Learning objectives

To show radiographic appearance of external devices in chest x-ray of patients in intensive care units (ICU).

To describe complications of external devices and how to detect them on chest x-ray
Background

The portable chest X-ray (PCXR) is one of the most commonly requested radiographic examinations in the critically ill patient. It's readily available, easy and quick to perform at the patient's bedside, and much less expensive than any other imaging modality. The PCXR plays a key role in aiding diagnosis, in monitoring evolution and in evaluating response to therapy.

The quality of the PCXR can be highly variable, ranging from good to uninterpretable. There are two groups of limitations to obtaining quality PCXR: The first group refers to the inability of critically ill patients to cooperate: without appropriate inspiration, in decubitus and anteroposterior projection. Patients are difficult to move and position adequately and so the chest may be imaged incompletely and in rotation artifact. The second group refers to the X-ray quality due to portable system, with difficulties in controlling scattered radiation and wide differences in film exposure. Digital systems, with exposure compensation and image processing, have improved the PCXR quality. And the introduction of picture archiving and communication systems (PACS) have increased fastness and disponibility of these images [1]. Nevertheless, PCXR still poses unique challenge to the technologist.

The radiograph should be obtained at peak inspiration using 70 to 80 KVp and short exposure times to minimize respiratory artefact. Focus to patient may be as high as possible to avoid magnification. External objects should be removed from the field as much as possible to avoid mistakes.

Important problems in these patients may be clinically silent or difficult to detect in the intensive care units (ICU), or the physical examination may be unreliable. Most invasive devices require radiographic confirmation of position after placement, because improper positioning may not be clinically apparent. So, PCXR is vital, often providing bedside clinicians with information they otherwise would not have.

A systematic approach is essential for interpreting PCXR, as well as any other radiographic examination [2]. These are the main steps:

To evaluate the technical quality
To locate all the external devices
To describe the cardiovascular system
To check the lung parenchyma and possible pleural effusions
To compare with prior studies

At last, clinical session in the ICU is recommended, with radiologists and clinical physicians, to achieve a multidisciplinary approach to critically-ill patients.
External devices [3,4]

Enteric Tubes

- **Function and position:** The ideal position varies between the gastric antrum or duodenum when the enteric tube is used exclusively for feeding and within the stomach when it is used for suction or medication administration (figure 1 on page 10).

- **Complications:**
  - When it is located in digestive tube, it may cause aspiration, when the tip is located in distal esophagus and reflux occurs or when the patient has gastric hernia and the tip remains in the herniated stomach (figure 2 on page 10). It sometimes requires endoscopic control to set the tube in the abdominal stomach, or duodenum (figure 3 on page 11). It may cause also pharyngeal or esophageal perforation, with pneumomediastinum, subcutaneous emphysema and other exceptional complications as we show in the next case. It is a 77-year-old man in the ICU due to an acute ischemic brain stroke. He had a history of laryngeal tumor treated by local radiotherapy. A nasogastric tube was set without difficulties and when aspiration was made to be sure of its location, dark and hot blood filled the syringe, coagulating immediately. It seemed to be in the venous system. PCXR was made (figure 4 on page 12) and nasogastric tube seemed to be a central venous catheter, going down through the superior cava vein, with a loop, and going up, with the tip in the right internal jugular vein. CT was made (figure 5 on page 13) and showed how the tube perforated the pharynx and achieved the venous system through the right thyrocervical trunk. The tube hooked one of the pacemaker’s lead, so the patient was referred to the angiography room where it was retired by a bifemoral approach (figure 6 on page 14).
  - When it is located in tracheobronchial system, it may cause bronchopulmonary injury; pneumothorax; pulmonary laceration or contusion; and even pneumonia when it is used for feeding. We present a case (figure 7 on page 15) in which the nasogastric tube goes down from the trachea, to the left main bronchus and the tip is in a segmental bronchus of the inferior left lobe. Feeding was initiated and the X-Ray chest realized after some hours showed a bronchopneumonia which corresponded with feeding in lung parenchyma.

Endotracheal and Tracheostomy Tubes

- **Function and position:** Endotracheal tube (figure 8 on page 16) is used for mechanical ventilation and tracheostomy tube (figure 9 on page 17) is secondary to laryngeal surgery or used to improve
breath efficacy in some patients. The tip of the tube should be 5 cm above the carina or above the aortic knob, with patient’s head in a neutral position. Maximum displacement of the tube ranges between 2 and 4 cm with neck flexion or extension.

- **Complications:**
  - **Malposition**: extubation or main bronchus intubation, usually the right (it causes atelectasis, iatrogenic pneumothorax).
  - **Tracheal rupture** is a rare but severe complication, which manifests as pneumothorax and pneumomediastinum.
  - **Tracheal stenosis** after prolonged intubation, which may cause problems in posterior intubations.
  - **Intubation of the esophagus** is also rare but devastating, and may be detected as an air column parallel to the trachea or stomach distended by gas.

**Chest Tubes**

**Pleural**

- **Function and position:** They are used to evacuate fluid, air or mixed collections from the pleural space. The tube is placed anterosuperiorly when a pneumothorax is detected and posteroinferiorly to evacuate a pleural effusion (figure 10 on page 18)

- **Complications:**
  - **Inadequate function due to malposition.** If the tube is posterior or is not high enough, will not evacuate the air. If it is anterior or in a pulmonary fissure, will not evacuate appropriately the pleural effusion.
  - **Pulmonary atelectasis** due to the tube mark is common, but usually solved when the tube is retired. When a chest tube is inserted into the pulmonary parenchyma, pulmonary contusion or laceration may be seen. In other cases a bronchopleural fistula may be caused, with recurrent pleural effusion. In extreme cases diaphragmatic or hepatic laceration may be seen. Intercostal artery bleeding is an uncommon but sometimes several procedural complication, because if it is not detected on time, the patient could even die.

**Mediastinal**

- **Function and position:** They are used after cardiac or mediastinal surgery. They can have different locations, just depending on the type and location of the surgery (figures 11 on page 19, 12 on page 20).
• Complications:

- Inadequate function is usually due to malposition, as the chest tubes. Liquid may accumulate and pericardial effusion or even cardiac tamponade is possible. In this case there was a mediastinal hematoma as a surgical complication detected as an apparent increase in the cardiac size (figure 13 on page 21) and diagnosed by echocardiography.

Venous Catheters

• Function and position: They are used for administering fluids, medication and nutrition, for monitoring hemodynamic function and for performing hemodialysis. By PCXR we can distinguish the type of catheter, with one lumen (figure 14 on page 22), two (figure 15 on page 23) or even three (figure 16 on page 24). They may be inserted via the subclavian vein or via the internal jugular veins (figure 14 on page 22, 17 on page 25) (central venous catheters) or peripherally in upper-extremity veins (figure 18 on page 26). The tip should be in the superior vena cava, slightly above the right atrium and beyond the most proximal venous valve to avoid the risk of thrombosis. It is also very common to see subcutaneous reservoir in oncologic patients, which may have one (figure 19 on page 27) or two lumen (figure 20 on page 28), depending on the type of chemotherapy the patient receives.

• Complications:

- Aberrant positioning is quite common. Usually it is located within the right atrium, where there is risk of arrhythmias (figure 21 on page 29), or intravenous. Intravenous locations may be: the veins of the upper extremity (figure 22 on page 30), cephalad within the internal jugular vein (figure 23 on page 31), traversing midline to the contralateral brachiocephalic vein, or going down to the inferior cava vein (figure 24 on page 32) or suprahepatic vein (figure 25 on page 33). These venous locations do not usually cause complications.
- Pneumothorax may be secondary to pulmonary damage in the moment of venous puncture (figure 26 on page 34). It does not usually require chest tube. If it is early detected, a simple puncture might control it.
- Hemothorax may be caused by a traumatic puncture, as in this case. There was a first non-effective puncture, and secondly a jugular access was achieved. After two days, the patient felt wrong and an important hemothorax with pneumothorax was found in CT, surely as a consequence of the first puncture (figure 27 on page 35)

- Miocardial rupture, pericardial tamponade, and vessel perforation are rare but severe complications, quite difficult to detect by PCXR.
- **Venous thrombosis** is not infrequent, and may not be detected by PCXR. Nevertheless it may cause pulmonary thromboembolism, and so, early detection and treatment is required.

**Pulmonary Artery Catheters or Swan-Ganz catheters**

- **Function and position:** They are used to measure pulmonary artery pressure, pulmonary capillary wedge pressure and cardiac output. Actually, we can usually see them in the first 48 hours after hepatic transplantation. The tip of the catheter should be in the right main pulmonary artery (figure 28A on page 36), left main pulmonary artery (figure 28B on page 36) or in the proximal interlobar artery, in the measurement moment. It may be proximal to these points when the catheter is not measuring. If we detect the tip beyond these vessels, the catheter should be retracted.

- **Complications:**
  - As we have seen in venous catheter, *pericatheter thrombus* is possible, but in arterial catheters consequences can be quite more severe: pulmonary artery occlusion and pulmonary infarct.
  - *Vascular damage* (pulmonary hemorrhage and pseudoaneurysm)
  - *Intravascular knots* are possible, and sometimes, as in our case, the catheter must be retired in the angiography room.
  - *Pneumothorax or hemothorax, arrhythmias and cardiac perforation* are possible, as we have seen in venous catheters.

**Intraaortic Balloon Pump (IABP)**

- **Function and position:** The intra-aortic balloon pump is a balloon device that inflates during systole to assist coronary perfusion and deflates during diastole to decrease cardiac afterload. It has a radio-opaque tip that should be within the proximal descending aorta, just distal to the origin of left subclavian artery (figure 29 on page 37).

- **Complications:**
  - *Cerebral or left upper-extremity ischemia* is caused if the tip is located too proximally.
  - If the tip is located too distal, *occlusion of the abdominal aortic branch arteries* may occur and renal and mesenteric ischemia happens.
  - *Limb ischemia* is also possible if the tip is located too distal.
  - *Aortic rupture* and balloon rupture with air embolization are other rare complications.
Cardiac Pacemakers and defibrillators

- **Function and position:** Cardiac pacemakers are not specific devices of critically ill patients, but are frequently seen in them. Cardiac pacemaker may have different number of leads (figures 30 on page 38, 31 on page 39), may have the typical covered leads of defibrillators (figure 32 on page 40), or may be epicardic pacemakers (figures 33 on page 41, 34 on page 42). And in severe patients, with risk of cardiac failure, we can see a defibrillator patch (figures 32 on page 40, 35 on page 43)

- **Complications:**
  
  - *Lead malposition* is quite difficult to detect in PCXR, but it is necessary to describe the apparent location of the leads to help clinical physician to detect malpositions.
  
  - *Lead fracture* is not uncommon and is clearly seen in the X-Ray (figure 31 on page 39). We have found several cases of defibrillator fragments after cardiac transplantation (figure 37 on page 45). We can see how a fragment remains in the superior cava vein (figure 36 on page 44), in the subclavian vein (figure 36 on page 44) or how a fragment migrates to liver (figure 38 on page 46)
  
  - *Twiddler syndrome* is a rare complication which causes pacemaker dysfunction due inadvertent or deliberate rotation of the pulse generator, with retraction of the lead, as in the case we show (figure 39 on page 47), which had to be recolocated.
  
  - *Myocardial rupture* is an uncommon but possible complication.

Other External Devices

We show other external devices which we have found in our daily practice, quite varied but also quite interesting.

- **Epidural catheter** *(anesthetic).* It is common to set an epidural catheter after surgery to control postsurgical pain, and we can detect them in the PCXR (figure 40 on page 48).

- **Brachitherapy wires** in neck tumours (figure 9 on page 17) or *brachitherapy seeds* located in the lung parenchyma (figure 41 on page 49) or which have migrated there from other anatomic regions, as prostate (figure 42 on page 50)

- **Biliary tubes** (figure 43 on page 51), **TIPS** (figure 42 on page 50) and *embolization* coils are some of the external devices we can find in cirrhotic patients or after complications of hepatic transplantation.

- It is not as uncommon as we could believe to find *vertebroplasty cement* embolized in the pulmonary arteries (thromboembolism) (figure 44 on page 52)
• *Pectus excavatum* is a morphologic alteration which does not usually requires surgery, but sometimes, when cardiac or respiratory functions are altered, is corrected. A metallic bar is used, as we see in this case (figure 45 on page 53)

• At last, as an uncommon and difficult image, we show the X-Ray of a patient, with a mediastinal collection due to postsurgical esophageal leak, which communicated with the skin. We can see the radio-opaque lines of the gauzes introduced in the wound (figure 46 on page 54).
Images for this section:

AP chest radiograph shows a nasogastric tube with the tip located in stomach (black arrow). ECG leads are also evident.

Fig. 0

© Radiology, Universidad de Navarra, Clinica Universitaria - Pamplona/ES
Nasogastric tube with the tip located in distal esophagus in a large hiatal hernia.

Fig. 0

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Patient with a hiatal hernia. Supine radiograph shows a nasoenteric tube (black arrows) which follows an unusual route, with several loops in the herniated stomach, but descending to the abdominal stomach. An endotracheal tube, cardiac pacemaker and central venous catheter are also visible.

Fig. 0

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Fig. 0

Frontal view of the chest shows a nasogastric tube (white arrow) located laterally in the neck that makes a loop and its tip is directed cranially.

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CT sagittal and coronal reconstruction showing abnormal passage of a nasogastric tube that is inserted into right jugular vein.

Fig. 0

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Fig. 0

Digital angiography images taken during the therapeutic procedure for removal of the nasogastric tube.

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Fig. 0

AP view of the chest and upper abdomen shows a feeding tube placed in the left lower lobe. After nasogastric feed was initiated, a left lower lobe consolidation was identified.

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Portable chest radiograph shows an endotracheal tube in a correct position (white arrow). A central venous catheter via the right jugular vein and a nasogastric tube are also visible. Patient with acute distress respiratory syndrome, due to influenza A virus pneumonia. Note the patchy, bilateral, alveolar pattern.

Fig. 0

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73-year-old patient with oral cavity cancer. Front view of the chest shows multiple brachytherapy catheters and a tracheostomy tube (white arrow).

Fig. 0

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Fig. 0

Chest tubes with distal tips in the apex and base of the left hemithorax. Also observed left thoracotomy skin staples.

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Frontal view of the chest shows an endotracheal tube in a correct position. Also seen are a central venous catheter, external wires and two mediastinal tubes (black arrows) after cardiac surgery of aortic coarctation.

Fig. 0

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Fig. 0

Frontal chest radiograph shows two mediastinal drainage tubes (black arrows) after surgical repair of a thoracic aortic aneurysm. Note also the sternal wires, the ECG leads and the central venous catheter.

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Cardiac surgery with postoperative mediastinal drainage tube. After drain tube removal an increased cardiac silhouette with straight edges is identified suggesting pericardial effusion.

Fig. 0

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Portable chest radiograph shows a right jugular vein catheter. The catheter tip is in the superior vena cava.

Fig. 0

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Fig. 0

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Frontal view of the chest shows a left subclavian bilumen catheter, used for dialysis. Subcutaneous reservoir is also evident.
Fig. 0

Frontal view of the chest shows a trilumen central catheter via the right jugular vein (white arrows). The tip is in superior cava vein.
Portable chest radiograph shows a central venous catheter which enters via the right jugular vein. Note also the ECG leads.

Fig. 0

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Fig. 0

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Fig. 0

Chest radiograph reveals a central venous catheter via the right subclavian artery (white arrows). A cardiac pacemaker and median sternotomy wires are also visible.

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Fontal view of the chest shows multiple external devices in a septic patient. There is a peripheral catheter with its tip within subclavian vein, external ECG leads, a nasogastric tube and an oxygen tube.

Fig. 0

© Radiology, Universidad de Navarra, Clinica Universitaria - Pamplona/ES
Peripherally inserted central catheter. The catheter tip is located in the right atrium.

Fig. 0

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Frontal view of the chest shows a peripherally inserted central catheter, with a loop. The tip is located within the axillary vein.

Fig. 0

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Fig. 0

Malpositioned Drum oriented cranially in the right jugular vein (black arrows). AP radiograph control post repositioning shows the distal tip in the right subclavian vein (white arrow)

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Portable chest radiograph shows a peripherally inserted catheter which passes through the right subclavian and superior vena cava. The tip should be removed some centimeters because it is in the inferior vena cava (black arrow).

Fig. 0

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Frontal view of the chest shows a peripherally inserted central catheter with the tip in a suprahepatic vein (black arrow). Mechanical mitral and aortic valve prosthesis are also seen.

Fig. 0

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Chest radiograph shows two pacemakers. One is located over the right pectoral area with right ventricular, right auricular and coronary venous lead. The abdominal one has two epicardial “corkscrew” electrodes (black arrows). Also seen sternal wires, a central venous catheter and Kirschner wires in left humerus.

Fig. 0

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Hemothorax secondary to traumatic puncture of the jugular vein. Coronal and axial CT images of the chest confirms the presence of hemopneumothorax.
Supine radiograph reveals a right jugular Swan-Ganz catheter which passes through the superior vena cava, right atrium and right ventricle, and get into the right pulmonary artery (figure A). Catheter located in the left pulmonary artery after repositioning (figure B).

Fig. 0

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Intra-aortic balloon pump (IABP). Supine chest radiograph shows an IABP located in the aorta, below the origin of the left subclavian artery (white arrow). A central venous catheter via the right jugular vein, endotracheal and nasogastric tubes and ventricular assist device (black arrows) are also seen.

Fig. 0

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Frontal view of the chest shows a mitral valve prosthesis and a pacemaker with its electrode in the right ventricle. Also shown are median sternotomy wires.

Fig. 0

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Fig. 0

Frontal view of the chest shows an atrioventricular pacemaker with two electrodes in the right atrium (open black arrow), one of them disconnected, and one in the right ventricle (black arrow).

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Frontal view of the chest shows a single defibrillator patch in the right hemithorax, an automatic implantable cardioverter defibrillator and a nasoenteric tube.

Fig. 0

© Radiology, Universidad de Navarra, Clinica Universitaria - Pamplona/ES
Frontal view of the chest shows typical epicardial pacing wires coiled on the patient's chest wall after cardiac surgery. Also seen two pleural tubes, a central venous catheter, a mitral valve prosthesis and a defibrillator patch.

Fig. 0

© Radiology, Universidad de Navarra, Clinica Universitaria - Pamplona/ES
Chest radiograph shows two pacemakers. One is located over the right pectoral area with right ventricular, right auricular and coronary venous lead. The abdominal one has two epicardial “corkscrew” electrodes (black arrows). Also seen sternal wires, a central venous catheter and Kirschner wires in left humerus.

Fig. 0

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Supine radiograph after transthoracic mitral valve replacement shows two defibrillator patches (white arrows), two right pleural drainage tubes (black arrows) and the tip of an epicardial pacemaker adjacent to the left heart. There are also a central venous catheter and an endotracheal tube.

Fig. 0

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Fig. 0

Frontal view of the chest shows a lead fragment of an explanted automatic implantable cardioverter debrillator (black arrow).

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68-year-old man after cardiac transplant. Supine chest radiograph shows a right jugular catheter, an endotracheal tube and a mediastinal drainage tube (black arrow). Retained lead fragment of an explanted automatic implantable cardioverter-defibrillator in the superior cava, left brachiocephalic and subclavian veins (white arrows).

Fig. 0

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Fig. 0

Frontal view of the chest shows a fragment of an automated implantable cardioverter-defibrillator projected over the hepatic silhouette (black arrow). Median sternotomy wires are also seen.

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Twiddler syndrome. Pacemaker wires are rolled over the subcutaneous generator.

Fig. 0

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Fig. 0

60-year-old patient after right thoracic surgery. Frontal chest view shows a peridural anesthesia catheter (white arrows), two pleural drainage tubes (black arrows), a central venous catheter in superior vena cava and skin staples.

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Supine radiograph shows multiple mediastinal brachytherapy seeds (black arrows) in a patient with lung squamous cell carcinoma. Note the migration of four of these seeds to the lung parenchyma. Median sternotomy wires and an automated implantable cardioverter-defibrillator are also evident.

Fig. 0

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Frontal view of the chest reveals a single brachytherapy seed in the left lung (white arrow). The patient had been treated with interstitial brachytherapy after being diagnosed of prostate carcinoma. There is also a transjugular intrahepatic portosystemic shunt (TIPS).

Fig. 0

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Liver transplant complicated with bile duct stricture. Front radiograph shows two biliary drainage tubes (black arrows) and a right central venous catheter.

Fig. 0

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Collimated frontal view of the spine shows vertebroplasty of three dorsal vertebrae (black arrows). Note the presence of pulmonary embolised vertebroplasty cement in right lung (white arrows). A left central venous catheter is also seen.

Fig. 0

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Frontal and lateral view of the chest show a concave steel bar under the sternum to correct pectus excavatum.

Fig. 0

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53-year-old man after esophagus cancer surgery. Frontal view of the chest shows contrast medium leak in the mediastinum. Adyacent linear opacities representing radiological markers of a surgical gauze are also evident.

Fig. 0

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Conclusion

Portable chest x-ray is the most common radiologic exam in intensive care units and critically ill patients. External devices are very common in such patients, and radiologists must know the radiological appearance of external devices and their complications, to help physicians in the management of these patients in a multidisciplinary approach to critically ill patients.
References


