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Back to Fundamentals: Radiographic Evaluation of Thoracic Lines and Tubes in Children

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OBJECTIVE. The purpose of this article is to provide an up-to-date review of the radiographic appearance of the most commonly used thoracic lines and tubes in pediatric patients in daily clinical practice.

CONCLUSION. Thoracic support lines and tubes are frequently used in children receiving hospital care. Evaluation of these devices is a fundamental skill in radiology. Many different devices are currently used, and new devices are regularly introduced. It is essential for radiologists to maintain a clear understanding of all devices currently in use.

Intrathoracic support lines and tubes are common in the hospital care of children, and familiarity with the radiographic appearance of these devices is essential for the radiologist. Physical examination has limited utility for assessing the position of a support device, and radiographs are well suited to evaluating most lines and tubes.

The American College of Radiology recommends that a chest radiograph be obtained after placement of all thoracic lines and tubes [1]. Radiographs depict the full length and course of the device and can be used to assess associated complications, such as malposition and pneumothorax. Although ultrasound has received increased attention as a tool for evaluating lines and tubes without the use of ionizing radiation [2–7], radiography remains the most commonly used modality for this indication. A large variety of different support devices are used in pediatric patients, and the list continues to grow. The challenge for the radiologist is to maintain a current understanding of each of these devices. The purpose of this article is to provide an up-to-date review of the radiographic appearance of the most commonly used thoracic lines and tubes in pediatric patients in daily practice.

Vascular Catheters

Umbilical Artery Catheter

Umbilical artery catheters (UACs) are frequently placed in neonates, most often premature infants in the neonatal ICU. UACs are used to monitor blood pressure and to infuse fluids and medications [8]. UACs are placed by transecting the umbilical cord and cannulating the umbilical artery [9, 10]. The catheter courses from the umbilical artery to the internal iliac artery to the common iliac artery to the aorta [11] (Fig. 1A).

Appropriately positioned UACs have a characteristic appearance on frontal radiographs (Fig. 1A). The catheter enters the umbilicus in the mid abdomen, dips in the pelvis along the course of the umbilical artery, and ascends through the internal and common iliac arteries to reach the aorta [11]. The position of the catheter tip should be assessed on all radiographs. Acceptable locations include a high position between the T6 and T9 or T10 vertebral bodies [11, 12] and a low position between L3 and L5 [11].

UACs can be malpositioned during placement (Fig. 2). In the chest, UACs may be advanced too far and reach the aortic arch, brachiocephalic artery, or subclavian artery. In the abdomen and pelvis, UACs may enter a branch vessel such as the celiac artery or pass inferiorly through the contralateral common iliac artery. Catheters may be curled within a vessel. Catheters may also perforate the vessel and become extraluminal, which can cause serious complications, including hemorrhage [11]. Additional potential complications include thrombosis, embolism, infection, and pseudoaneurysm [13, 14].

Umbilical Venous Catheter

Umbilical venous catheters (UVCs) are often used for vascular access in the neo-

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natal ICU. Like UACs, UVCs are placed by transecting the umbilical cord and cannulating the umbilical vein [9, 10]. When appropriately positioned, the catheter extends through the umbilical vein to the umbilical recess, crosses the left portal vein, and passes through the ductus venosus to the inferior vena cava (IVC) [15] (Fig. 1A). The ideal position of the UVC tip is at the junction of the IVC and right atrium or in the lower right atrium [15, 16]. UVC position is typically assessed with frontal radiographs, although lateral radiographs are often helpful to improve localization (Fig. 3).

UVCs may be malpositioned within the thorax when they are advanced too far (Fig. 2). The UVC may pass from the IVC into the superior vena cava. It may pass from the right atrium through a patent foramen ovale into the left atrium and into a pulmonary vein. Occasionally, it may enter the right atrium, pass through the tricuspid valve, and enter the right ventricle and pass to the pulmonary artery. Abnormal positions below the diaphragm are often seen on chest radiographs and may include coiling within the umbilical recess, passage to the left or right portal veins, or low positioning within the ductus venosus. When the position of a UVC is unclear on a frontal radiograph, the addition of a lateral radiograph is often helpful for troubleshooting (Fig. 3). UVCs may perforate the vessel wall and cause a hematoma or fluid collection if IV fluids are administered through the malpositioned line [11, 15]. In the chest, UVCs can perforate the left or right atrial wall [11, 15].

Peripherally Inserted Central Catheter

Peripherally inserted central catheters (PICCs) are inserted into a peripheral vein and passed to a central vein. PICCs are often used in pediatric patients who need long-term vascular access. PICCs are most frequently placed through the cephalic or basilic vein in the upper extremity or the saphenous vein in the lower extremity. In adults, upper extremity insertion sites are preferred owing to reported greater infection rates in lower extremity PICCs [17, 18]. In children, the evidence is mixed. Several studies [19–21] have shown no difference or lower complication rates with lower extremity PICCs, but another [22] showed higher infection rates with these devices. Given the mixed evidence, the site of PICC insertion in children is based on location of the most suitable vein. Upper extremity PICC tips should be positioned within the superior vena cava, and lower extremity PICC tips should be placed within the IVC [23–26] (Fig. 4). Sometimes, PICCs cannot be advanced to a central location, and the tip is positioned within a noncentral vein such as the brachiocephalic, subclavian, axillary, or saphenous vein. These noncentrally located lines are sometimes referred to as midline catheters or long IVs and may be used when vascular access is limited. A central location is preferred, however, because noncentral locations are associated with more complications, including leaking at the PICC insertion site and phlebitis [27].

PICCs may be malpositioned during placement (Fig. 4). Malposition is more common when the catheter is placed at the bedside than under fluoroscopic guidance [28]. Chest radiography may show the catheter tip in a noncentral location, within a branch vessel, or rarely, perforated through a vessel wall, causing pleural effusion or pericardial effusion [29]. Additional complications associated with PICCs include phlebitis, infection, catheter occlusion, catheter fracture, and thrombus [27, 30, 31].

Pulmonary Artery (Swan-Ganz) Catheter

Pulmonary artery (Swan-Ganz) catheters are balloon floatation catheters that are primarily used for hemodynamic monitoring of pediatric patients in critical condition [32–35]. These catheters are placed through the internal jugular vein and pass through the superior vena cava, right atrium, and right ventricle to reach the pulmonary artery. The catheter can be advanced distally and the balloon inflated to measure pulmonary capillary wedge pressure. When pulmonary capillary wedge pressure is not being actively measured, the ideal location of the catheter tip is within the right or left pulmonary artery or in the proximal portion of one of the lobar branches [36, 37].

Radiographs are typically used to monitor the position of pulmonary artery catheters (Fig. 5). Rare complications caused by pulmonary artery catheters include pulmonary infarction if the catheter is left in a peripheral location for a prolonged time, particularly if the balloon is left inflated; cardiac arrhythmia; traumatic injury to the tricuspid valve; and pulmonary artery pseudoaneurysm and rupture [36, 38]. It is essential to identify the pulmonary artery catheter tip on all radiographs and inform the ICU staff if a catheter is left in a peripheral location or if a new pulmonary opacity is seen in association with a pulmonary artery catheter, which may indicate pulmonary infarction or pulmonary artery rupture.

Extracorporeal Membrane Oxygenation Cannula

Extracorporeal membrane oxygenation (ECMO) is a life support technique that allows oxygenation of the blood in cases of respiratory or cardiac failure. ECMO functions by removing deoxygenated blood from the body through a drainage cannula, pumping blood through the ECMO circuit to the oxygenator (where O_2-CO_2 gas exchange occurs), and then returning oxygenated blood to the body through a reinfusion cannula [39].

In children with cardiac failure or cardiopulmonary failure or in neonates with respiratory failure a venoarterial mode is used. In peripheral venoarterial ECMO, the distal portion of the drainage cannula is placed within the right atrium, most often through the right internal jugular vein, and the reinfusion cannula tip is most often placed in right common carotid artery (Fig. 6A). It is important to note that arterial reinfusion cannulas typically do not have a radiolucent distal portion, but venous drainage cannulas often do, and the tip may or may not contain a radiopaque dot [39]. Alternatively, central ECMO may be used, in which cannulas are placed through a sternotomy. In central ECMO, the drainage cannula is typically placed directly within the right atrium, and the reinfusion cannula is typically placed directly in the ascending aorta (Fig. 6B).

In cases of respiratory failure without cardiac failure, a venovenous mode may be used [39]. Venovenous ECMO may be achieved through two separate cannulas or a single cannula with two lumens. In two-site venovenous ECMO, the drainage cannula tip is typically placed at the inferior cavoatrial junction through a common femoral vein, and the reperfusion cannula tip is typically placed in the right atrium through the right internal jugular vein and directed toward the tricuspid valve under echocardiographic guidance to prevent admixing of oxygenated and deoxygenated blood [39]. In single-site venovenous ECMO, a single dual-lumen cannula is most often placed through the right internal jugular vein and positioned so that reinfusion port is in the right atrium and the two drainage ports are positioned in the superior vena cava and IVC (Fig. 6C).

Radiographs are typically used to assess the positions of ECMO cannulas and may show kinking or malposition. Bleeding is the most common complication of ECMO and may occur at the cannula insertion site, at a recent surgical site, or in other sites, such as the brain. When central venoarterial ECMO is used, the sternotomy is typically kept open to facilitate detection of bleeding at the cannula insertion sites, and a sternotomy spacer is often visible on chest radiographs [39] (Fig. 6B).

Esophageal and Tracheal Tubes

Nasogastric, Orogastric Tubes, and Nasoduodenal Tubes

Nasogastric and orogastric sump tubes are frequently placed in pediatric patients primarily to provide gastric drainage, They may also be used to administer medications and food. Sump tubes have two lumens: a larger lumen that can be used for suction, irrigation, and administration of medications or food and a smaller lumen that allows air to enter the tube and equalize the pressure within the stomach during suctioning. Nasoduodenal feeding tubes are smaller-bore flexible tubes that frequently have weighted tips and are ideally placed with the tip distal to the pylorus to administer feedings. Although bedside methods, such as auscultation, may be used to assess tube tip position, radiography is the reference standard for assessing nasogastric, orogastric, and nasoduodenal tube position [40]. On radiographs, an appropriately positioned nasogastric or orogastric tube is seen passing through the thorax in the midline with tip and side holes located below the gastroesophageal junction within the stomach (Figs. 1, 2A, 4A, 4B, 6A, and 6C). The ideal nasoduodenal tube position is with the tip in the duodenum, past the pylorus (Fig. 1B). Radiography is the first-line imaging study for evaluating malposition. Potential malpositions include coiling within the pharynx or esophagus, passage into the airway, high position within the esophagus above the gastroesophageal junction, side hole positioning within the esophagus, and perforation through the pharynx or esophagus [41, 42] (Fig. 4C).

Endotracheal and Tracheostomy Tubes

Endotracheal tubes (ETTs) are used in children with acute respiratory distress or who need anesthesia, and tracheostomy tubes are used in children with prolonged respiratory compromise [16]. Chest radiographs are routinely used to assess ETT and tracheostomy tube position. The ideal position of the ETT tip is midway between the clavicular heads and the carina, projecting over the air-filled trachea [11, 16] (Figs. 1, 4C, 6A, and 6B). ETT position changes with head position: the tip moves inferior with neck flexion and superior with neck extension [11], following the adage “the hose goes with the nose.” The ideal position of a tracheostomy tube is with its tip projecting over the air-filled trachea (Fig. 7A). Potential ETT malpositions include placement within a bronchus, esophageal intubation, and pharyngeal perforation [16, 42] (Figs. 2C and 3).

Drainage Catheters

Mediastinal Drain

Mediastinal drainage catheters are primarily used after surgery to prevent or reduce postoperative hematoma and hemopericardium [43]. If cardiac surgery is performed without entering the pleural space, then a single mediastinal drain may be placed. Alternatively, mediastinal drains may traverse the pleural space if pleural drainage is also required [43]. Mediastinal drains typically contain a radiopaque filament and are easily evaluated on chest radiographs (Figs. 5, 6B, and 8).

Pleural Drainage Tube

Pleural drainage tubes, or chest tubes, may be used to drain a pleural effusion, empyema, or pneumothorax [44–46]. Pleural drainage tubes are usually placed in the anterior superior chest to treat pneumothorax and in the posterior inferior chest to drain pleural effusion [47]. Chest tubes are also placed during thoracic surgery to reduce the incidence of postoperative pneumothorax, pleural effusion, and hemothorax [43] (Figs. 5, 6B, and 8). Conventional chest tubes are straight and contain a radiopaque filament, which is visible on chest radiographs. Alternatively, pigtail catheters, which are also radiopaque and exhibit a characteristic distal curl, may be positioned in the pleural space. Chest tubes contain side holes, which are typically visible on radiographs. In assessment of a chest tube on radiographs, the tip of the tube and all side holes should be located within the pleural space. Pleural drainage tubes may become malpositioned, and the side holes or entire tubes may retract into the soft tissues of the chest wall.

Cardiac Occluder and Mechanical Assist Devices

Cardiac Occluder Device

Historically, atrial septal defect, patent foramen ovale, ventricular septal defect, and patent ductus arteriosus (PDA) were exclusively treated with surgical closure. More recently, percutaneous devices have been introduced that allow closure of these lesions without surgery.

The radiographic appearances of different atrial septal defect and patent foramen ovale closure devices vary depending on the type, but in most pediatric patients, these devices have the appearance of two flat disks connected by a waist with central radiopaque markers that project over the atrial septum [48]. When appropriately positioned in pediatric patients, the device typically projects to the right of or over the spinous processes on frontal radiographs and between T7 and T9 on frontal and lateral radiographs [49] (Fig. 7B). Occasionally, the disks may not be apparent because of cardiac motion, and only the radiopaque markers are visible [49]. The radiographic appearance may be slightly different in adults, in whom the disks may be less apparent, and the device is more likely to project over the spinous process [50]. Embolization is a rare complication. Potential sites of embolization include the right atrium, left atrium, pulmonary artery, left ventricle, and aorta [51–53]. Device position is typically monitored by echocardiography, though radiographs may show malposition [53].

Ventricular septal defect closure devices look like atrial septal defect closure devices, but the waist between the two disks is typically wider [54]. Ventricular septal defect closure devices project to the left of the spine on frontal chest radiographs [50, 53] (Fig. 7A).

PDA closure devices are used in children and adults to mitigate the risks of associated endocarditis and heart failure due to left-to-right shunting [53]. In small infants, percutaneous PDA occlusion is technically challenging; therefore, these patients typically undergo surgical closure [53]. The appearance of PDA closure devices varies depending on the type, and they may have the appearance of coils (Gianturco coils, Nit-Occlud coils [PFM Medical]), a pear shape (Gianturco-Grifka vascular occlusion device), or a plug with a retention skirt (Amplatzer duct occluder) [53]. On radiographs, PDA occlusion devices should overlie the position of the PDA, which is most often to the left of the spine, above the left main bronchus [53] (Fig. 7C).

Intraaortic Balloon Pump

The intraaortic balloon pump (IABP) is a mechanical assist device used to temporarily improve myocardial perfusion and improve cardiac output. It consists of an elongated balloon mounted on a catheter, which is positioned within the descending thoracic aorta through a femoral artery. The IABP functions by inflating the balloon with carbon dioxide during diastole to improve coronary perfusion and deflating the balloon during systole to reduce cardiac afterload [47].

Radiographs are used to assess the appropriate position of an IABP. The appearance of the device on chest radiographs can be deceptively subtle, because the length of the balloon is radiolucent and only the tip contains a small radiopaque marker [37] (Fig. 8). The tip of the IABP should be positioned just below the origin of the left subclavian artery [47]. If positioned too high, the balloon can occlude an aortic arch branch vessel and if positioned too low, the balloon can occlude a renal artery. Other complications include lower limb ischemia, vessel perforation, arterial dissection, and embolization [37].

Ventricular Assist Device

Ventricular assist devices (VADs) are mechanical pumps that can be used to support the function of the right ventricle, left ventricle, or both ventricles [47, 48] (Fig. 5). Left VADs are the most commonly used in pediatrics. They function by pumping blood into an inflow cannula placed in the left ventricle and out of an outflow cannula placed in the ascending aorta. The VAD and cannulas are visible on radiographs, and vascular catheters should be kept distant from the inflow cannula because they can become entangled in the device and cause potentially life-threatening malfunction [47]. Complications of VADs include hemorrhage, sepsis, thromboembolism, renal failure, technical failure, and neurologic sequelae [47].

Implanted Electrical Devices

Pacemaker

Cardiac pacemakers are used in patients of all ages who have abnormal cardiac rhythms, and use of these devices can be temporary or permanent [47]. If temporary cardiac pacing is needed after cardiac surgery, epicardial leads may be left in place during surgery and then removed afterward. On chest radiographs, temporary epicardial pacer leads exhibit characteristic knots at the skin surface and have a straight tip [43] (Fig. 6B). When permanent cardiac pacing is required, a pulse generator is implanted within the subcutaneous tissues, and leads are placed through either a transvenous approach with endocardial fixation or an epicardial approach during open surgery [47] (Fig. 9).

In pediatric patients there are two common configurations for implanted cardiac pacemakers. In one, the pulse generator is positioned within the subcutaneous tissues of the upper abdomen and connected to leads sewn directly to the myocardium (Fig. 9). In the other, the pulse generator is positioned within the subcutaneous tissues of the chest and connected to transvenous leads, which pass through the subclavian or jugular vein (Fig. 9). Transvenous leads may be implanted in the right atrium, right ventricle, or coronary sinus and have a typical corkscrew tip used to fix the lead to the myocardium [55].

Complications of cardiac pacemaker placement that may be detected on chest radiographs include pneumothorax, myocardial perforation (lead seen passing outside the myocardium), and incorrect lead placement [55]. Long-term complications that may be detected on chest radiographs include lead fracture and dislodgment [55].

Automated Implantable Cardioverter Defibrillator

Automatic implantable cardioverter-defibrillators (AICDs) look like cardiac pacemakers and often incorporate pacing functions. However, they are also used to monitor the electrical activity of the heart and deliver a shock when a life-threatening rhythm is detected. AICD generators are typically larger than pacemaker generators of a similar generation. Newer models, however, have smaller pulse generators, and generator size is therefore not a reliable way to differentiate AICDs from pacemakers [55]. The best way to differentiate an AICD from a conventional pacemaker on chest radiographs is by the presence thick radiopaque shock coils surrounding the lead (Figs. 5 and 9). These shock coils are usually located in the right ventricle and often in the superior vena cava [55].

Complications of AICDs are similar to complications of conventional pacemakers. They may include pneumothorax, myocardial perforation, incorrect lead placement, lead fracture, and lead dislodgment [55].

Vagal Nerve Stimulator

Vagal nerve stimulators are used to treat intractable epilepsy in children and adults [56]. A vagal nerve stimulator consists of an electrode implanted around the left vagus nerve in the neck and a generator implanted under the skin in the left chest wall [57]. On radiographs, the generator resembles a cardiac pacemaker, the leads extending into the left neck rather than to the heart [57] (Fig. 10). As with cardiac pacemakers, incorrect lead placement, lead fracture, and lead dislodgment can be visualized on radiographs [58, 59].

Conclusion

Radiologists play a central role in the evaluation of thoracic lines and tubes in children. It is essential for radiologists to be familiar with a wide range of medical devices used in the care of children to confirm appropriate position and diagnose malposition and complications.

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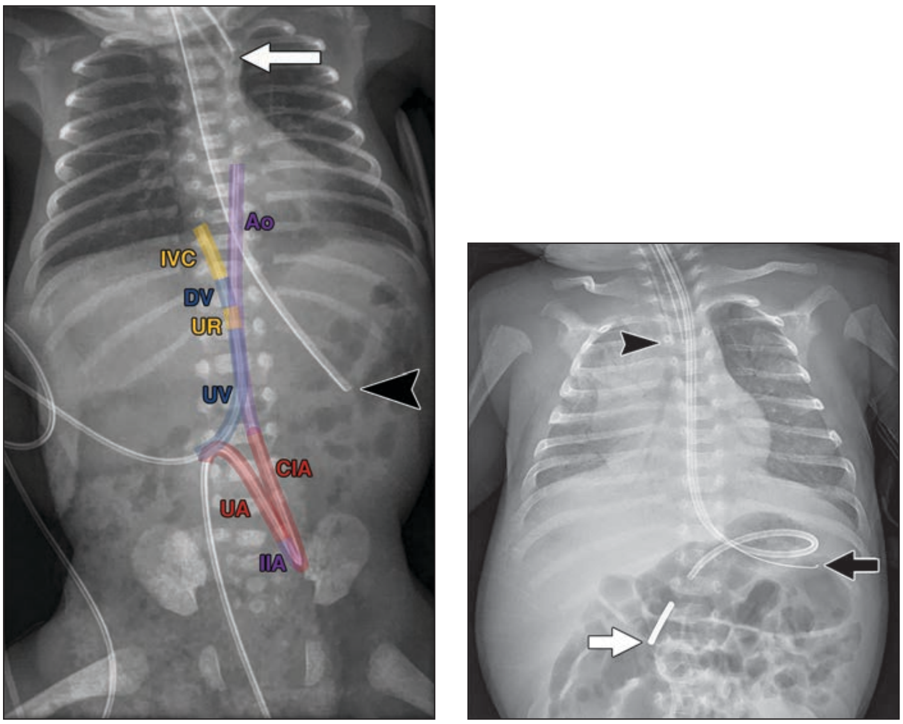
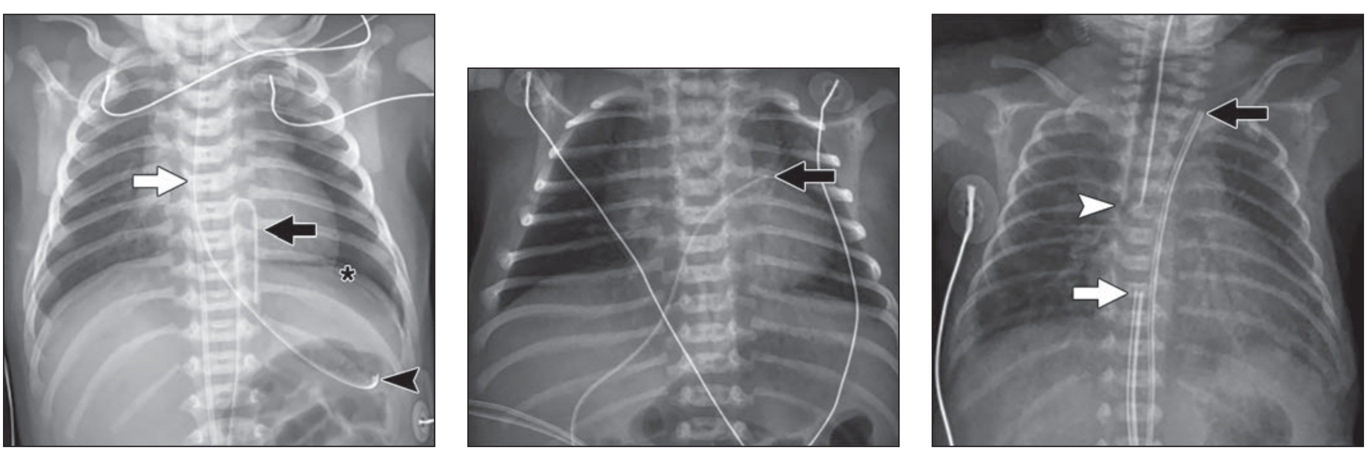


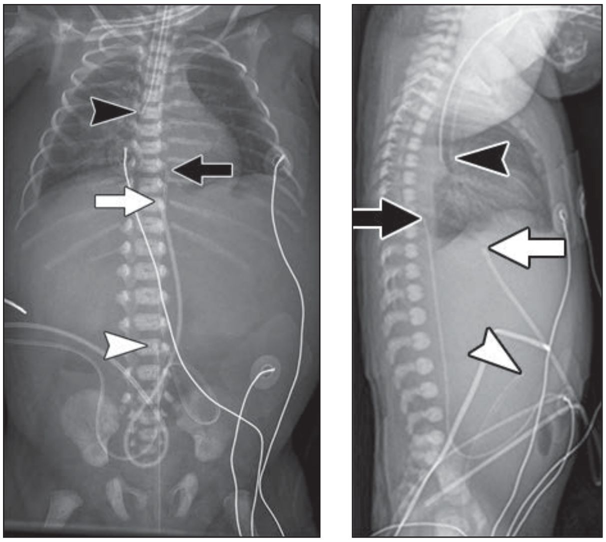
A B

Fig. 1—Appropriately positioned lines and tubes.
A, 1-day-old boy born at 24 weeks' gestation. Frontal radiograph of chest and abdomen shows appropriately positioned endotracheal tube (*arrow*) with tip between clavicular heads and carina, umbilical artery catheter passing through umbilical artery (UA) to internal iliac artery (IIA) to common iliac artery (CIA) to aorta (Ao) with tip at level of T6, umbilical venous catheter passing through umbilical vein (UV) to umbilical recess (UR) to ductus venosus (DV) to inferior vena cava (IVC) with tip at inferior cavoatrial junction, and orogastric tube (*arrowhead*) with tip in stomach.
B, 4-week-old boy. Frontal chest radiograph shows weighted nasoduodenal tube (*white arrow*) with tip in duodenum, nasogastric tube (*black arrow*) with tip in stomach, and endotracheal tube (*arrowhead*) with tip between clavicular heads and carina.



A B C

Fig. 2—Malpositioned umbilical catheters.
A, 1-day-old boy. Frontal chest radiograph shows malpositioned umbilical venous catheter (*white arrow*) with tip in upper right atrium and malpositioned umbilical artery catheter (*black arrow*) with tip curled in thoracic aorta. Left basilar pneumothorax (*asterisk*) and appropriately positioned orogastric tube (*arrowhead*) with tip in stomach are also evident.
B, 1-day-old girl. Frontal chest radiograph shows malpositioned umbilical venous catheter (*arrow*) passing from right atrium through foramen ovale to left atrium. Tip is located in left superior pulmonary vein.
C, 0-day-old boy. Frontal chest radiograph shows malpositioned umbilical artery catheter (*black arrow*) with tip in left common carotid artery. Malpositioned endotracheal tube (*arrowhead*) with tip in right main bronchus and umbilical venous catheter (*white arrow*) with tip in upper right atrium are also evident.

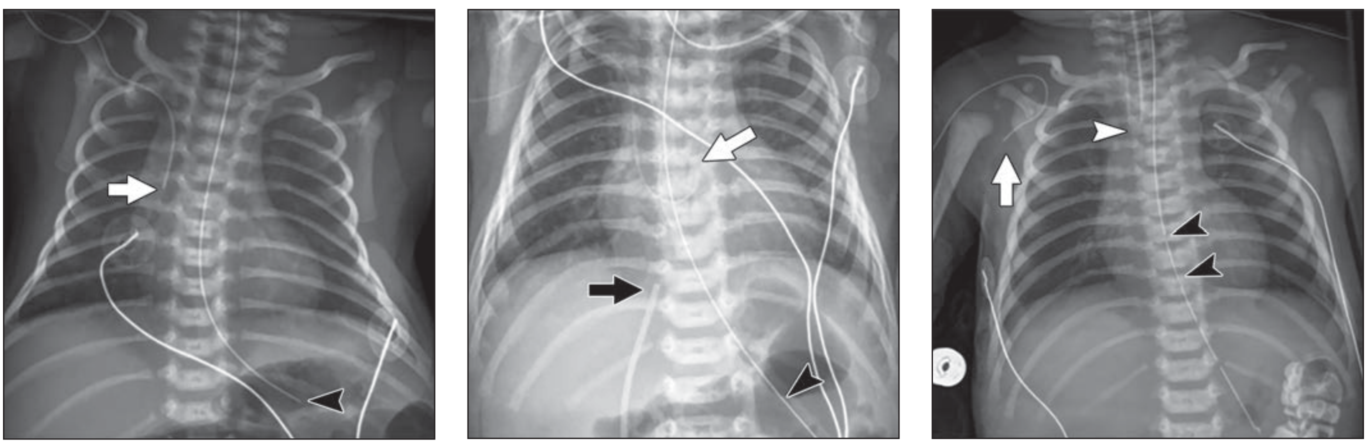


A B

Fig. 3—6-day-old girl in critical condition with malpositioned umbilical venous catheter and endotracheal tube.

A, Frontal radiograph of chest and abdomen shows malpositioned umbilical venous catheter (*white arrow*) below inferior vena caval–right atrial junction, malpositioned endotracheal tube (*black arrowhead*) in right main bronchus, appropriately positioned umbilical artery catheter (*black arrow*) at level of T8, and malpositioned bladder catheter (*white arrowhead*) located too high within abdomen.

B, Lateral radiograph shows umbilical venous catheter (*white arrow*) malposition within ductus venosus better than does **A**. Malpositioned low endotracheal tube (*black arrowhead*), malpositioned high bladder catheter (*white arrowhead*), and appropriately positioned umbilical artery catheter (*black arrow*) also are evident.



A B C

Fig. 4—Appropriately positioned and malpositioned peripherally inserted central catheters (PICCs).

A, 12-day-old girl. Frontal chest radiograph shows right upper extremity PICC (*arrow*) in appropriate position with tip in superior vena cava. Appropriately positioned orogastric tube (*arrowhead*) with tip in stomach is also evident.

B, 8-day-old boy. Frontal chest radiograph shows malpositioned right upper extremity PICC (*white arrow*) curled in right atrium. Appropriately positioned orogastric tube (*arrowhead*) passing to stomach and umbilical venous catheter (*black arrow*) with tip at inferior cavoatrial junction are also evident.

C, 7-day-old girl. Frontal chest radiograph shows malpositioned right upper extremity PICC (*arrow*) curled in right axilla and malpositioned orogastric tube with tip in stomach but with side holes (*black arrowheads*) in esophagus. Endotracheal tube (*white arrowhead*) is appropriately positioned.

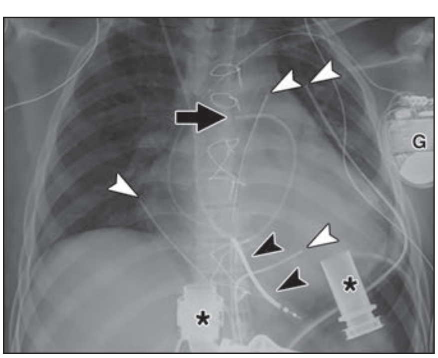


Fig. 5—17-year-old boy with cardiomyopathy who has undergone left ventricular assist device (LVAD) placement and has appropriately positioned lines and tubes. Frontal chest radiograph shows cardiomegaly, median sternotomy wires, pulmonary artery catheter (*arrow*) with tip in main pulmonary artery, automated implantable cardioverter defibrillator with generator (G) and single lead with radiopaque shock coil (*black arrowheads*) in right ventricle, LVAD (*asterisks*), and four chest tubes (*white arrowheads*).

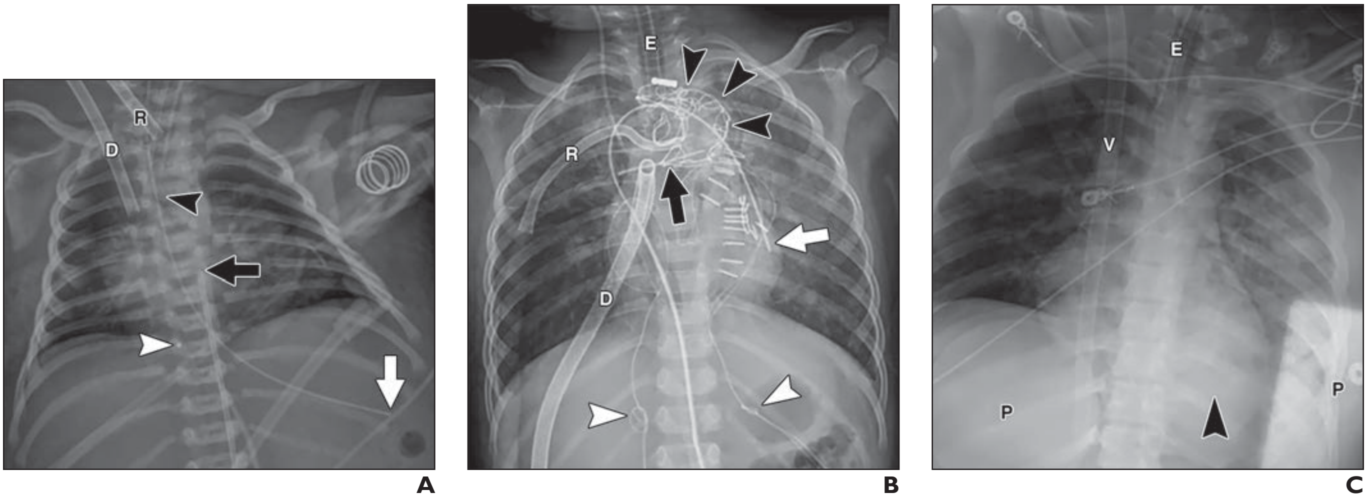


Fig. 6—Radiographic appearance of different modes of extracorporeal membrane oxygenation (ECMO).
A, 2-day-old boy undergoing peripheral venoarterial ECMO. Frontal chest radiograph shows drainage cannula (D) with radiopaque tip (*white arrowhead*) in right atrium and reinfusion cannula (R) in right common carotid artery. Endotracheal tube (*black arrowhead*), orogastric tube (*white arrow*), and umbilical artery catheter (*black arrow*) are appropriately positioned.
B, 3-year-old girl undergoing central venoarterial ECMO. Frontal chest radiograph shows sternotomy spacer (*black arrow*) and surgical sponges (*black arrowheads*) indicating open chest, drainage cannula (D) directly entering right atrium, reinfusion cannula (R) in aortic arch, mediastinal drain (*white arrow*), epicardial pacer wires with characteristic knots (*white arrowheads*), and endotracheal tube (E).
C, 18-year-old boy undergoing single cannula venovenous ECMO. Frontal chest radiograph shows single cannula (V) extending from right internal jugular vein to inferior vena cava. Endotracheal tube (E), nasogastric tube (*arrowhead*), and transcutaneous pacer pads (P) are evident.

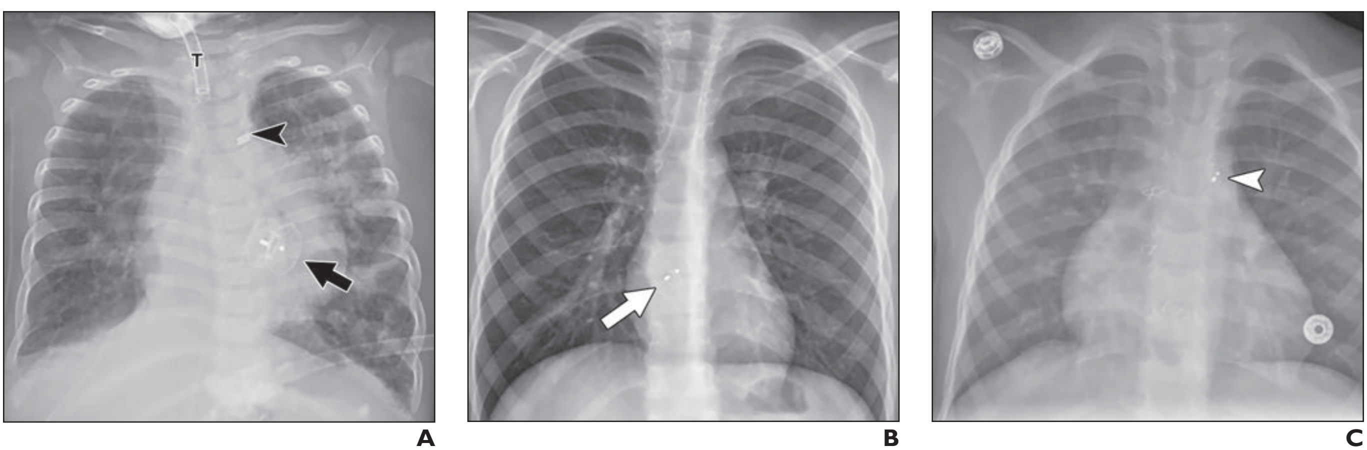


Fig. 7—Radiographic appearance of cardiac closure devices.
A, 19-month-old girl with chronic lung disease of infancy. Frontal chest radiograph shows ventricular septal defect closure device (*arrow*), tracheostomy tube (T), and ductus arteriosus clips (*arrowhead*).
B, 10-year-old boy. Frontal chest radiograph shows atrial septal defect closure device (*arrow*).
C, 4-year-old boy. Frontal chest radiograph shows ductus arteriosus closure device (*arrowhead*) and breakage of most inferior sternotomy wire.

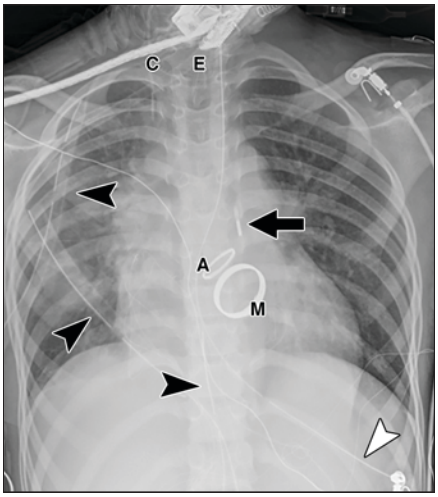
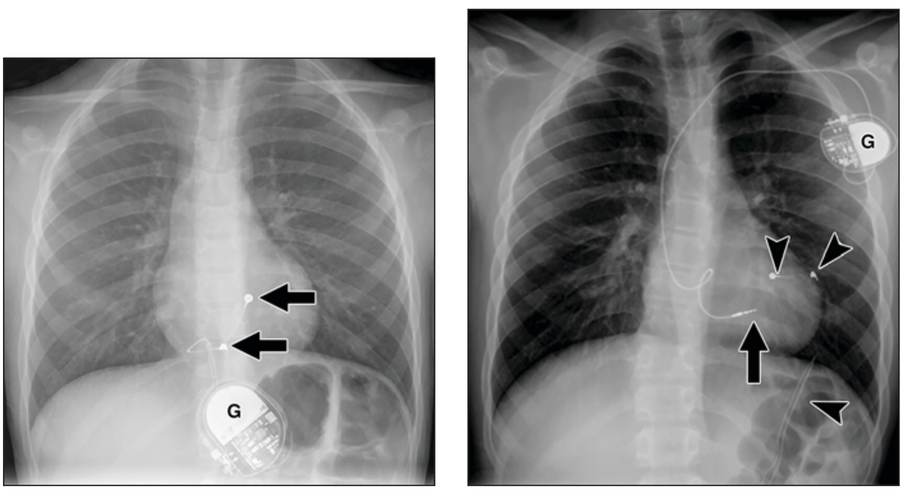


Fig. 8—10-year-old boy who has undergone aortic and mitral valve replacement and intraaortic balloon pump (IABP) placement and has appropriately positioned lines and tubes. Frontal chest radiograph shows radiopaque marker of IABP (*arrow*) within descending thoracic aorta, prosthetic aortic valve (A), prosthetic mitral valve (M), nasogastric tube (*white arrowhead*) passing to stomach, three chest tubes (*black arrowheads*), endotracheal tube (E) in high position with tip at level of clavicular heads, and central line (C) with tip at junction of right internal jugular vein and subclavian vein.



A B

Fig. 9—Appropriately positioned pacemakers with epicardial and transvenous leads.
A, 9-year-old boy with repaired tetralogy of Fallot. Frontal chest radiograph shows generator (G) in upper abdominal wall with two epicardial leads (*arrows*).
B, 11-year-old girl with atrioventricular block. Frontal chest radiograph shows generator (G) in left chest wall with single transvenous lead (*arrow*) terminating in right ventricle. Fractured abandoned epicardial pacer leads (*arrowheads*) are also evident.

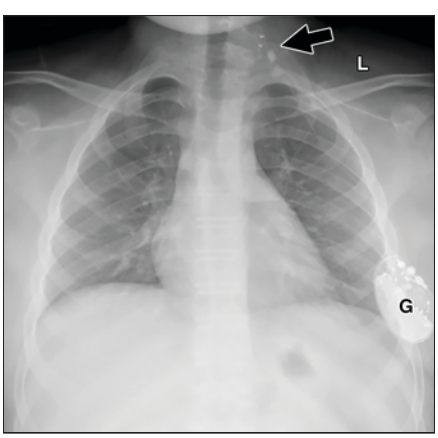


Fig. 10—15-year-old girl with seizures and appropriately positioned vagal nerve stimulator. Frontal chest radiograph shows generator (G) in left chest wall with leads (*arrow*) extending to left neck.