What every radiologist should know about... "Medical Devices"

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Learning objectives

The objective of this work is to learn to identify at different imaging modalities the main medical devices that use patients, and know their role, correct position and possible complications arising from misuse thereof.

Background

Medical devices are instruments used for the prevention, diagnosis, monitoring and even treatment of various diseases that may present patients.

Every day, and at different imaging modalities, radiologists are finding that patients are carriers of various medical devices (catheters, tubes,...), which can be related with any organ or system of the human body.

NERVOUS SYSTEM:

1) Cerebrospinal fluid shunts(Figure 1 and 2): Allows to drain excess cerebrospinal fluid from ventricular system into the peritoneum (ventriculo - peritoneal shunt) or into the right atrium (ventriculo - atrial shunt), which helps to decrease intracranial pressure. Ventriculo - peritoneal shuts are the treatment choice of hydrocephalus.

These systems are compose of three elements: a proximal catheter situated in ventricular system, a one - way valve connected to a reservoir, and a distal catheter placed in the subcutaneous tissue that flows into the peritoneal cavity.

- **Position:** Ventricular catheter is usually placed in the frontal horn of the right lateral ventricle, near the foramen of Monro.
- **Complications:**
  - Malposition (Figure 3).
  - Valvular dysfunction: It may be due to blockage, breakage or migration of the catheter (by migration, the catheter may be introduced through an inguinal hernia, lead to intestinal perforation,..) (Figure 4 and 5).
  - Central nervous system infection.
  - Intracranial hemorrhage.
  - Anomalous drainage of cerebrospinal fluid (hyperdrainage valvular syndromes).
2) **Intracranial pressure sensor** (Figure 6): Allows to monitor intracranial pressure. Its main indication is the cranioencephalic trauma, but also is used in other situations that present with intracranial hypertension (intracranial hemorrhage, tumors,...).

- **Position**: These devices can be intraparenchymal, intraventricular or subdural. Intraparenchymal sensors should be placed in cerebral hemisphere more damaged, about 15 or 20 mm deep within the cerebral white matter.
- **Complications**: Local bleeding and infection are the most common complications.

3) **Intracranial catheters** (Figure 7): Intracranial catheters most commonly used are those that serve to evacuate subdural hematomas. They are gravity drainage devices, so they are rarely used in subdural hematomas (acute subdural hematomas are evacuated after performing a craniotomy, as being made of freshly clotted blood, gravity drainage would not be effective).

4) **Aneurysms clips** (Figure 8): Cerebral aneurysms clips are used to clamp off the neck of an aneurysm, depriving it of its blood supply, which is useful in the prevention and treatment of certain intracranial hemorrhages.

Currently, the most of aneurysms clips are made from non-ferromagnetic materials, such as tantalum, so they are compatible with MRI equipment.

5) **Coils** (Figure 9): They are used for endovascular treatment of cerebral aneurysms and arteriovenous malformations.

6) **Carmustine wafers** (Figure 10): They are small wafers impregnated with a chemotherapeutic agent (carmustina), which are used as adjunctive therapy for treatment of glioblastoma multiforme and anaplastic astrocytoma. The wafers are implanted in the tumor cavity after surgery to prevent tumor recurrence, so that it will slowly release the chemotherapeutic agent into the tumor surgical cavity over a 2 - 3 weeks period.

At CT, carmustina wafers appear as small hyperdense linear images.

**GASTROINTESTINAL SYSTEM:**

1) **Nasogastric, nasoduodenal and nasojejunal tubes** (Figura 11): They are employed to administer enteral nutrition in patients who retain intestinal peristalsis but are not be able to ingest food, decompress the stomach or small intestine, collect samples or perform gastric lavage.
2) **Gastrostomy and jejunostomy tubes** (Figure 13): They are used to feed ill patients permanently or for long periods of time (typically over 6 - 8 weeks). Gastrostomy and jejunostomy tubes can be surgically, endoscopically, or percutaneously placed.

   - **Position:** These devices should be located in the anterior abdominal wall, with its distal end situated in the stomach (gastrostomy) or proximal jejunum (jejunostomy).
   - **Complications:**
     - Dysfunction: It is usually due to blockage or rupture of the tube.
     - Output accidental tube.
     - Aspiration of gastrointestinal contents.
     - Pressure necrosis of the gastric or intestinal wall.
     - Gastric or intestinal perforation.
     - Gastrointestinal hemorrhage.
     - Abdominal wall hematoma, infection at the edges of the stoma,…

3) **Esophageal stent** (Figure 14): They are very useful in the treatment of dysphagia due to benign and malignant esophageal diseases (esophageal tumors, lung cancer, fistulas,…). Esophageal stent can be made with plastic or metal. The latter, in turn, are divided into covered (with a waterproof material affixed to the inner wall, theoretically, prevent tumor progression within the esophageal lumen) or uncovered.

   - **Position:** To be well placed, the stent should be cover at least 2 cm of healthy esophagus both distal and proximal to the stenosis.
   - **Complications:**
     - Migration of the stent: It is the most common complication (Figure 15).
- Obstruction of the stent due to tumor growth or food bolus impaction.
- Gastro-oesophageal reflux and aspiration of gastrointestinal contents.
- Esophageal perforation.

4) **Biliary drainage** (Figure 16): They allow the passage of bile from the intrahepatic bile duct into the duodenum, keeping tract permeable in case of obstruction due to both benign and malignant diseases (cholangiocarcinoma, pancreatic head or distal bile duct neoplasms,...).

Biliary drainages can be made with plastic or metal (the most frequent) and their designs are highly variable.

- **Position:** In order to be properly positioned, the stent should broadly cover any obstruction (it must be 2 to 3 cm longer that the stricture) and free the papilla (if that is not affected by the tumor).
- **Complications:**
  - Obstruction of the stent, which may be due to accumulation of biliary sludge or tumor infiltration.
  - Migration of the stent.
  - Intestinal perforation.

5) **Kelhr’s Tube** (Figure 17): This device acts by gravity drainage, which is placed intraoperatively after surgery of the biliary tract. It is a tube shaped "T" which is arranged such that its two shorter ends are situated inside the bile duct (choledocus and common hepatic duct) and its longer end exits to the outside through the abdominal wall.

**RESPIRATORY SYSTEM:**

1) **Endotracheal tube** (Figure 18): They keep permeable and isolated the airway.

- **Position:** In an adult, the tip of the tube should be situated approximately 5 cm above the tracheal carina.
- **Complications:**
  - Malposition: It is the most common complication. Although the endotracheal tube is fixed to the mouth of the patient, the tip can ascend or descend (it ascends 2 cm when the patient extends the neck and falls 2 cm when it flexes the neck). If the distance from the distal end of the endotracheal tube to the carina is greater than 6 cm, when the patient extends the neck may be extubated. Conversely, if that distance is less than 2 cm, when
the patient flexes the neck may occur selective bronchial intubation (usually the right main bronchus), resulting in a hyperinflation intubated lung and collapse contralateral lung.

- Tracheal laceration: It usually occur in the posterior wall of the trachea (membrane wall).

2) **Thoracostomy tubes** (Figure 19 and 20): The main indication is the treatment of pleural effusion and pneumothorax.

  • **Position:**

- Pleural effusion: The tube is usually placed posterioinferiorly (when the patient is standing the fluid tends to go down).

- Pneumothorax: The tube is usually placed anterosuperiorly (when the patient is standing the air tends to go up).

  • **Complications:**

- Malposition: Chest tubes can be placed improperly outside the pleural cavity, resulting in lung lacerations, esophageal perforation, diaphragmatic perforation, liver or spleen laceration,…

- Empyema.

- Hemothorax (due to intercostals artery injury).

**CARDIOVASCULAR SYSTEM:**

1) **Central venous catheter** (Figure 21 and 22): They can be used to administer fluids, medication or nutrition, for hemodynamic monitoring or performing hemodialysis.

  • **Position:** Central venous catheters can be introduced by the subclavian, internal jugular or femoral veins. It tip should be located in the superior cava vein, to 2.5 cm from the mouth of the brachiocephalic venous trunk.

  • **Complications:**

- Malposition: The most common mistake is channeling retrograde internal jugular vein from the subclavian vein.

- Pneumothorax: The apex of the lung is located about 5 mm of the subclavian vein, so it is not uncommon inadvertent puncture when you are trying to canalize the vein.

- Arterial puncture (mainly subclavian artery) and hematoma.
- Venous perforation and instillation of fluids in mediastinum, pleural cavity or subcutaneous tissue.

- Venous thrombosis.

- Nervous injury.

- Pinch-off syndrome: It occurs when a long-term central venous catheter is compressed between the clavicle and the first rib.

2) **Subcutaneous ports** (Figure 23): These devices are designed for easy, long-term access to the vascular system (or peritoneal cavity). The port is usually connected to a central venous catheter or to an arterial catheter and can be used for instillation of fluids, medications, parenteral nutritional solutions and blood products. It can also be used for withdrawal of blood samples.

   - **Position:** The port typically sits in the subcutaneous tissue of infraclavicular fossa.

3) **Swan-Ganz catheter** (Figure 24): It is used for measuring hemodynamic pressures (pressure in the right atrium and ventricle, pulmonary artery pressure, pulmonary capillary pressure and cardiac output).

   - **Position:** Ideally, the catheter should be situated in a main pulmonary artery.
   - **Complications:**

     - Malposition: If the tip of the catheter is in a position beyond a main pulmonary artery, it can lead to a complete vessel occlusion and, consequently, a pulmonary infarction (Figure 25).

     - Arrhythmias: They are usually secondary to the formation of loops (due to the length of the catheter) inside the heart chambers.

4) **Prosthetic heart valves** (Figure 26): They are useful in the treatment of valvular stenosis and insufficiency (mitral and aortic valves are the most frequently replaced).

   Heart valve prostheses can be of two types: Mechanical (its duration is unlimited, but require lifelong anticoagulant therapy) or biological (its duration is limited, but not require permanent anticoagulant therapy).

   Sometimes, instead of needing a prosthetic valve, you can use an annuloplasty ring to fix a dilated valve annulus without replacing the valve (Figure 27).

   - **Position:** In the chest X-ray, the radiologist must draw:
- Posteroanterior projection: A line that links right cardiophrenic angle with the left pulmonary hilum.

- Lateral projection: A line that links costophrenic angle with the tracheal carina.

The aortic valve is positioned above the two lines, while the mitral valve is below them.

  - **Complications:**

- Infectious endocarditis.

- Thrombosis and embolism.

- Prosthetic dysfunction.

5) **Cardiac pacemaker** (Figure 28): They are used in the treatment of many diseases that present with a heart rhythm disorder, mainly atrioventricular block and sinus node disease.

A cardiac pacemaker is basically composed of two main elements: a pulse generator connected to one or several electrodes. Depending on the number of electrodes we can name unicameral pacemaker (the electrode is located in right atrium or right ventricle), bicameral pacemaker (the electrodes are located in right atrium and right ventricle) or tricameral pacemaker (the electrodes are located in right atrium, right ventricle and left ventricle).

Tricameral pacemakers (Cardiac Resynchronization Therapy) are useful in the treatment of congestive heart failure functional class III - IV of NYHA.

  - **Position:**

- Generator: It is typically located in the subcutaneous tissue of infraclavicular fossa.

- Electrodes: They can be of two types:

  1. **Endocardial:** These electrodes are most frequently used. They are usually introduced through the subclavian vein and brought to right atrium and / or right ventricle.
  2. **Epicardial:** They are sutured to the epicardium during cardiac surgery.

  - **Complications:**

- Malposition.

- Dysfunction: It may be due to breakage or migration of the electrodes.
- Pneumothorax.
- Pericardial effusion.
- Myocardial perforation.

6) **Implantable Cardioverter Defibrillator (ICD)** (Figure 29): It is useful in the monitoring and treatment of malignant ventricular arrhythmias (ventricular tachycardia and ventricular fibrillation).

7) **Implantable loop recorder** (Figure 30): It is used for prolonged monitoring (over 1 year) of the cardiac rhythm.
   - **Position**: They are usually located in the subcutaneous tissue of the left pectoral region.

8) **Coronary artery stent** (Figure 31): It is used in patients with ischemic heart disease for the treatment of stenosis or occlusion of the coronary arteries.
   - **Complications**: The most common complications are stent thrombosis and restenosis.

9) **Median sternotomy sutures** (Figure 32): Median sternotomy is the standard surgical approach for coronary bypass surgery.

**GENITOURINARY SYSTEM:**

1) **Foley catheter** (Figure 33): It is commonly used to monitor urine output or decompress the bladder in case of urinary retention. The Foley catheter consists of a simple tube to which is attached a balloon that is inflated to keep the catheter in place in the bladder.

2) **Ureteral stents** (Figure 34): It is used primarily in the treatment of ureteral strictures, intrinsic (calculi, blood clots, neoplasms,...) and extrinsic (fibrosis, lymphadenopathy, neoplasms,...), and in the treatment of urinary fistulas, allowing urine to flow unimpeded into the bladder.

The most common design for a ureteral stent is the double pig - tail, which prevents the catheter migrates proximally or distally.

   - **Position**: The proximal end of the catheter is residing in the renal pelvis while its distal end does it in the bladder.
   - **Complications:**
- Perforation of the ureter.
- Hematuria.
- Urinary tract infection.

3) **Intrauterine device (IUD)** (Figure 35): All these devices act as a contraceptive and they have a somewhat similar T-shaped configuration. They should be located inside the endometrial cavity.
   - **Complications:**
   - Pelvic inflammatory disease (Figure 36).
   - Uterine perforation.

**OTHER MEDICAL DEVICES:**

1) **Breast tissue expander** (Figure 37): After a mastectomy, it may sometimes be necessary to use a breast tissue expander. This device will gradually fill with saline, which is intended to achieve a correct expansion of the chest area of tissue before placing a final prosthesis.

2) **Breast prosthesis** (Figure 38): Depending on what your site of implantation, breast implants can be of two types: Retropectorales (located behind the pectoral muscle) or retroglandulares (located between the breast and the pectoralis major muscle).

**Images for this section:**
**Fig. 1**: Cerebrospinal fluid shunt. (a and b) Head CT scan showing a cerebrospinal fluid shunt with its distal end stayed in front horn of the right lateral ventricle.
Fig. 2: Cerebrospinal fluid shunt. Chest x-ray (a) and abdomen (b) showing the subcutaneous route in a cerebrospinal fluid shunt along the thoracic and abdominal wall until it enters the peritoneal cavity.
**Fig. 3:** Cerebrospinal fluid shunt poorly positioned. Head CT (a, b, c and d) showing a cerebrospinal fluid shunt badly positioned with its distal end housed inside the left thalamus.
**Fig. 4:** Perforation of the colon by a cerebrospinal fluid shunt. Abdominal X-ray (a and b) showing a cerebrospinal fluid shunt with its distal end inside the abdomen wound around the colon and extraluminal presence of air.

**Fig. 5:** Perforation of the colon by a cerebrospinal fluid shunt. Abdomen CT showing a cerebrospinal fluid shunt with its distal end through the colon and the presence of pneumoperitoneum.
Fig. 6: Intracranial pressure sensor
Fig. 7: Subdural drainage catheter. (a) Preoperative brain CT showing a left chronic subdural hematoma fronto - parietal which has rebleeding. (b, c and d) Postoperative brain CT after subdural hematoma evacuation and placement of a subdural drainage catheter.
Fig. 8: Aneurysms clips. (a and b) Brain CT scan showing an aneurysm clip in the area of circle of Willis.
**Fig. 9:** Coils. (a and b) Brain CT scan which shows the artifact caused by coils in the area of circle of Willis.

**Fig. 10:** Carmustine wafers. Brain CT showing carmustine wafers on the periphery of a cavity after resection of an anaplastic astrocytoma.
Fig. 11: Nasogastric tube
Fig. 12: Perforation of the esophagus by a prnasogastric tube. (a and b) Chest CT which shows how the nasogastric tube through the wall of the esophagus and reaches the lung parenchyma, makes a loop, and drawn back into the esophagus.

Fig. 13: Gastrostomy tube
Fig. 14: Esophageal stent
Fig. 15: Migrated esophageal stent. Abdomen X-ray (a) and CT (b) showing esophageal stent has migrated and is now located in the sigmoid colon, without signs of perforation.
**Fig. 16:** Biliary stents. Abdomen X-ray (a) and CT (b) showing different types of biliary stents. In (a) may be also two ureteral stents inside the urinary tract.
Fig. 17: Kelhr’s Tube
Fig. 18: Endotracheal tube
Fig. 19: Thoracostomy tube. (a and b) Chest X-ray showing a loculated pleural effusion in the left hemithorax with a thoracostomy tube inside.
**Fig. 20:** Thoracostomy tube. (a and b) Chest X-ray showing a right pneumothorax with a thoracostomy tube inside.

**Fig. 21:** Central venous catheter. (a and b) Chest X-ray showing a central venous access via the right subclavian vein and with its distal end stayed in superior vena cava.
Fig. 22: Central venous hemodialysis catheter
Fig. 23: Subcutaneous ports
Fig. 24: Swan - Ganz catheter
Fig. 25: Swan - Ganz catheter malpositioned. (a, b, c and d) Chest CT showing a Swan - Ganz catheter stayed with its distal end in a segmental branch of right inferior lobule.
Fig. 26: Prosthetic heart valve (mitral)
Fig. 27: Annuloplasty ring. Chest X-ray showing a mitral annuloplasty ring. You can also see the median sternotomy sutures and a bicameral cardiac pacemaker.
Fig. 28: Cardiac pacemaker. (a and b) Chest X-ray in which there is a bicameral cardiac pacemaker with electrodes housed in right atrium and ventricle.

Fig. 29: Implantable Cardioverter Defibrillator
Fig. 30: Implantable loop recorder
Fig. 31: Coronary stent in the left anterior descending artery.
Fig. 32: Median sternotomy sutures
Fig. 33: Foley catheter
Fig. 34: Ureteral stent
Fig. 35: Intrauterine device
Fig. 36: Pelvic inflammatory disease in a patient with an intrauterine device
Fig. 37: Breast tissue expander
Fig. 38: Bilatera breast prosthesis
Imaging findings OR Procedure details

Chest X-ray will be, in most cases, the method of choice if what you want is to control the correct positioning of the various medical devices. In the event of suspected complications from the use of these items you may have to resort to more sophisticated imaging modalities, mainly computed tomography.

Conclusion

There are many medical devices, which can be related with any organ or system of the human body. The important thing is not to know the specific name of each device, if not learn to recognize the different imaging techniques.

Chest X-ray will be, in most cases, the method of choice if what you want is to control the correct positioning of the various medical devices. In the event of suspected complications from the use of these items you may have to resort to more sophisticated imaging modalities, mainly computed tomography.

References


of the head, neck, spine, chest, and abdomen.


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