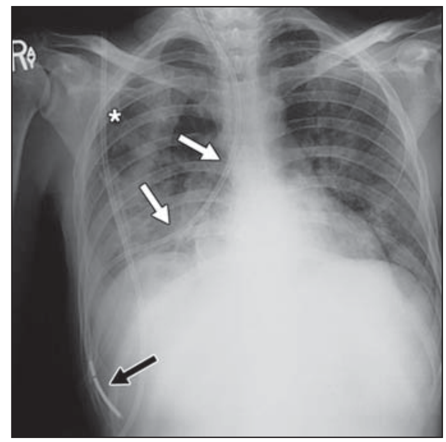


Fig. 20—30-year-old man with malpositioned feeding tube. Anteroposterior chest radiograph shows that feeding tube has entered right main bronchus, traversed right lower lobe bronchus (*white arrows*), and has its tip overlying right upper quadrant of abdomen (*black arrow*), raising concern for possible perforation of right hemidiaphragm. Note associated right pneumothorax (*asterisk*).

FOR YOUR INFORMATION

This article is part of a self-assessment module (SAM). Please also refer to "Chest Radiography in the ICU: Part 2, Evaluation of Cardiovascular Lines and Other Devices," which can be found on page 572.

Each SAM is composed of two journal articles along with questions, solutions, and references, which can be found online. You can access the two articles at www.ajronline.org, and the questions and solutions that comprise the Self-Assessment Module by logging on to www.arrs.org, clicking on *AJR* (in the blue Publications box), clicking on the article name, and adding the article to the cart and proceeding through the checkout process.

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