CME SAM

Chest Radiography in the ICU

AJR FOCUS ON:

Chest Radiography in the ICU: Part 2, Evaluation of Cardiovascular Lines and Other Devices

Myrna C. B. Godoy[1]
Barry S. Leitman[2]
Patricia M. de Groot[1]
Ioannis Vlahos[3]
David P. Naidich[2]

OBJECTIVE. In this pictorial essay, we discuss and illustrate normal and aberrant positioning of the cardiovascular support and monitoring devices frequently used in critically ill patients, including central venous catheters, pulmonary artery catheters, left atrial catheters, transvenous pacemakers, automatic implantable cardioverter defibrillators, intraaortic counterpulsation balloon pump, and ventricular assist devices, 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.

Keywords: catheter, critical care, medical devices, thoracic devices, thoracic radiography

DOI:10.2214/AJR.11.8124

Received October 23, 2011; accepted after revision October 24, 2011.

[1]Department of Diagnostic Radiology, The University of Texas M. D. Anderson Cancer Center, 1515 Holcombe Blvd, Unit 371, Houston, TX 77030. Address correspondence to M. C. B. Godoy (MGodoy@mdanderson.org).

[2]Department of Radiology, New York University Langone Medical Center, New York, NY.

[3]Department of Radiology, St. George's Hospital NHS Trust, London, UK.

CME/SAM
This article is available for CME/SAM credit.

AJR 2012; 198:572–581

0361–803X/12/1983–572

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, 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.

Central Venous Catheters

Central venous catheters (CVCs) are used in critically ill patients for venous access and central venous pressure monitoring. They are usually placed via the subclavian, internal jugular, or—less frequently—femoral veins. Small-caliber peripherally inserted central catheters are usually introduced via antecubital veins and can remain in place for up to several months. The CVC tip should be located in the superior vena cava (SVC), below the anterior first rib on the chest radiograph, ideally slightly above the right atrium [2, 3]. Although the right atrium accurately reflects central venous pressure, the tip of the CVC should not be placed in this region because such placement increases the risks of arrhythmia, myocardial rupture, and cardiac tamponade [2, 4]. Similar positioning is desirable for dialysis catheters.

Adequate positioning must be verified radiographically because malposition has been described in up to 40% of CVCs [3]. Abnormal positioning not only may interfere with central venous pressure measurement but also may lead to adverse effects caused by the infusion of potentially toxic substances that would be otherwise diluted in the central venous system [5, 6]. A misplaced CVC may have its tip terminating in the right heart or in central systemic veins, such as the azygos and internal jugular veins [7] (Fig. 1). A catheter in the azygos vein may appear to be looped within the SVC at the level of the junction of the trachea and the right main bronchus. This abnormal positioning can be confirmed by a lateral view showing the CVC coursing posteriorly along the arch of the azygos vein at a level just below the aortic arch [4] (Fig. 2).

More unusual abnormal positioning includes placement of the CVC in the internal mammary, superior intercostal, thymic, left pericardiophrenic, or inferior thyroid veins [7] (Figs. 3 and 4). The presence of anatomic variations, such as a persistent left SVC (Fig. 5), an anomalous pulmonary vein, and atrial or ventricular septal defects (Fig. 6) may also result in an aberrant course of the catheter. Inadvertent catheterization of the subclavian artery will present with a pulsatile flow in the catheter and an abnormal catheter position on radiograph (Fig. 7).

Pneumothorax is the second most frequent acute complication of CVC insertion, occurring in up to 5% of all line placements [3]. To monitor for this complication, a chest radiograph should be always obtained after any successful or unsuccessful attempt at CVC placement. In the ICU setting, an upright or contralateral decubitus radiograph may be useful when looking for small pneumothoraces, which could become larger, particularly in patients receiving positive pressure ventilation.

Vascular perforation is another life-threatening complication. Radiographic findings that indicate vascular injury include unusual trajectory of the catheter, an apical cap due to extrapleural hematoma, a new pleural effusion due to hemothorax, and mediastinal widening due to mediastinal hematoma [2] (Fig. 8). A gentle curve of the tip of the catheter and position of the tip against the lateral wall of the SVC are potential signs of impending venous perforation [2, 4, 5]. If the CVC is extravascular, fluid may accumulate in the mediastinum or pleural space. Extravascular positioning can be confirmed by injecting a contrast medium through the catheter before imaging (Fig. 9).

Knotting, looping, and kinking of the catheter may occur. Venous thrombosis is a complication related to prolonged catheter placement and may result in pulmonary embolism. Catheter fragmentation is seen in approximately 1% of CVC placements (Fig. 10). Fragmentation may result from compression between the first rib and clavicle, which is designated a "pinch-off syndrome" (Fig. 11). Migration of a fragmented catheter may result in arrhythmia, vascular injury, pulmonary embolism, or rarely death [3]. Minimally invasive endovascular retrieval techniques can be used to recover intravascular catheter fragments.

Pulmonary Artery Catheters

The pulmonary artery catheter, also called a Swan-Ganz catheter, is used to monitor circulatory hemodynamics in critically ill patients by measuring pulmonary capillary wedge pressure. This measurement helps in the differentiation of cardiogenic pulmonary edema from noncardiogenic pulmonary edema.

The catheter is inserted via the subclavian vein or the internal jugular vein. The ideal position of the tip of the catheter is in the right or left main pulmonary arteries, and the tip should not extend beyond the proximal interlobar pulmonary artery (within 2 cm of the hilum) [3]. The balloon at the tip of the catheter should be inflated only when measurements are being obtained. Occlusion of a pulmonary artery branch may occur if the catheter is too distal, if there is persistent inflation of the balloon, or if a clot is formed around the distal tip of the catheter; such occlusion can result in pulmonary infarction. A chest radiograph may reveal the infarction as a wedge-shaped pleural-based pulmonary opacity [4] (Fig. 12).

The previously described complications related to CVC insertion, such as catheter misplacement, looping, coiling, knotting, pneumothorax, and vascular injury, also may occur as a result of pulmonary artery catheter placement. Uncontained pulmonary artery rupture, pulmonary artery dissection, and pseudoaneurysm formation are rare but potentially fatal complications (Fig. 13). The latter may present as a new pulmonary nodule even months after the removal of the catheter [8]. Balloon rupture and development of a fistula between the pulmonary artery and bronchial tree are other rare complications.

Left Atrial Catheter

Left atrial catheters are used to monitor left atrial pressure, obtain blood samples, and administer drugs. The catheter is usually inserted into the right superior pulmonary vein near the junction with the left atrium during cardiac surgery. It typically appears on a radiograph as a thin curvilinear line within the left atrium [9] (Fig. 14).

A left atrial catheter may impinge on a prosthetic valve, causing dysfunction, or slip into the pericardium, with risk for tamponade when solutions are infused [9]. There is risk for bleeding and cardiac tamponade when the left atrial catheter is removed. Catheter fragmentation or retention are other potential complications [10]. A fragmented catheter may embolize or become infected.

Pacemakers

Temporary and permanent cardiac pacemakers are used to treat a variety of conduction abnormalities. Transvenous pacing is the preferable method for temporary pacing in the ICU, usually placed via internal jugular or subclavian veins (Fig. 15). Temporary pacing can also be performed via epicardial, transthoracic, transesophageal, or transcutaneous pacemakers. Permanent pacemakers are composed of a pulse generator (battery pack and control unit), which is implanted in the anterior chest wall, and lead wires with electrodes for contact with the endocardium or myocardium. They range from single-lead pacemakers to complex devices with multiple atrial and ventricular leads [11]. Biventricular pacing or cardiac resynchronization therapy can be used to treat severe congestive heart failure. In such cases, in addition to the typical pacing electrodes in the right atrium and right ventricular apex, left ventricular pacing electrode is introduced through the coronary sinus and placed into a left ventricular cardiac vein to stimulate the left ventricular myocardium. Alternatively, a left epicardial lead may be used [11] (Fig. 16). An additional benefit can be obtained when an automatic implantable cardioverter-defibrillator (AICD) is combined with the pacemaker, given the risk of ventricular tachycardia or ventricular fibrillation in these patients. AICD devices may have a single high-voltage shock coil within the right ventricle or may have an additional coil in the SVC or brachiocephalic vein. These coils can be positioned either within a single wire or in two separate wires [3] (Fig. 17). External pacemaker-defibrillators are also frequently used in the ICU.

Pneumothorax and vascular injury may occur during the transvenous insertion of the electrodes. Myocardial perforation is uncommon and usually occurs in the right ventricle. It should be recognized when an electrode tip is seen projecting beyond the cardiac border [3] (Fig. 18). It is usually not clinically significant, but it may result in pericardial effusion and cardiac tamponade (Fig. 19).

The incidence of lead fractures in pacemakers has decreased with technologic improvement of these devices and is estimated to be about 1–4% [12, 13]. Lead fractures most commonly occur at the venous access site, as a result of compression of the lead between the clavicle and the first rib, near the tip of the lead or near the battery-control pack [13] (Fig. 20). They may result from manipulation of the implanted pulse generator by the patient, leading to rotation of the generator in its pocket, which causes lead traction and dislodgement (twiddler syndrome) [14].

Circulatory Assist Devices

Intraaortic Counterpulsation Balloon Pump

The intraaortic counterpulsation balloon pump (IABP) is a mechanical device used to support patients in cardiogenic shock. It consists of a catheter surrounded by an inflatable balloon approximately 25 cm long, with a small cylindric radiopaque marker at the catheter's distal tip. The IABP is introduced via the femoral artery and advanced until its tip (the radiopaque marker) is in the descending thoracic aorta 2 cm distal to the origin of the left subclavian artery (just caudal to the aortic arch) [11, 15]. The balloon is inflated during diastole to increase coronary artery perfusion and is deflated during systole to decrease the left ventricular afterload. A chest radiograph will show a long tubular radiolucent structure in the aorta if the balloon is inflated at the moment the image is acquired (Fig. 21). This should not be mistaken for an abnormal air collection in the mediastinum.

Complications occur in 8–36% of IABP placements and are mostly vascular [16, 17]. Overadvancement of the catheter may cause occlusion of the left common carotid or left vertebral arteries, resulting in cerebral ischemia, or obstruction of the left subclavian artery, causing left arm ischemia (Fig. 22). If the location of the catheter is too distal, the renal or mesenteric arteries may became occluded; in addition, the device will be less effective [4, 15, 16] (Fig. 23). Another possible complication is the development of aortic dissection, reported in 1–4% of IABP catheter insertions, which should be suspected if the chest radiograph shows loss of definition of the descending thoracic aorta and lateral positioning of the catheter along the aorta [16]. Balloon rupture with gas embolization is an extremely rare but potentially fatal complication [17].

Ventricular Assist Devices

Ventricular assist devices are used to replace the function of the left ventricle, the right ventricle, or both. Left ventricular assist devices (LVADs) have been used in patients with heart failure as a bridge to heart transplantation, as a destination therapy for those ineligible for transplantation, or as a bridge to myocardial recovery [18]. A wide variety of LVADs are currently available. Most models consist of a pump that takes blood from the left ventricular apex through an inflow cannula and pumps it into the ascending aorta through an outflow cannula connected to a conduit that is anastomosed to the ascending aorta. The conduit is not radiopaque on conventional radiograph but can be visualized on CT (Fig. 24). Alternatively, the actual pumping chamber may be placed within the left ventricle with the outflow cannula connected to the ascending or descending aorta [18] (Fig. 25). The Impella (Abiomed) ventricular assist device is a relatively new small LVAD that has the advantage of a less invasive placement compared with standard ventricular assist devices because it can be inserted via catheterization through the common femoral artery, into the ascending aorta, across the valve, and into the left ventricle. It may also be placed directly through the aorta in cases of postcardiotomy heart failure. A small pump is located in the proximal thick portion of the catheter (Fig. 26), which pumps up to 2.5 L/min from the left ventricle, therefore reducing myocardial workload and increasing cardiac output [19].

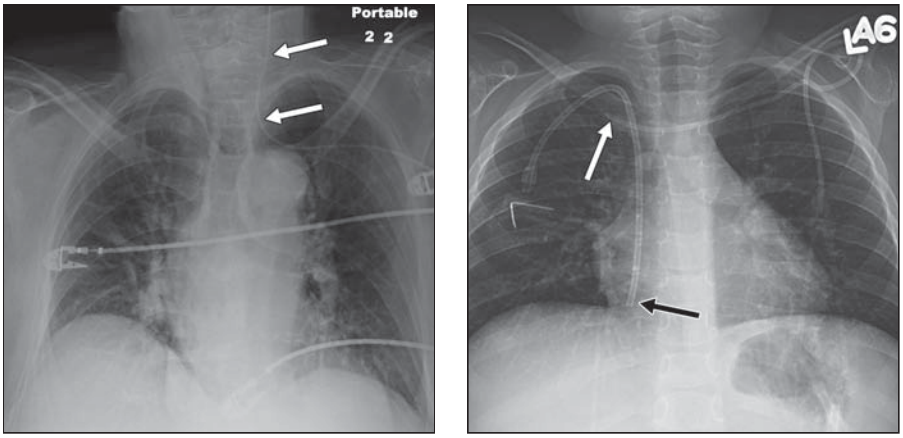
The use of an LVAD may unmask right heart failure, necessitating placement of a right ventricular assist device. The right ventricular assist device has an inflow cannula that connects with the right atrium or ventricle and an outflow cannula that is directed into the pulmonary artery [20]. Complications of ventricular assist devices include pneumothorax, hemothorax, postoperative hemorrhage in the pericardium or mediastinum (Fig. 27), cardiac tamponade, thromboembolism, arrhythmia, infection, pneumoperitoneum, bowel obstruction, and mechanical failure [5, 11, 20].

Conclusion

Various devices are 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.

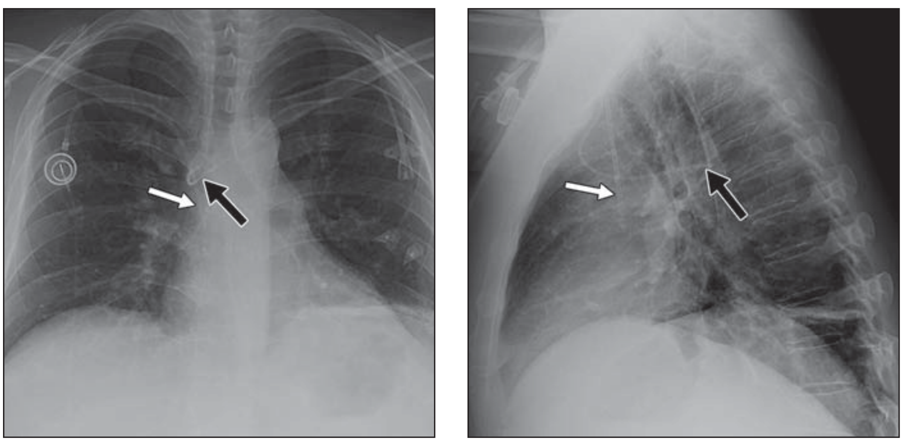
References

1. Amorosa J, Bramwit M, Khan A, et al. *ACR appropriateness criteria: routine chest radiograph*. Reston, VA: American College of Radiology, 2008
2. Rubinowitz AN, Siegel MD, Tocino I. Thoracic imaging in the ICU. *Crit Care Clin* 2007; 23:539–573
3. Trotman-Dickenson B. Radiography in the critical care patient. In: McLoud TC, Boiselle P, eds. *Thoracic radiology: the requisites*. Philadelphia, PA: Mosby Elsevier, 2010:136–159
4. Wechsler RJ, Steiner RM, Kinori I. Monitoring the monitors: the radiology of thoracic catheters, wires, and tubes. *Semin Roentgenol* 1988; 23:61–84
5. Collins J, Stern E. Monitoring and support devices—"tubes and lines". In: Collins J, Stern E, eds. *Chest radiology: the essentials*. Philadelphia, PA: Lippincott Williams & Wilkins, 2008:63–77
6. Ravin CE, Putman CE, McLoud TC. Hazards of the intensive care unit. *AJR* 1976; 126:423–431
7. Díaz ML, Villanueva A, Herraiz MJ, et al. Computed tomographic appearance of chest ports and catheters: a pictorial review for noninterventional radiologists. *Curr Probl Diagn Radiol* 2009; 38:99–110
8. Tocino I. Chest imaging in the intensive care unit. *Eur J Radiol* 1996; 23:46–57
9. Leitman BS, Naidich DP, McGuinness G, McCauley DI. The left atrial catheter: its uses and complications. *Radiology* 1992; 185:611–612
10. Santini F, Gatti G, Borghetti V, Oppido G, Mazzucco A. Routine left atrial catheterization for the post-operative management of cardiac surgical patients: is the risk justified? *Eur J Cardiothorac Surg* 1999; 16:218–221
11. Hunter TB, Taljanovic MS, Tsau PH, Berger WG, Standen JR. Medical devices of the chest. *RadioGraphics* 2004; 24:1725–1746
12. Alt E, Völker R, Blömer H. Lead fracture in pacemaker patients. *Thorac Cardiovasc Surg* 1987; 35:101–104
13. Chang SH, Tan CK, Lee SH. Clinical images: fracture of a pacemaker lead. *CMAJ* 2009; 181:823
14. Sharifi M, Inbar S, Neckels B, Shook H. Twiddling to the extreme: development of twiddler syndrome in an implanted cardioverter-defibrillator. *J Invasive Cardiol* 2005; 17:195–196
15. Wiener MD, Garay SM, Leitman BS, Wiener DN, Ravin CE. Imaging of the intensive care unit patient. *Clin Chest Med* 1991; 12:169–198
16. Hurwitz LM, Goodman PC. Intraaortic balloon pump location and aortic dissection. *AJR* 2005; 184:1245–1246
17. Cruz-Flores S, Diamond AL, Leira EC. Cerebral air embolism secondary to intra-aortic balloon pump rupture. *Neurocrit Care* 2005; 2:49–50
18. Carr CM, Jacob J, Park SJ, Karon BL, Williamson EE, Araoz PA. CT of left ventricular assist devices. *RadioGraphics* 2010; 30:429–444
19. Meyns B, Dens J, Sergeant P, Herijgers P, Daenen W, Flameng W. Initial experiences with the Impella device in patients with cardiogenic shock: Impella support for cardiogenic shock. *Thorac Cardiovasc Surg* 2003; 51:312–317
20. Knisely BL, Collins J, Jahania SA, Kuhlman JE. Imaging of ventricular assist devices and their complications. *AJR* 1997; 169:385–391



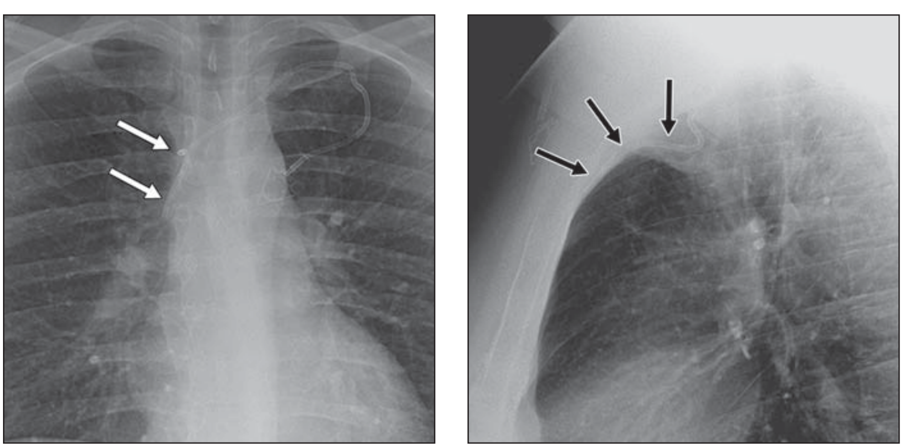
A B

Fig. 1—Two patients with misplaced central venous catheters.
A, 69-year-old man. Anteroposterior chest radiograph shows left peripherally inserted central catheter (*arrows*) with abnormal trajectory into left internal jugular vein.
B, 6-year-old girl. Posteroanterior chest radiograph shows two misplaced catheters. Right internal jugular central venous catheter (*black arrow*) has its tip in right atrium. Left subclavian central venous catheter (*white arrow*) has its tip in right subclavian vein.



A B

Fig. 2—50-year-old man with misplaced central venous catheter in azygos arch.
A, Posteroanterior chest radiograph shows left subclavian central venous catheter (*black arrow*) with its tip in azygos vein. Right subclavian port catheter (*white arrow*) is in appropriate position with its tip in superior vena cava (SVC).
B, Lateral view shows posterior orientation of misplaced catheter, confirming its position in azygos vein (*black arrow*). Note appropriate trajectory of right port catheter in SVC (*white arrow*).



A B

Fig. 3—29-year-old man with right internal mammary vein placement of central venous catheter.
A, Magnified posteroanterior chest radiograph shows catheter (*arrows*) in unusual parasternal position, slightly lateral to superior vena cava.
B, Magnified lateral chest radiograph shows catheter (*arrows*) coursing anteriorly along expected position of right internal mammary vein.

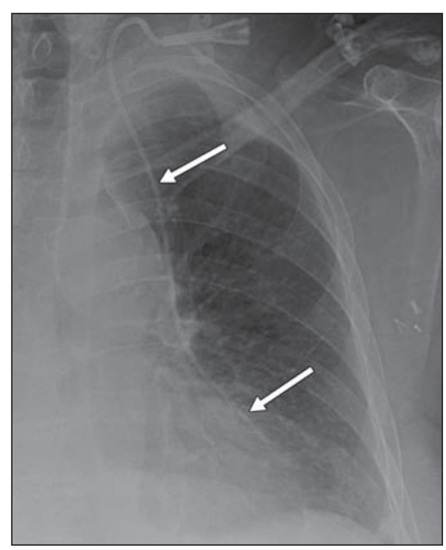
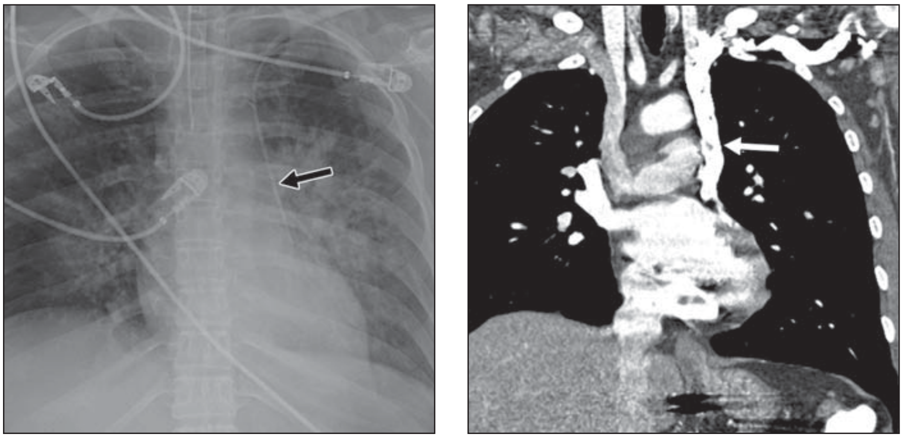


Fig. 4—58-year-old woman with misplaced central venous catheter in pericardiophrenic vein. Magnified anteroposterior chest radiograph shows left internal jugular catheter (*arrows*) coursing along left cardiac border, consistent with placement in pericardiophrenic vein.



A B

Fig. 5—48-year-old woman with pneumonia and persistent left superior vena cava (SVC) placement of central venous catheter.
A, Anteroposterior chest radiograph shows left paramediastinal course of catheter (*arrow*) toward coronary sinus, instead of crossing midline to enter SVC on right, as expected. This is typical appearance of catheter placement within persistent left SVC.
B, Coronal CT reformatted image confirms presence of persistent left SVC (*arrow*).

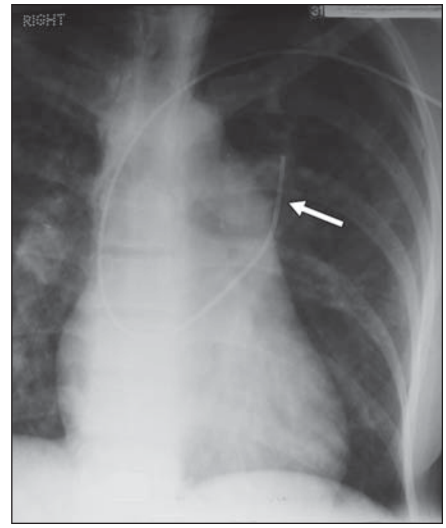
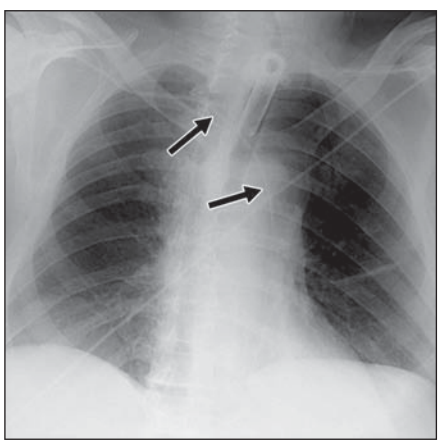
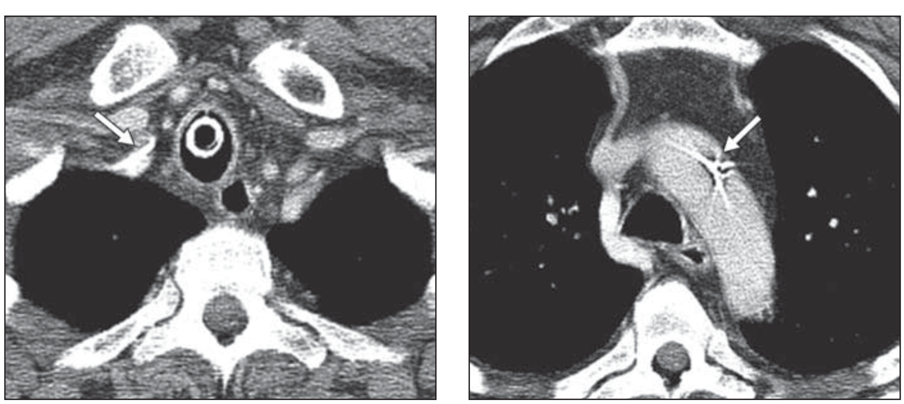


Fig. 6—15-year-old girl with atrial septal defect (ASD) and misplaced central venous catheter. Magnified anteroposterior chest radiograph shows left subclavian central venous catheter (*arrow*) that has entered right atrium and passed through ASD into left atrium and subsequently into left superior pulmonary vein.

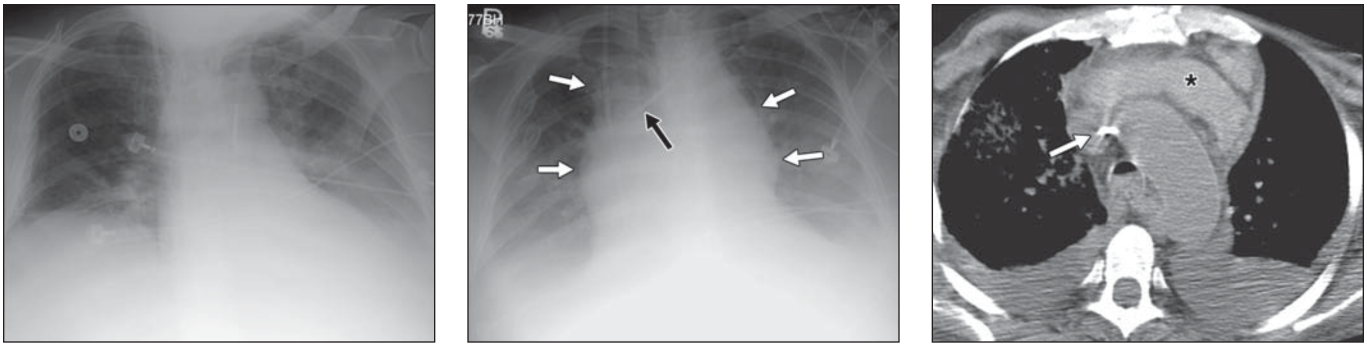


A

Fig. 7—65-year-old man with subclavian artery placement of central venous catheter.
A, Magnified anteroposterior chest radiograph shows right subclavian central line (*arrows*) crossing mediastinum and projecting over aorta.
B and **C,** Sequential CT images show central venous catheter coursing within right subclavian artery (*arrow*, **B**) with its tip in aortic arch (*arrow*, **C**).

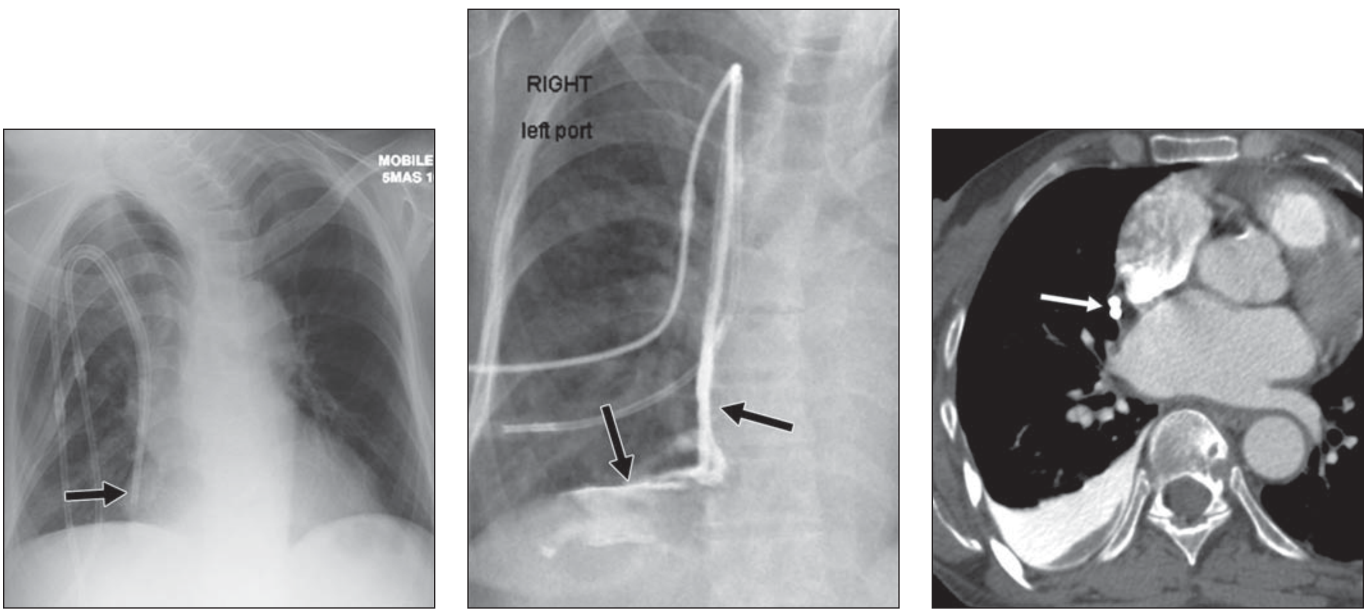


B C



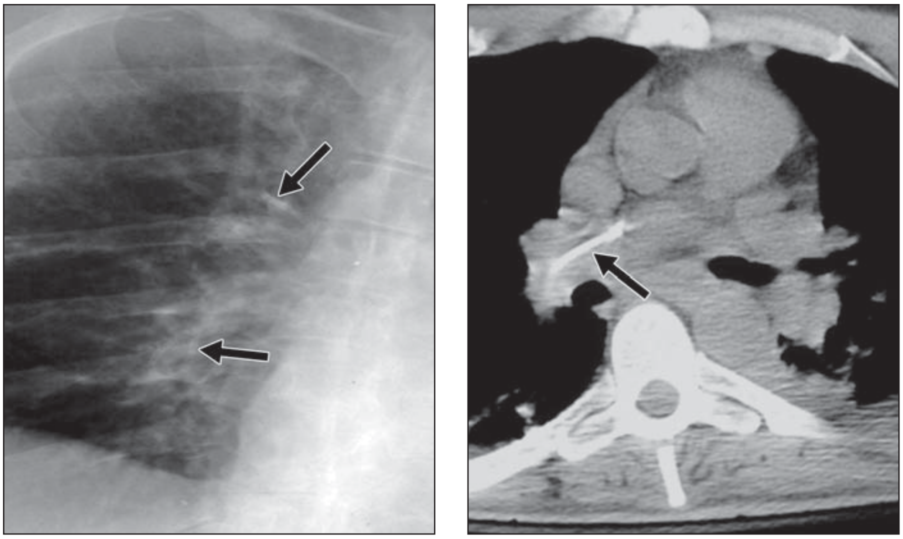
A B C

Fig. 8—77-year-old man with mediastinal hematoma as complication of central venous catheter placement.
A, Anteroposterior chest radiograph obtained before procedure.
B, Follow-up chest radiograph obtained after replacement of central venous catheter (*black arrow*) via left internal jugular vein shows mediastinal widening (*white arrows*), with increased mediastinal density and convex margins, and increased bilateral pleural effusions.
C, CT image shows large hyperdense hematoma (*asterisk*) in anterior mediastinum and bilateral pleural effusions. Note fluid within trachea. Central line (*arrow*) can be seen coursing outside venous lumen parallel to superior vena cava.



A B C

Fig. 9—48-year-old woman with extravascular placement of double-lumen dialysis catheter.
A, Anteroposterior chest radiograph shows catheter (*arrow*) inserted via right subclavian vein with its tip projecting over right atrium.
B, Because there was clinical suspicion of malpositioning of catheter, IV contrast medium was injected and was seen to extravasate into pleural space (*arrows*).
C, Magnified CT image confirms extraluminal position of catheter (*arrow*), coursing parallel to superior vena cava and right atrium, as well as presence of contrast material in right pleural space.



A B

Fig. 10—50-year-old man with central venous catheter fragmentation and embolization.
A, Magnified anteroposterior chest radiograph shows catheter fragment (*arrows*) that has embolized into pulmonary arterial system.
B, CT image confirms presence of embolized catheter fragment (*arrow*) in distal right main pulmonary artery.

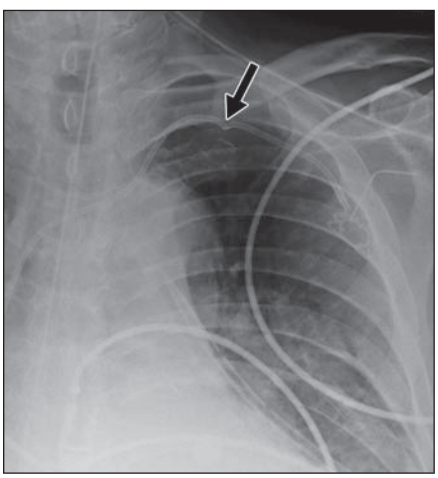


Fig. 11—50-year-old woman with pinch-off syndrome. Magnified anteroposterior chest radiograph shows abrupt bend and luminal narrowing (*arrow*) of central venous catheter in region of left clavicle and left first rib, which may result in catheter fragmentation.

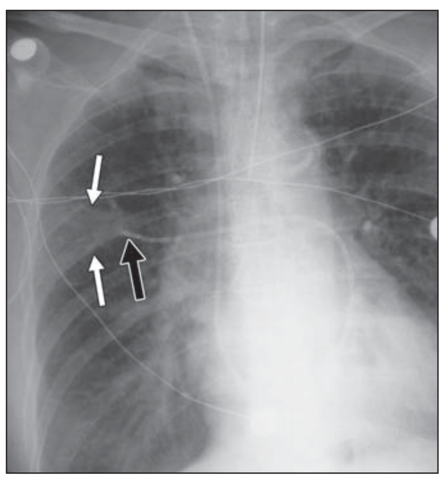


Fig. 12—72-year-old woman with pulmonary infarction as complication of pulmonary artery catheter placement. Magnified anteroposterior chest radiograph shows that tip of catheter (*black arrow*) is too distal (i.e., > 2 cm lateral to hilum). There is wedged-shaped opacity (*white arrows*) distal to catheter, consistent with pulmonary infarction.

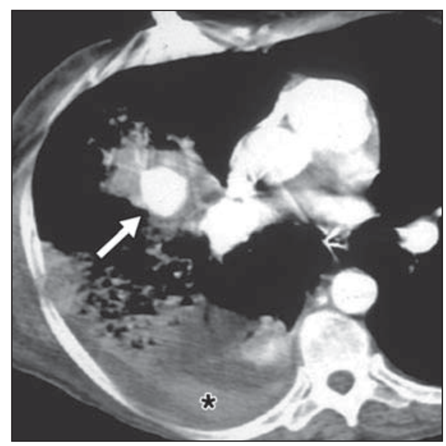


Fig. 13—57-year-old man with pulmonary artery pseudoaneurysm as complication of pulmonary artery catheter placement. CT image shows well-defined enhancing lesion (*arrow*) within right upper lobe, consistent with pulmonary artery pseudoaneurysm, which occurred immediately after placement of pulmonary artery catheter. Note adjacent pulmonary hemorrhage (consolidation) and hemothorax (*asterisk*).

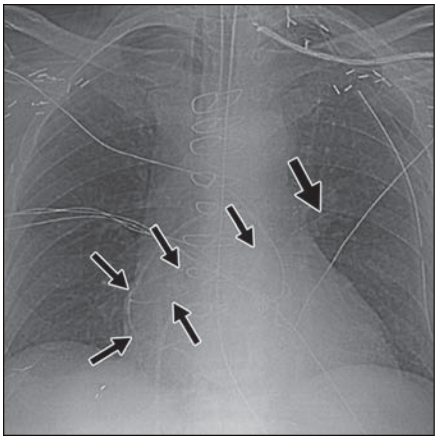


Fig. 14—53-year-old man with normal positioning of left atrial catheter. Anteroposterior chest radiograph shows left atrial catheter (*thin arrows*) with its distal tip in left superior pulmonary vein (*thick arrow*).

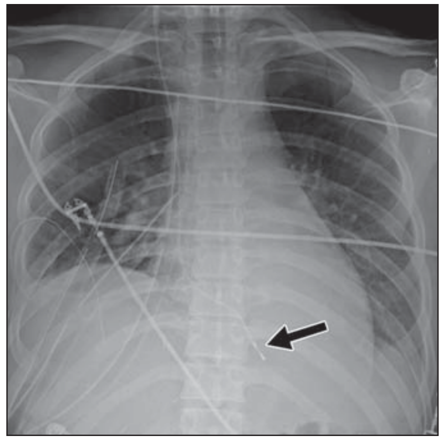


Fig. 15—47-year-old man with transvenous temporary pacemaker. Anteroposterior chest radiograph shows transvenous pacemaker lead introduced via right internal jugular vein. Electrode tip of pacemaker (*arrow*) projects over right ventricular apex, as expected.

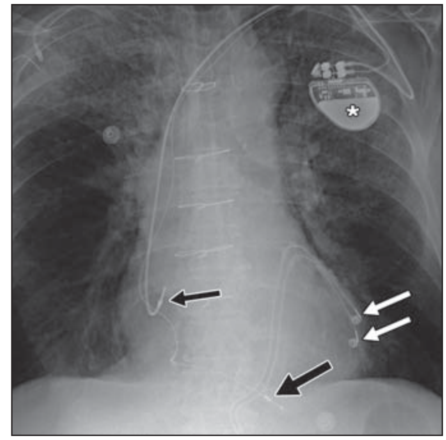


Fig. 16— 69-year-old man with biventricular pacemaker with epicardial leads. Magnified anteroposterior chest radiograph shows normal position of leads projecting over right atrium (*thin black arrow*) and right ventricular apex (*thick black arrow*). Also noted are two epicardial leads (*white arrows*) and battery-control pack (*asterisk*).

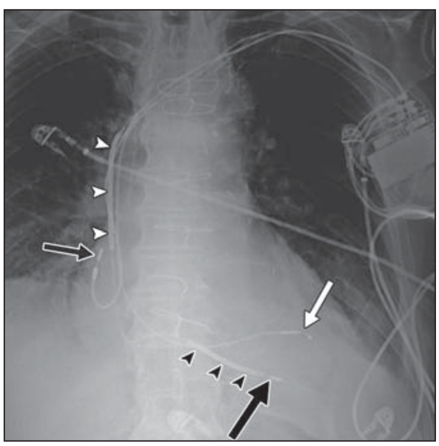
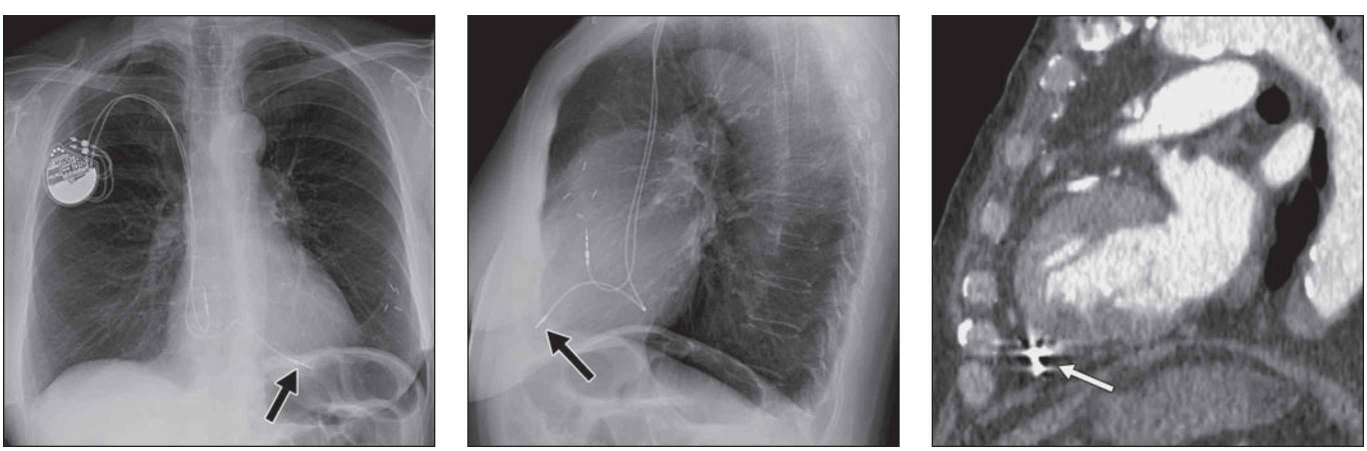


Fig. 17—84-year-old man with biventricular pacemaker combined with automatic implantable cardioverter defibrillator. Magnified anteroposterior chest radiograph shows pacemaker lead tips in right atrium (*thin black arrow*), right ventricle (*thick black arrow*), and coronary sinus branch (*thin white arrow*). High-voltage defibrillator coils are located along right ventricular lead in superior vena cava (*white arrowheads*) and right ventricle (*black arrowheads*).



A B C

Fig. 18—75-year-old woman with displacement of pacemaker lead.
A, Posteroanterior chest radiograph shows dual-lead pacemaker. Tip of right ventricular lead (*arrow*) is projected at edge cardiac silhouette.
B, Lateral chest radiograph shows that tip of right ventricular lead (*arrow*) is projecting slightly lower than expected.
C, Sagittal reformatted CT image shows that lead has perforated myocardium and pericardium (*arrow*) but is not associated with pericardial effusion.

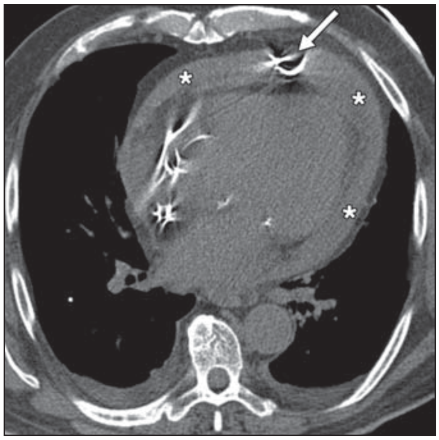


Fig. 19—55-year-old man with hemopericardium. CT image shows hemopericardium (*asterisks*) that resulted from myocardial perforation as complication of placement of automatic implantable cardioverter-defibrillator (AICD) device. Note tip of right ventricular lead (*arrow*) within hyperdense pericardial effusion. Cardiac tamponade may occur as a rare complication of AICD placement.

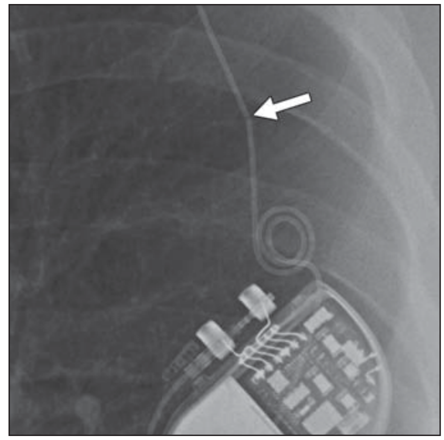
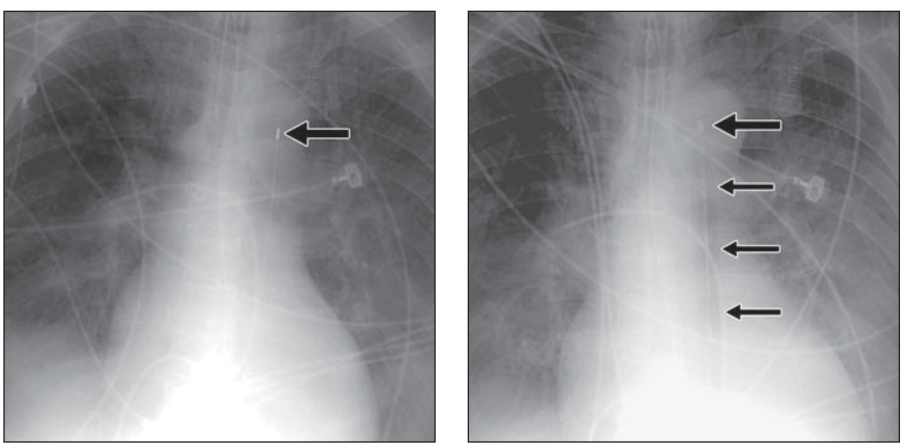


Fig. 20—67-year-old man with pacemaker lead fracture. Magnified anteroposterior chest radiograph shows fracture (*arrow*) in pacemaker lead near battery-control pack. Lead fractures most commonly occur at venous access site, near tip, or near battery-control pack.



A B

Fig. 21—67-year-old man with normal positioning of intraaortic counterpulsation balloon pump.
A, Magnified anteroposterior chest radiograph obtained during systole shows catheter's radiopaque tip (*arrow*) within upper descending thoracic aorta indicating proper positioning.
B, Magnified anteroposterior chest radiograph obtained during diastole shows inflated radiolucent balloon (*thin arrows*) as well as radiopaque tip (*thick arrow*) within upper descending thoracic aorta. Catheter is inflated during diastole to increase myocardial perfusion and is deflated during systole to decrease left ventricular afterload.

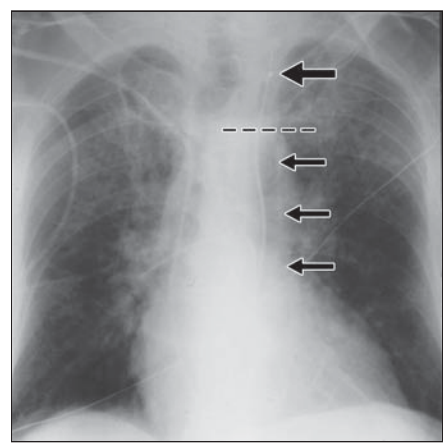


Fig. 22—62-year-old man with malpositioned intraaortic counterpulsation balloon pump. Anteroposterior chest radiograph during diastole shows inflated radiolucent balloon (*thin arrows*). Radiopaque tip of balloon catheter (*thick arrow*) is abnormally located beyond aortic arch (*dashed line*). It is projected over left common carotid artery. This abnormal positioning can result in cerebral ischemia.

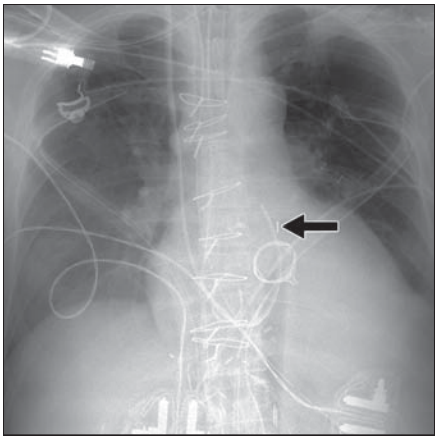
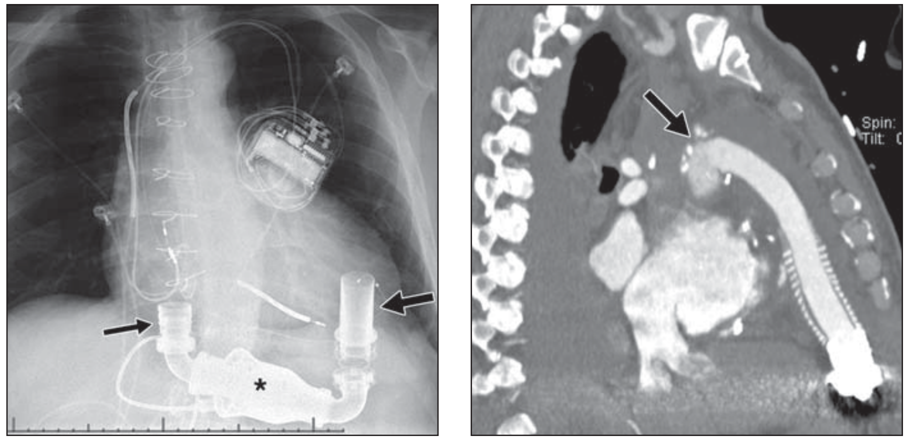


Fig. 23—59-year-old man with malpositioned intraaortic counterpulsation balloon pump. Anteroposterior chest radiograph obtained during diastole shows inflated radiolucent balloon (*arrow*) with its radiopaque tip in mid thoracic aorta. Counterpulsation is less effective when catheter is too low and may result in obstruction of abdominal aortic branches, such as renal or mesenteric arteries.



A B

Fig. 24—76-year-old man with ischemic cardiomyopathy and left ventricular assist device (LVAD; HeartMate II, Thoratec).
A, Anteroposterior chest radiograph shows pump (*asterisk*), which replaces function of left ventricle, projecting over upper abdomen. Inflow cannula of LVAD (*thick arrow*) is inserted into left ventricular apex. Outflow cannula (*thin arrow*) connects to ascending aorta through graft conduit that is not radiopaque.
B, Reformatted sagittal maximum intensity projection CT image shows anastomosis (*arrow*) of outflow conduit to ascending aorta.

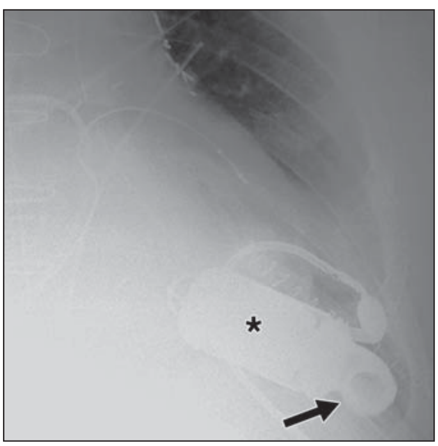


Fig. 25—72-year-old man with ischemic cardiomyopathy and left ventricular assist device (Jarvik 2000). Magnified anteroposterior chest radiograph shows ventricular assist device in left lower hemithorax. This device is unique because pumping chamber (*asterisk*) is placed within left ventricle. Outflow cannula (*arrow*) is connected to ascending aorta through nonradiopaque conduit.

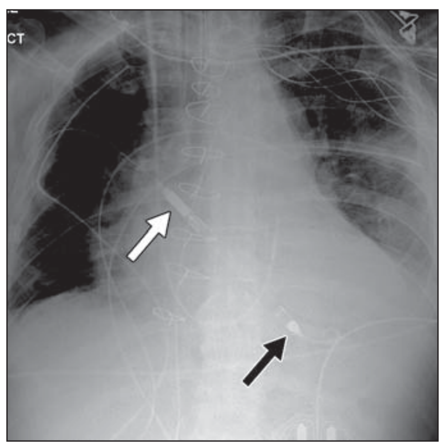


Fig. 26—62-year-old woman with Impella (Abiomed) ventricular assist device. Magnified anteroposterior chest radiograph shows ventricular assist device (*black arrow*) with its distal aspect with pigtail in left ventricle. Outflow portion of device (*white arrow*) is located in aorta and has thick area that contains pump.

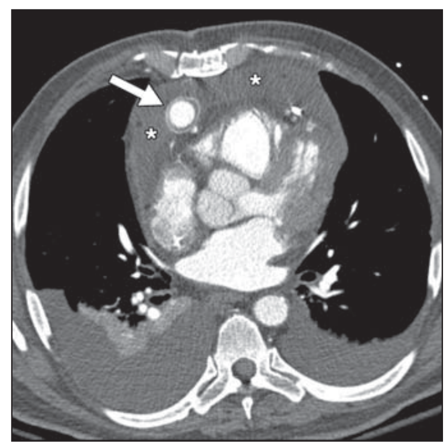


Fig. 27—66-year-old man with postoperative pericardial hematoma following left ventricular assist device placement. CT image shows hyperdense pericardial fluid collection (*asterisks*) surrounding outflow cannula (*arrow*). Mediastinal and pericardial bleeding are common complications of ventricular assist device placement and usually do not require reoperation.

FOR YOUR INFORMATION

This article is part of a self-assessment module (SAM). Please also refer to "Chest Radiography in the ICU: Part 1, Evaluation of Airway, Enteric, and Pleural Tubes," which can be found on page 563.

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.

The American Roentgen Ray Society is pleased to present these SAMs as part of its commitment to lifelong learning for radiologists. Continuing medical education (CME) and SAM credits are available in each issue of the *AJR* and are ***free to ARRS members. Not a member?*** Call 1-866-940-2777 (from the U.S. or Canada) or 703-729-3353 to speak to an ARRS membership specialist and begin enjoying the benefits of ARRS membership today!