Survival Radiology: neonatal chest X-ray for residents.

Poster No.: C-2351
Congress: ECR 2015
Type: Educational Exhibit
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Keywords: Education and training, Education, Conventional radiography, Pediatric, Lung
DOI: 10.1594/ecr2015/C-2351

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Learning objectives

To describe the normal neonatal chest X-ray and particularities that may mimic cardiopulmonary disease.

To remember the importance of the collocation of tubes and catheters used in pediatric intensive care units and its complications.

To review the main causes of neonatal respiratory distress and its findings on radiographs.

Background

The neonatal period is an extremely important interval of time elapsed between birth and 28 days of age. It represents the time of the greatest risk to the infant and approximately 65% of all deaths that occur in the first year of life happen during this 4-week period.

In the first 24 hours of life occur the main physiologic adjustments needed for extraterine life being the aeration of the lung and the transition to air-breathing the most important events immediately after birth and they allow major changes in cardiopulmonary physiology.

An inadequate pulmonary adaptation is the most important cause of morbility in preterm neonates whose lungs usually are physiologically and morphologically immature and they may develop respiratory distress syndrome (RDS), being surfactant deficiency a frequently cause of it, and may necessitate prolonged mechanical ventilation, increasing the risk of lung injure with consequent bronchopulmonary dysplasia (BPD). All those abnormalities can be assessed by chest-X-ray.

Many of this newborns are monitored and treated in pediatric intensive care units (PICU) where tubes or catheters are used for treatment; the placement of them aslo can be evaluated by chest-x ray.

Due this important and critical period of time, it's essential make a quality report, mentioning if the chest x-ray is optimal, the position of catheters and signs of respiratory distress, keeping in mind that sometimes, normal varieties of the neonatal anatomy can mimic disease.
Findings and procedure details

1. NEONATAL CHEST X-RAY: NORMAL FINDINGS.

Sometimes the neonatal chest radiograph may strike fear into the heart of many radiology residents, especially if we are not used to work with newborn patients and we have no knowledge of their normal chest appearance. Furthermore, radiographs in the PICU are usually performed with portable X-rays and in a single view; consequently, many of them are not technically optimal and may difficult a proper diagnosis.

First of all, we have to assess if there is good inspiration or rotation because both can mimic pathology. A chest properly inspired usually has a trapezoidal morphology, with ribs horizontally disposed and parallel to each other, with cardiophrenic sinuses well delineated. Some authors also say that the anterior arch of the sixth rib is projected over the diaphragm (Fig.1). Any degree of rotation may simulate disease, such as cardiomegaly or an hyperdense hemithorax (Fig.2).

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**Fig. 1:** Characteristics of an optimal chest radiography.

**References:** Radiagnóstico, H.U La Fe. Valencia/ES
We should keep in mind that thymic configuration also may mimic disease and some signs are useful to identify its normal appearance (fig.3).

2. TUBES AND CATHETERS: THE IMPORTANCE OF ITS CORRECT POSITIONING.

The practice of neonatal intensive care usually requires the placement of tubes or catheters for treatment, nutrition, mechanical ventilation and to monitor blood gases and blood pressure. Some of them can be placed through an umbilical artery or umbilical vein, being the mouth the access to endotracheal and nasogastric tubes. It’s essential to ensure the correct positioning of them to avoid potential complications (Fig.4):

![Fig. 4](image)

**2. TUBES AND CATHETERS: THE IMPORTANCE OF THEIR CORRECT POSITIONING.**

2. Optimal levels:

- **Umbilical venous catheter.**
  - At the level of D9 (ICV)
  - Inferior hepatic border: L1-L2.

- **Catéter arterial umbilical (CAU).**
  - At the level of D6 (D5-D9) or L3-L5

**Origin of main arterial vessels:**
- Caeliac trunk: D12
- SMA: D12-D1
- Renal arteries: L1-L2
- IMA: L3
- Aorto-iliac bif.: L4

- **Endotracheal tube:**
  - 1.5 cm over the carina (with baby’s head midline).

**References:** Radiodiagnostico, H.U La Fe. Valencia/ES
There is disagreement about which is the correct position of the tip. Some authors suggest that the **umbilical venous catheter** should be placed next to the cavo-atrial junction, usually (but not always) at the level of ninth vertebral body (D9). An intracardiac placement may cause arrhythmias and even death in case of atrial wall perforation and cardiac tamponade.

Regarding **umbilical arterial** catheters, the level preferred is the sixth vertebral body (D6) or L3-L5, but sometimes the tip may be placed between D5 and D9. It's important to **avoid the origin of main arterial vessels**, whose levels are:

- D12 (level of coeliac trunk).
- D12-L1 (level of the superior mesenteric artery, SMA).
- L1-L2 (level of renal arteries).
- L3 (inferior mesenteric artery, IMA).
- L4 (aorto-iliac bifurcation).

Some newborns with respiratory distress syndrome may require an **endotracheal tube** which inserted via the mouth or nose into the trachea for mechanical ventilation. It should be placed **1.5 cm above the carina (with baby’s head midline)**.

### 2.1 Complications associated with catheters.

Complications associated to catheters are usually related with an abnormal positioning, although sometimes are inherent to the catheter. **Catheters inside an artery or into the portal vein may cause thrombosis** (Fig.5) or **portal cavernomatosis** (Fig.6).
Fig. 5: Complications associated with catheters. A) Incorrect umbilical arterial catheter in a 26 weeks preterm. The tip is placed in the left subclavian artery. B) Different patient with the tip of an umbilical catheter catheter into the right portal bifurcation with consequent portal thrombosis. (C). D) Aorto-iliac thrombosis in a newborn who came from other hospital and was monitored by arterial umbilical catheter.

References: Radiodiagnostico, H.U La Fe. Valencia/ES

Hepatic perfusion defects (Fig 7) and intra-hepatic collections are also described (Fig 8).
Fig. 8: Intrahepatic collection in a preterm who underwent an incorrect umbilical catheter placement.

References: Radiagnóstico, H.U La Fe. Valencia/ES

3. MAIN CAUSES OF NEONATAL RESPIRATORY DISTRESS.

Some preterm babies may have difficulties to adapt their respiration to extrauterine life because of an incomplete pulmonary maturation. The maturation deficiency is both structural and biochemical. Structurally, a preterm lungs have an incomplete development of the alveolar system and tracheobronchial airway.

The respiratory distress syndrome is strongly associated with the biochemical component, a surfactant deficiency, which is the most frequent cause of respiratory distress in the preterm. It is presented in the first few hours of life and symptoms include tachypnoea, expiratory grunting, nasal flaring.
Chest X-ray usually shows **bilateral and symmetrical ground glass opacities or granulated pattern with diffuse distribution.** Lungs are usually small and air bronchogram can be seen; These radiographic findings are usually present shortly after birth but they also may appear after 12-24 hours (**Fig.9**). If there is severe surfactant deficit, **both hemithorax may be opaque** (**Fig.10**). After surfactant therapy there may be asymmetric improvement.

**Fig. 9**: Chest X-ray on a 27 weeks preterm shows a diffuse bilateral granulated pattern likely due to surfactant deficiency which went worse within 24 hours. After endotracheal surfactant therapy there was progressive improvement.

**References:** Radiagnóstico, H.U La Fe. Valencia/ES

**Fig. 10**: Chest X-ray on a 27 weeks preterm shows a diffuse bilateral granulated pattern likely due to surfactant deficiency which went worse within 24 hours. After endotracheal surfactant therapy there was progressive improvement.

**Fig. 11**: Transient tachypnoea of the newborn (**TTN**), also known as retained fetal fluid, is related with neonatal tachypnoea for the first few hours of life, lasting up to one day. The tachypnea resolves by two days (**Fig. 11**). This is more common in babies delivered by caesarean due to lack of thoracic compression.
Fig. 11: Diffuse interstitial bilateral pattern in a newborn delivered by caesarean. This finding may be similar to surfactant deficiency but in his case is usual a rapid resolution some hours later.

References: Radiodiagnostico, H.U La Fe. Valencia/ES

Many babies with respiratory distress due to deficit surfactant (or any other etiology) may need excessive oxygen concentration and prolonged mechanical ventilation. Both therapies prolonged on time are a well known cause of bronchopulmonary dysplasia due to oxygen toxicity and barotrauma.

Initially, high levels of oxygen may cause capillary wall damage, with interstitial fluid seepage and pulmonary oedema, which allows the development of mucosal necrosis. Barotrauma due to positive mechanic ventilation sometimes entails alveolar damage. Both are followed by eosinophilic exudate, squamous metaplasia and final interstitial fibrosis.

The radiologic appearance depends on the grade of damage and fibrosis and are classified in four stages, being the third and the fourth the most serious with large lucent areas alternating with thin strands of increase opacity, an appearance that has come to be called "bubbly lungs" (Fig. 12 and Fig.13). Lungs are usually hyperinflated.
**Fig. 12:** 4/06/2013: Diffuse reticular pattern due to surfactant deficiency on a 24 weeks preterm who required mechanic ventilation for a long time. Endotracheal tube can be seen. 8/06/2013: Pulmonary hyperinflation and persistent reticular pattern with disperse small lucent areas. 24/7/2013: "Bubbly lungs" appearance after a month under mechanical ventilation.

**References:** Radiodiagnostico, H.U La Fe. Valencia/ES

Images for this section:
**Fig. 2:** Rotated chest X-ray may simulate cardiomegaly or hyperdense hemithorax (image on the left). New X-ray study in the same patient reveals no cardiopulmonary disease (image on the right).

1. **NEONATAL CHEST X-RAY: NORMAL FINDINGS.**

   **Thymus: normal appearance.**

   ![Thymus indentation sign.](image)
   ![Thymic wave sign.](image)
   ![Thymic sail sign.](image)

**Fig. 3:** Some signs are useful to recognize the normal appearance of the thymus on newborns.
Fig. 6: Complications associated with catheters: Two different patients developed portal cavernomatosis due to a catheter placement into the portal vein.
**Fig. 7:** Complications associated with catheters: Chest X-ray: 37 weeks preterm with umbilical venous catheter placed presumably at the right portal vein. B-mode ultrasound and Power Doppler images show a right portal vein thrombosis (yellow arrow) and a focal area of hepatic perfusion defect (red arrow).
Fig. 10: Chest X-ray on a preterm neonate who requires non-invasive intermittent oxygen therapy shows a severe case of distress respiratory with dense bilateral symmetric lung consolidation with effacement of the cardiomeediastinal and diaphragm contours. Air bronchograms are present. There is also an incorrect placement of umbilical venous catheter.
Fig. 13: Bronchopulmonary dysplasia: "Bubble lungs" appearance.
Conclusion

It's important to know about the normal appearance and variability of the neonatal radiograph and the main findings in respiratory disease. Furthermore, asseverate the correct placement of catheters is critical to avoid complications.

Personal information

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