EXTERNAL DEVICES IN THE PEDIATRIC CRITICAL CARE UNIT

Dispositivos externos en unidad de cuidado crítico pediátrico

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Summary
Plain radiography is a useful diagnostic modality in the follow-up of patients in hospitalization services, surgery and intensive care units. This article gives an overview of the most commonly used pediatric devices. It also briefly describes the indications, radiological findings and associated complications with the insertion of the devices. This information allows to recognize and confirm their proper position and identify opportunely those who are poorly positioned, which can cause serious complications.

Resumen
La radiografía simple es un método diagnóstico útil en el seguimiento de pacientes en servicios de hospitalización, cirugía y unidad de cuidados intensivos. Este artículo ofrece una visión general de los dispositivos pediátricos más usados. También se describen de manera breve las indicaciones, hallazgos radiológicos y complicaciones asociadas a la inserción de los dispositivos. Esta información permite reconocer y confirmar la adecuada posición e identificar oportunamente los dispositivos mal ubicados, que pueden causar complicaciones graves.

Objectives
The radiologist must be able to:

- Recognize different pediatric devices on simple x-ray and their optimal location.
- Identify the bad positioning of the devices and correlate it with complications.
- Know the indications of the different paediatric devices.

Abbreviations: AP: anteroposterior, atrioventricular AV, CVC: central venous catheter, PD: peritoneal dialysis, ECG: electrocardiogram, ECMO: extracorporeal membrane oxygenation, PICC: peripheral insertion central catheter.

Introduction
Plain radiography is a tool in the evaluation and follow-up of patients in hospitalization services, surgery and intensive care units. It is a quick method for the evaluation of devices used in pediatrics: it allows to verify the position and identify complications caused by their use. The portable system should be used, taking into account the limitations of mobility in critically ill children and its monitoring elements: tubes, probes and drains.

In this review, the most commonly used devices in pediatric patients will be discussed, as well as their clinical indication, the findings to be found in the radiography and their possible complications.

1. Devices for monitoring and treatment in paediatrics

1.1 Esophageal temperature sensor

Clinical indication

Allows the central body temperature to be estimated continuously. Its value and precision depend on the anatomical location, which must be in the distal third of the esophagus (1). It is mainly used in

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the intensive care unit (Hypothermia protocol) and during surgical procedures, such as cardiovascular surgery (2,3).

Radiological findings

Se observan los dispositivos electrónicos en sondas en la parte del esófago distal (figura 1).

1.2 Endotracheal tube

Clinical indication

This device preserves the permeability of the airway, ensures ventilation and protects against bronchoaspiration. Intubation can be performed electively or urgently (4).

Radiological findings

The endotracheal tube should be approximately at the height of C7-T2, above the carina, more or less in the middle of the trachea, as the location of the tube can be modified by the flexo-extension movement of the head (5,6). Lateral chest radiography makes it possible to evaluate whether the tube is in the trachea or esophagus (7). A selective intubation of the right bronchus can be found, due to its anatomical position, and could be accompanied by an atelectasis of the contralateral side (Figure 2).

Complications

The main complications during this procedure are: fracture of teeth, esophageal intubation, selective pulmonary intubation, laceration or perforation of pharynx, larynx, esophagus or trachea, if it is nasotracheal intubation (4).

1.3 Tracheostomy

Clinical indication

Severe upper airway obstruction: Secondary to subglottic stenosis, craniofacial syndromes, laryngeal and craniofacial tumors, vocal cord paralysis, obstructive sleep apnea, laryngeal trauma from accidents or burns.

Prolonged ventilation/pulmonary protection: Chronic, postoperative lung disease of complex congenital cardiopathies, neurological or neuromuscular diseases (8,9).

Radiological findings

Under the lower edge of the cricoid cartilage is observed a radiopaque device corresponding to the cuff, an inflatable device attached to the tracheostomy probe, which was designed to occlude the space between the walls of the trachea and the probe so as to allow mechanical ventilation. The probes may be made of opaque plastic or metal, with or without an external humidification drum (9) (Figure 3).

Complications

Subcutaneous emphysema, pneumomediastinum, pneumothorax, bleeding from vascular injury, tracheoesophageal fistula, malposition of the tracheostomy cannula, granuloma and laryngotracheal stenosis (8).

1.4 Thoracostomy or chest tube

Clinical indication

The chest tube is indicated for drainage of large, high-density pleural effusions and complicated parapneumonic effusions. In addition, for the management of pneumothorax greater than 20% or tension, which may be secondary to traumatic injury, barotrauma during mechanical or spontaneous ventilation; it may also be used to administer medications, such as fibrinolytics in empyema (10,11).

Radiological findings

The radiologist should identify the position of the tube, whether it is anterior or posterior, whether it relates to the collection of air or liquid to be drained or residual, the position of the holes with respect to the chest wall and whether there is any type of bend in the tube. If there is free pleural effusion or complete pneumothorax, the ideal position is 4 and 5 intercostal space between the anterior and middle intercostal line, leaving the apical tube if air is to be drained, and basal if liquid is to be drained (Figure 4). In case of pneumothorax, it can also be drained through the second intercostal space with clavicular midline.

Complications

The most common is the formation of a pneumothorax. Less common are laceration of intercostal vessels (secondary haemothorax); puncture below the diaphragm and injury of solid viscera (liver or spleen), subcutaneous emphysema, cough, infection or pulmonary contusion (12).

2. Classification of central venous catheters

Central venous catheters can be exteriorized simple or tunneled, or with subcutaneous repertoire.

2.1 Central venous catheter (CVC): It can have different approach routes, the most used is by the subclavian vein followed by the internal jugular vein and the femoral vein.

2.2 Tunneled catheters: The most commonly used are Hickman®, Broviac® or Groshong® type catheters. Generally, the subclavian vein or the jugulosubclavian confluent is punctured and a subcutaneous pectoral route is left. The Groshong® type has a valve at its tip that decreases the possibility of occlusion by passive blood flow.

Clinical Indication

Hemodynamic monitoring, to measure central venous pressure (CVP). It is a vascular access that allows to place several infusions (medicines, parenteral nutrition), or in those patients with difficult peripheral venous access, for treatments of short duration or that require a rapid placement. The femoral venous catheter is used in case of shock, for administration of large volumes of fluids and/or blood products, when other venous accesses fail due to its high rate of local infection and uncomfortable position.

Tunneled catheters have a longer duration, are used for long treatments, up to 12 months.

Radiological findings

In the CVC, the tip should be found at the junction of the superior vena cava with the right atrium (13,14). This junction is difficult to determine in pediatric patients due to the size of the thymus. It is expected to be approximately at the height of T6 and below the right main bronchus. The tip of the catheter should have a straight course, if a curvature is observed it might suggest that it is against the tricuspid valve or the wall of the right atrium (13-15). If the position of the catheter tip is not clear, contrast dye or CT scan may be used to confirm its position. The probability of persistent left superior vena cava should also be considered as an anatomical variant (16,17) (Figures 5 and 6).

Complications

Pneumothorax, arterial puncture, hematoma, air embolism, neurological deficit, arrhythmias, catheter malposition, migration, infection, tricuspid valve damage, thrombosis (18-20). Complications in the femoral catheter are puncture of the femoral artery, thrombosis or tear of the femoral vein (20), puncture of the hip joint capsule, perforation of the peritoneum.

2.3 Venous catheter with reservoir

This catheter has a subcutaneous reservoir (metallic or plastic), with a silicone cup for access, attached to a catheter that is placed in the venous system. The ports can be of one or two chambers.

Clinical Indication

Chemotherapy, parenteral nutrition, antibiotics for prolonged periods of time (21).

Radiological findings

The path of the catheter is followed through the subclavian vein and its distal end is located in the vena cava at the entrance to the right atrium (Figure 7).

Complications

Vascular damage, hematomas, infection, hemothorax, pneumothorax, brachial plexus injury, thoracic duct injury, arrhythmias or cardiac tamponade. Other risks are exteriorization of the reservoir or catheter through the skin, bacteremia or sepsis, extravasation due to rupture or inadequate application of elements, thromboembolism (19,22,23).

Simple chest radiography or fluoroscopy plus injection of contrast medium makes it possible to recognize any leaks in the catheter, as well as to recognize catheter plugging by fibrin.

2.4 PICC catheter (peripherally inserted central catheter)

Clinical indication

It is mainly used for prolonged intravenous therapy (antibiotic, parenteral nutrition, chemotherapy), as well as for the administration of irritant drugs that should not be given by peripheral venous route (24-26).

Radiological findings

It is inserted through the veins of the upper extremity (cephalic, basilic, brachial) or lower and the proper position of its distal end is verified with a chest x-ray, which identifies the tip of the catheter in the superior vena cava in the distal third, outside the cardiac silhouette or in the cavoatrial junction; in chest radiography, the right tracheobronchial angle is used as the best reference point to locate the cavoatrial junction (13,14,27). When in a suboptimal position above this location, there is a greater risk of migration of the distal extremity, stenosis or thrombosis (28,29). Ideally, the catheter should be positioned with fluoroscopic and ultrasound guidance, most of those not guided by images end up in the right atrium, with the risk of atrial perforation or arrhythmias during the procedure (14,15) (Figure 8).

Complications

There may be migration or fracture of the catheter or arterial location, local infection or bacteremia, venous thrombosis, catheter dysfunction and phlebitis. The risk of perforation and arrhythmias from poor atrial positioning is rare, but may occur (28-30).

2.5 Umbilical catheter

Clinical indication

It is indicated in the first 24 hours of life. It can be venous catheter or arterial catheter.

Umbilical venous catheter: Used as emergency vascular access, central venous pressure monitoring, exchange transfusion, central venous access for infusion of parenteral fluids and medication (31,32).

Radiological findings

It follows an ascending path from the umbilical region to the left portal vein and the venous canal to the inferior vena cava and the right atrium, the ideal position is the inferior vena cava in its most cephalic position or at the cavoatrial junction. In the lateral projection it takes the form of an S and passes through the liver before reaching the inferior vena cava (33).

Complications

The complications described are haemorrhage or haematoma, hepatic necrosis, portal hypertension and portal cavernomatosis, portal thrombosis, haemorrhage due to disconnection of the system, atrial perforation and arrhythmias (when poorly positioned), thromboembolism and infection (30,32).

Umbilical arterial catheter: Allows frequent determination of arterial blood gases, continuous blood pressure monitoring, infusion of parenteral fluids, exchange transfusion, resuscitation.

Radiological findings

Arterial catheter: follows its path from the navel to the pelvis, until it reaches the right or left iliac artery and then ascends to the aorta. The tip of the catheter is recommended: high, in the distal thoracic or upper abdominal aorta above T12, but below T4; or low, below the renal arteries. The ideal position is between T5-T8, the second position of choice is caudal between L3-L5, it should be remembered that the celiac trunk is located at the height of T12. The upper mesenteric artery at T12-L1, the renal artery at L1-L2, the lower mesenteric artery at L3 and the aortic bifurcation at L4 should be avoided being close to the origin of the main vessels when positioning the catheter (32) (Figures 9 and 10).

Complications

The complications described are embolism or thrombosis, haemorrhage and, less frequently, ischemia, aneurysm or dissection (30).

Figure 1. Thermometer in the middle third of the esophagus (arrow): Arterial and venous connections in connection with ECMO. Orotracheal tube projected at the height of T3-T4. Right pleuromediastinal probe and bilateral thoracotomies. Right distal subclavian catheter with distal end projected into the right jugular.

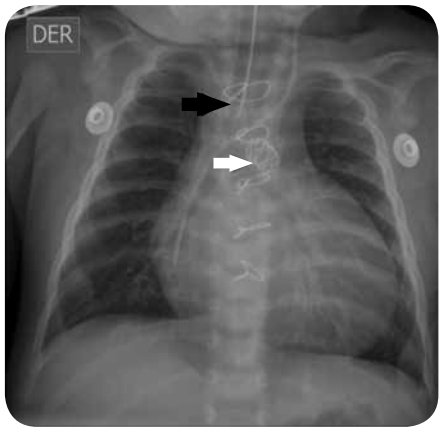

Figure 2. Orotracheal tube located approximately in the middle third of the clavicles and the carina, at the height of T3 (black arrow). Giant endoprosthesis in the ductus arteriosus and sternal cerclage material (white arrow).

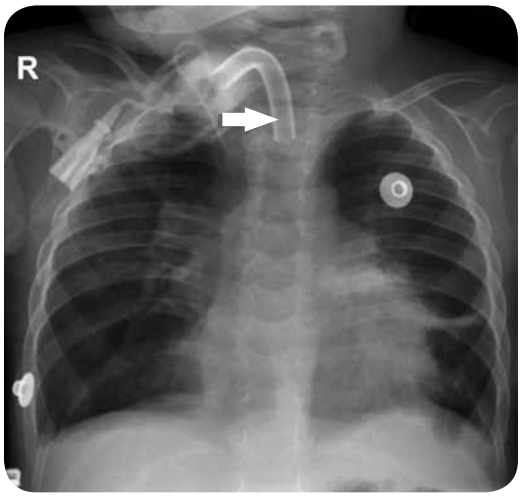

Figure 3. Tracheostomy cannula with distal end projected at the height of T2-T3. Right supraclavicular rolled catheter with distal end projected into the superior vena cava.

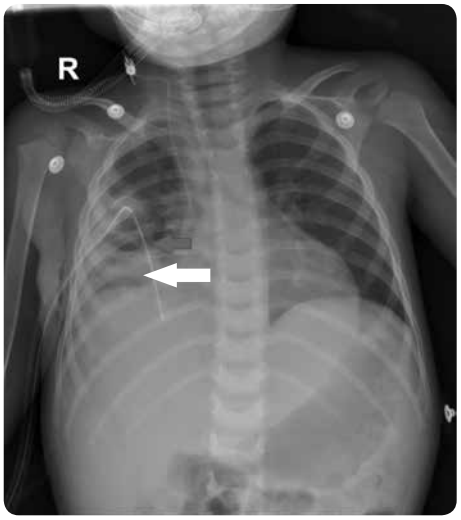

Figure 4. Right chest tube. Note the holes in the thoracic cavity, angulation of the thoracic cavity with distal location at the pulmonary base, for management of pleural effusion, external monitoring electrodes.

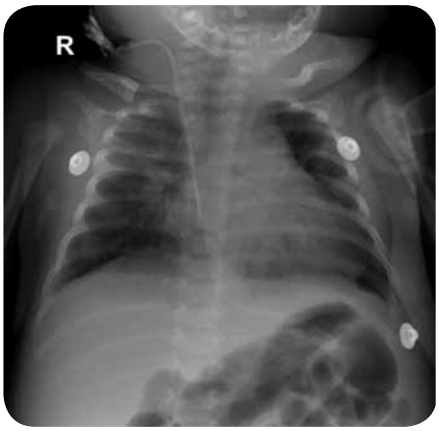

Figure 5. Right jugular catheter with distal end in the right atrium.

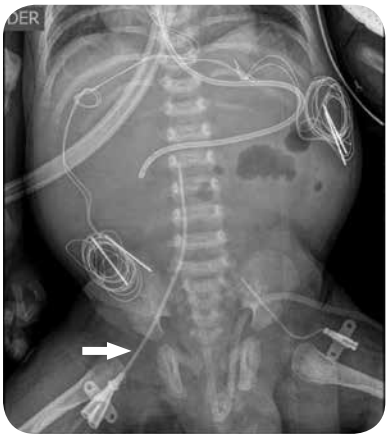

Figure 6. Esophageal trajectory catheter with distal end projected into the first portions of the duodenum. Images compatible with temporal pacemaker electrodes. Right femoral catheter with end projected at the height of T10 and left femoral with end in the iliac region (arrow). Image projected in the pelvic cavity in relation to peritoneal dialysis catheter.

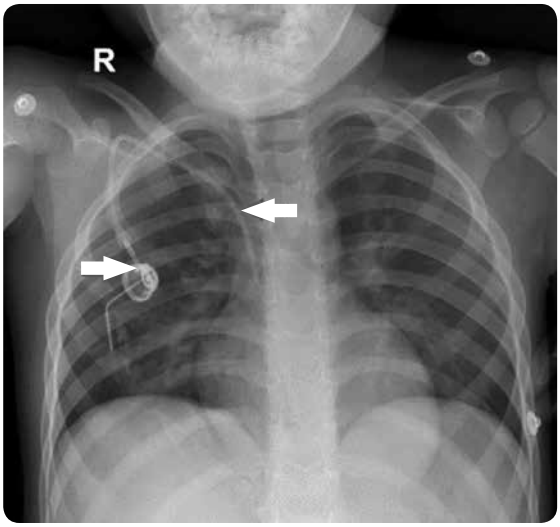

Figure 7. Right subclavian catheter, with chemotherapy reservoir on the same side, the distal end of which is projected into the superior vena cava.

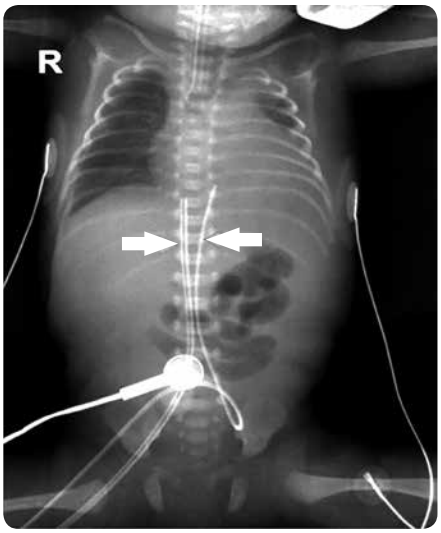

Figure 10. Orotracheal tube at the height of T4. Signs suggestive of left pleural effusion. Umbilical catheters: arterial with distal end at the height of T8 and venous end at the height of T9.

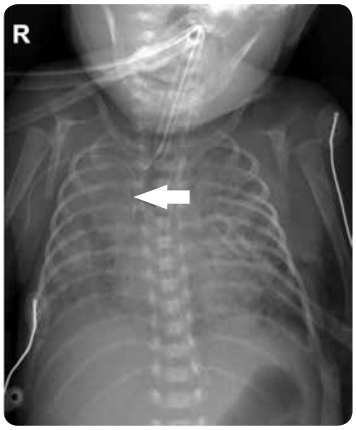

Figure 8. Right peripheral central insertion catheter (PICC) with extreme in the cavoatrial junction. Endobronchial tube, end located 1 cm from the carina, projected at T2-T3 level. Left hemithorax drainage catheter. Enteral probe in the esophageal pathway, with distal end at the gastroesophageal junction.

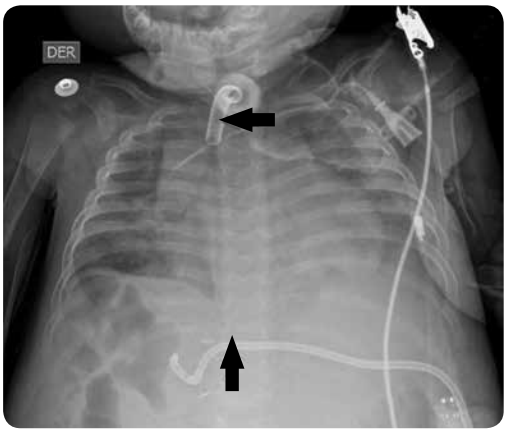

Figure 11. Tracheostomy cannula. Left subclavian catheter with distal end in the superior vena cava. Percutaneous peritoneal catheter located in the right hypochondrium.

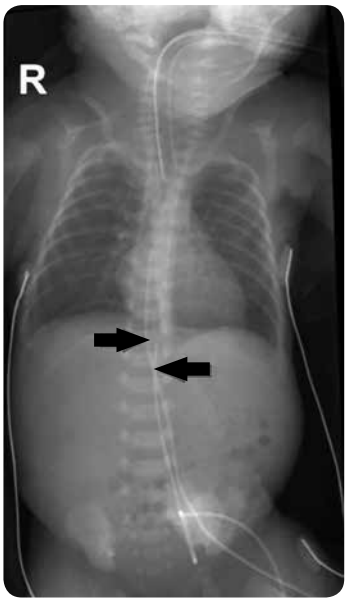

Figure 9. Esophageal probe in the gastric chamber. Central trachea. Orotracheal tube at the height of T2-T3. Venous umbilical catheter projected at the height of the vertebral body T8. Arterial umbilical catheter with distal end at the height of the intervertebral space T12 and L1.

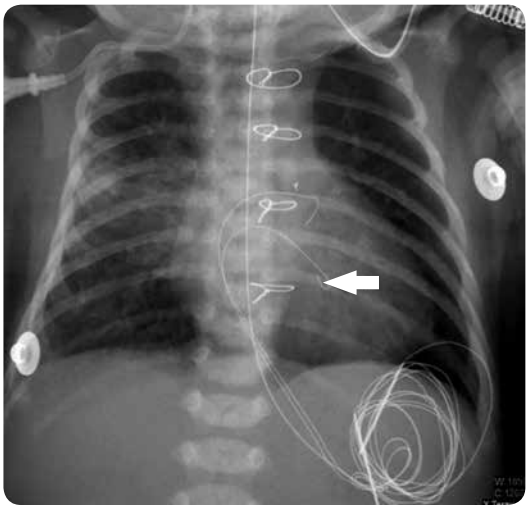

Figure 12. Sternal cerclage wires, surgical clips over the mediastinal region and epicardial pacemaker electrode by surgical antecedent. Right subclavian catheter with ascending jugular end.

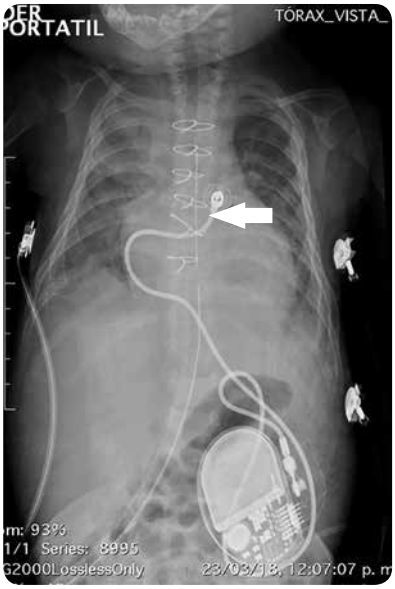

Figure 13. Pacemaker in abdomen, electrode indicates epicardial implant site.

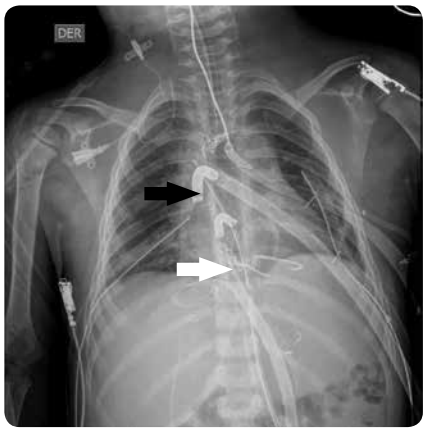

Figure 14. Arterial and venous connections by connection with ECMO. Orotracheal tube at the height of T3-T4. Right pleuromediastinal probe and bilateral thoracotomy. Right distal subclavian catheter with distal end in the right jugular vein.

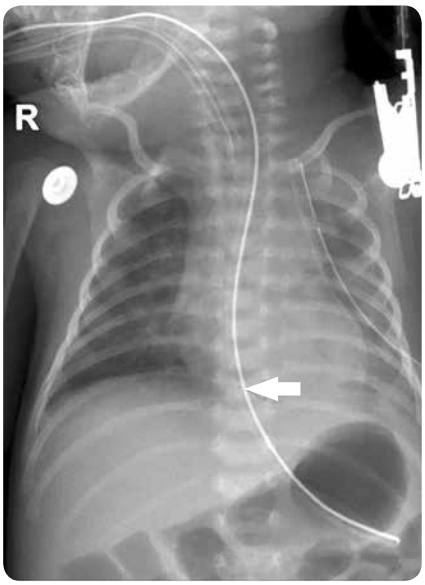

Figure 15. Drainage catheter in the left hemithorax with its distal end projected toward the apex. No signs of pleural effusion. Enteral probe towards the gastric chamber.

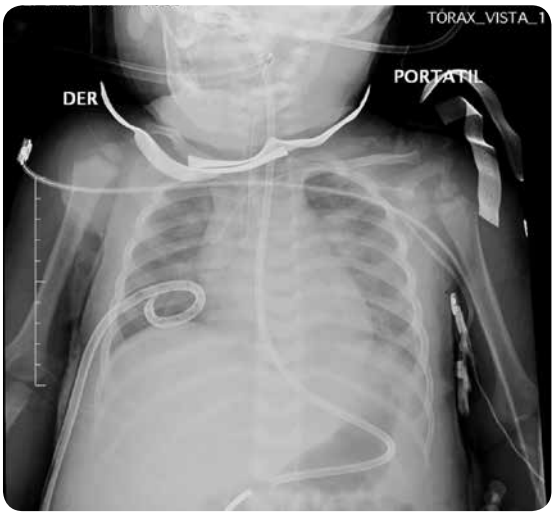

Figure 16. Esophageal catheter with postopyloric distal end. Pleural drainage catheter at the pulmonary base. Left PICC catheter with distal end in superior vena cava.

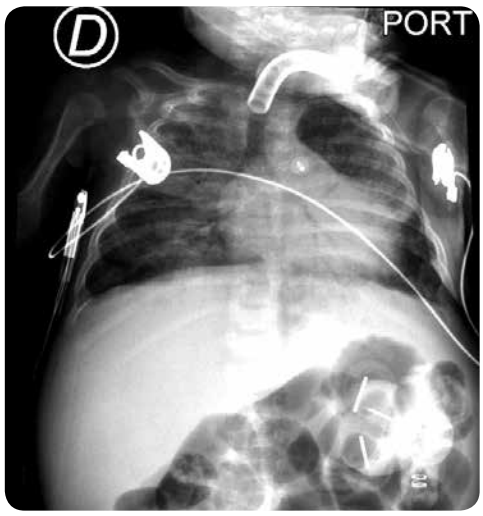

Figure 17. Gastrostomy probe projected in left hypochondrium, no signs of pneumoperitoneum.

2.6 Peritoneal catheter

Clinical indication

Peritoneal dialysis is indicated as the first option in infants and young children with vascular access difficulties, home away from the nearest hospital and hemodynamic and cardiovascular instability (34,35).

Absolute contraindications are abdominal wall defect, bladder extrophy, recent abdominal surgery and severe peritoneal membrane failure. Having an ostomy is not a contraindication, although it does increase the difficulty. Tenckhoff's catheter, the most used, has a straight or curved design, it has one or two dacron sleeves to facilitate its anchorage. Young children with low adipose panniculus have a higher risk of extrusion of the external cuff and single cuff catheters are preferred (36).

Radiological findings

In simple x-ray of the abdomen, the catheter is verified in its position: in men the rectovesical space is preferred and in women, in the Douglas sac (37) (Figure 1 1).

Complications

The obstruction causes catheter malfunction and poor renal clearance performance, clogging by fibrin or blood clots, catheter misplacement or migration; catheter outlet, subcutaneous tunnel or peritonitis infections. One way to verify is by fluoroscopic study, which can detect adhesions or malposition, such as paracolic or retroperitoneal location. Intestinal perforation could be evidenced by pneumoperitoneum (34).

2.7 Pacemaker

Clinical indication

Prevent sudden death and improve quality of life through diagnoses based on electrocardiographic findings (38).

Implants are used in patients with post-surgical atrioventricular (AV) block, complete congenital AV block, sinus node disease, and long QT syndrome (39-41).

Radiological findings

Intravenous pacemaker: The electrode is positioned with a gentle curve to avoid fracture and is tunneled subcutaneously to the subpectoral region.

Epicardial pacemaker: Helicoidal probes of 2nd turns and others of hook are visualized with frequency projected in the right atrium and less frequent in the ventricle. The generator is located in the abdominal region, behind the anterior rectus muscles of the abdomen or the obliques (Figures 12 and 13).

Complications

Hematoma of the introducer entry site, skin erosion at the tunnelling site, infection; in addition, sensing and capture failures may exist. Others, such as pneumothorax, hemothorax and arterial puncture, in addition, pain with stimulation (42).

Myocardial perforation is a rare complication, less than 1%, but potentially serious. In chest radiography the ventricular electrode is identified in an atypical position, projecting below the diaphragm (43). Twiddler syndrome is a rotation of the box along the longitudinal axis, due to improper handling, so that the electrodes are wound around the box and its displaced ends. If it rotates around the transverse axis it is known as Reel syndrome (44).

2.8 Extracorporeal membrane oxygenation (ECMO)

It is a form of prolonged but temporary support of cardiorespiratory functions in patients with reversible respiratory or cardiorespiratory disease (45).

Clinical indication

It is used in respiratory or cardiac failure refractory to conventional medical management. Examples of respiratory indications: respiratory distress, bypass for lung transplantation, pneumonia, asthmatic state and congenital diaphragmatic hernia. Examples of cardiac indications: cardiogenic shock, post-cardiotomy, bypass as a cardiorespiratory assistance device (46).

There are two types of ECMO: venovenous (VV), which is used only for respiratory support, does not provide hemodynamic support, and venoarterial (VA), which does provide hemodynamic support (47).

Radiological findings

ECMO VV may have a single lumen or two VV sites or one site and two lumens. In the two VV sites with only one lumen the reinfusion cannula reaches the right internal jugular vein and the drainage cannula reaches the common femoral vein.

The VA has a drainage cannula in the right atrium through the right internal jugular vein, the femoral vein or directly into the atrium and returns to the thoracic aorta through the cannula located in the right carotid artery, femoral artery or aorta.

Complications

Those derived from failure of the circuit, the oxygenator or ECMO equipment. Others, such as hemorrhage (surgical site, pulmonary, gastrointestinal), ischemic or hemorrhagic stroke, convulsions, cardiac dysfunction, renal failure, sepsis. Prolonged duration of ECMO support after pediatric cardiovascular surgery results in poorer postoperative outcomes (48) (Figure 14).

2.9 Orogastric or nasogastric tube

Clinical indication

The nasogastric tube is placed to feed or decompress the stomach contents. Enteral feeding is given by nasogastric or nasojejunal tube. In children younger than three months, the tube is placed orally so as not to make it difficult to breathe (49). The nasogastric feeding tube passes through the nasal fossa into the esophagus and has its distal end in the stomach. It is used in short-term feeding. The orogastric tube is also used in the case of fracture of the base of the skull, fracture of the bones of the face, nasal packing, deviated septum, patient undergoing esophageal or gastric surgery, administration of medications, gastric lavage, gastric emptying or resting (49).

Radiological findings

The course of the probe descends down the esophagus and should be located in the proximal portion of the gastric chamber, has an anterior curvature and to the left. When the probe is rolled up in the esophagus it is suggestive of esophageal atresia; if it is in the left hemithorax it may indicate diaphragmatic hernia (49,50) (Figure 15).

Complications

The probe may be lodged in the airway and cause bronchoaspiration, esophageal perforation during the procedure, as well as in the retropharynx or posterior thorax, especially in neonates (51-53). Others may be aspiration pneumonia and catheter obstruction (54).

2.10 Nasojejunal catheter

Clinical indication

This probe is placed distal to the pylorus. It can be located posterior to the pylorus or distal to the Treitz angle. The location immediately distal to the pylorus is the minimum required to avoid an increase in

gastric residue or frequent gastroparesis in critical patients. It improves the nutrition provided in comparison with the gastric feeding. The post-pyloric location or the one posterior to the Treitz angle do not have a significant difference (55). It is used to provide food, administer medications, ileus or delay gastric emptying, gastroesophageal fistula, pancreatitis (50) (Figure 16).

Complications

Plugging or displacement of the probe, erosion of the oesophageal mucosa, nasopharyngeal discomfort, diarrhoea, ulceration or necrosis due to pressure on the intestinal wall (56).

2.11 Gastrostomy

Clinical indication

Maintain enteral nutrition in patients with undamaged digestive system, but with swallowing problems, obstruction or other causes. It is only performed on those who require nutritional support for a period longer than 3-4 weeks (57-60).

Radiological findings

The gastrostomy tube is located in the anterior wall of the abdomen, with its distal end housed in the stomach or proximal jejunum. The existence of persistent or increasing pneumoperitoneum in a standing x-ray should always be a sign of suspected perforation (58,61) (Figure 17).

Complications

Peritonitis secondary to perforation during the procedure, catheter outlet, stoma light occlusion, gastrointestinal bleeding, aspiration pneumonia, stoma infection (57,61).

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