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Chest X-ray in pediatrics. A systematic interpretation

Radiografía de tórax en pediatría. Una interpretación sistematizada

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ABSTRACT. Reading the chest radiograph requires training and repetition. The basic projections are: left lateral and posteroanterior. It is recommended to follow an order in interpretation: patient identification, projection, description of the technique (using the mnemonics GERICA), review of soft tissues, bony parts, diaphragmatic dome, mediastinum, cardiac silhouette and finally the lung parenchyma; all this considering the differences in pediatric age (changes in the technique by age group, bone variations, normal values of the cardiothoracic index, presence of thymus, etc.). All this will help us not to overlook any alteration and get the most out of this study, which is present in the daily life of every clinician.

Keywords: chest radiograph, pediatrics, interpretation.

RESUMEN. La lectura de la radiografía torácica requiere de entrenamiento y repetición. Las proyecciones básicas son: lateral izquierda y posteroanterior. Se recomienda seguir un orden en su interpretación: identificación del paciente, tipo de proyección, descripción de la técnica (mediante la nemotecnia GERICA), revisión de partes blandas, partes óseas, cúpula diafragmática, mediastino, silueta cardíaca y al final, el parénquima pulmonar; todo esto considerando las diferencias propias en la edad pediátrica (cambios en la técnica por grupo etario, variaciones óseas, valores normales del índice cardiotorácico, presencia de timo, etcétera). Esto ayudará a no pasar por alto ninguna alteración y obtener el mejor provecho de este estudio, el cual se encuentra presente en el día a día de todo médico clínico.

Palabras clave: radiografía torácica, pediatría, interpretación.

INTRODUCTION

Chest radiography is a usual diagnostic instrument in pediatric patient care that provides timely information, hence the importance of proper analysis and interpretation. It is commonly said, «A picture is worth more than a thousand words». An adequate exercise in radiographic evaluation can provide dynamic information derived from a static image.[1]

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Radiological technique

The routine radiological examination of the thorax makes two projections: posteroanterior (PA) and left lateral (L). They are performed with the patient standing or sitting, the PA at a focus-film distance of 1.8 meters, and the left side at 2 meters.

The correct exposure is achieved using kilovoltage peaks (kVp), ranging from 100 to 140, to reduce the radiation scatter index, visualize the bone structures with better density and, in turn, adequately identify the lung parenchyma and mediastinum. The image results from the sum of the passage of a polychromatic X-ray beam through an object that contains areas with different absorption coefficients, registering on the film the combination of the response to the intensity of the emitted light and the non-absorbed portion of radiation.[1-4] They are performed in maximum inspiration and in apnea.

In the chest X-ray, the mediastinal structures and the diaphragm overlap the lung parenchyma, so in a PA projection, we will have 40% hidden areas; therefore, a lateral projection is always recommended.[2-4]

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In patients with poor clinical conditions, infants, and uncooperative patients, frequent in the pediatric age, X-rays are taken in an anteroposterior projection (AP) and with portable equipment, with the drawback of obtaining images of low technical quality; since this projection is performed at a shorter focus-film distance, structures are magnified, and fewer sharp images are obtained.[5]

There are other radiological projections, such as expiratory radiography, which detects small pneumothoraxes and localized air trapping associated with foreign bodies, and the lateral decubitus projection with a horizontal beam that evaluates free fluid in the pleural cavity, among others.

Basic concepts and terminology

In conventional radiology, we have five densities: air, fat, water, calcium, and metal *(Figure 1)*.

Remember, **radiolucent** is any object, organ, or tissue that allows light to pass through it and translates as dark shades. While **radiopaque** is any object, organ, or tissue that does not allow the passage of light or puts resistance to the passage of light on it and translates as light shades in the radiological image.

Interpretation

There should be a systematized analysis in the interpretation of thoracic radiography. We suggest the following order:

1. Patient's name and date.
2. Projection.
3. Technique (GERICA).
4. Soft parts.
5. Bony parts.
6. Diaphragmatic dome / costophrenic and cardiophrenic angles.
7. Mediastinum (carinal clarity, bronchi, thymus, hilar).
8. Cardiac silhouette.
9. Pulmonary parenchyma.
10. Pleura.

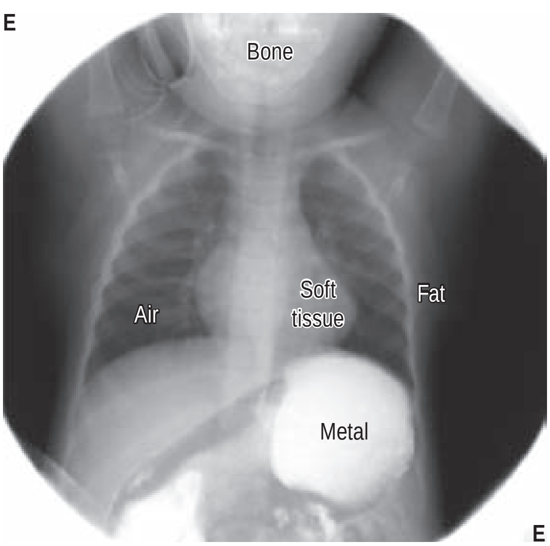

Figure 1: Radiological densities.
Image property of the author.

All radiological projections, including the lateral one, are interpreted in the same order.

1. Patient's name and date. First and essential step. On a printed radiograph, these data are found pointing to the patient's right side.
2. Type of projection.
3. Technique. Interpretation of the technical quality of the radiograph. The points to interpret are:

GE: degree of exposure.
R: rotation.
I: inspiration.
C: complete.
A: artifacts.

We propose the GERICA mnemonic to remember them during the interpretation.

a. Exposure degree (GE): the thoracic spine should be visualized through the cardiac silhouette. If the film is underexposed, the diaphragm and lung bases will not become visible. The digital technique allows processing to adjust the exposure. A shorter exposure time will have a whiter appearance (underexposed). The longer the exposure time, the blacker (overexposed) will be appreciated. Avoid saying: burnt, soft, hard, black, or white.
b. Rotation (R): to determine whether the plate is rotated, the following methods are suggested: 1) measure the distance between the vertebral spinous apophyses and the medial ends of both clavicles, which should be equidistant;[3] 2) measure in both hemithoraxes the distance between the most medial portion of the anterior costal arches and the lateral contours of the spinal column.[6]
The rotated side is the one that approaches the film. It does not matter if the projection is AP or PA.
c. Inspiration (I): the degree of inspiration will be adequate if the diaphragmatic dome or the cardiophrenic angles are projected over the seventh and eighth intercostal space or ninth posterior costal arch or, failing that, fifth or sixth anterior costal arch (eighth and fifth, respectively, in the neonate).[2,7]

The importance of adequate inspiration lies in the fact that the pulmonary structures are grouped in an exhaled radiograph and can simulate an alveolar lesion.[3]

d. It must be verified that the radiological image is complete (C); for this, the larynx and both costodiaphragmatic angles must be observed,[2] as well as the soft parts of the costal grill in its totality.
e. If artifacts (A) are present (probes, cannulas, catheters, etc.), they must be identified and described in the technique since they translate the degree of severity of the patients, and their clinical conditions, in addition to avoiding any interpretation error.

Radiological description

It is suggested to start with the parts from the least to the most interesting to avoid overlooking minor alterations.

4. Soft parts. The skin, subcutaneous tissue, muscles, and breasts make up the soft tissues of the rib cage and will behave like fat density. Intentionally look for emphysema, tumors, asymmetries, etcetera.[2]
5. Bone structures. Carefully observe the vertebrae and each of the ribs, looking for lesions. The morphology of the child's thorax changes as it grows. Thus, the thorax of the neonate has a trapezoidal morphology and horizontal ribs. In contrast, the thorax of the older child acquires the rectangular morphology typical of adults, with a larger vertical diameter.
6. Diaphragmatic dome/costodiaphragmatic and cardiophrenic angles. In 90% of the population,[6] the right diaphragmatic dome is usually about 2 to 3 cm higher than the left.[2] The continuity of the diaphragm should be visible in both AP and PA and lateral views. The costodiaphragmatic and cardiophrenic angles under normal conditions are acute and nearly symmetrical.
7. Mediastinum. It is an opaque region where we cannot differentiate the structures that make it up since most have water density and lose their limits between them. In a PA projection, the right mediastinal border from top to bottom is formed by the superior vena cava, right hilum, and part of the cardiac silhouette corresponding to the right atrium. The left subclavian artery, aortic button, left hilum, left atrial appendage, and left ventricle are on the left profile.
   a. Trachea: it is observed as a column of air between 5 and 7 cm at the level of T4 in infants and between 10 and 12 cm at the level of T5 in children older than three years. The diameter of the trachea remains constant, and its walls are parallel. It is common for children under five to observe lateral deviations due to their great flexibility. This physiological deviation is generally directed to the right, contrary to the direction of the aortic arch.[7]
   b. Bronchi: the left-side main bronchus is longer, and its bifurcation is greater than the right-side main bronchus, which is short and rapidly bifurcates into its lobar branches and is located behind the right pulmonary artery. This translates as bronchial situs solitus.[8]
   c. Thymus: it is an organ of soft tissue density, which projects to both sides of the superior mediastinum towards the fourth chondrocostal cartilage approximately. It may be visible in children under three years of age.[2] The radiological signs described are:
      - *Wave sign:* produced by the imprinting of the ribs on the thymus, visualized as a ripple.
      - *Sail sign:* homogeneous triangular radiopacity of the right and sometimes left side, with the major base adjacent to the mediastinal alignment and the apex downward and outward, like a ship's sail *(Figure 2)*.[2]
      - *Convergence sign:* the thymus covers the upper part of the cardiac silhouette like a cap, determining at the point of convergence of the two a notch on the right side, the left side, or both.
      - *Hilar overlay sign:* in marked hypertrophy of the right lobe of the thymus, the cardiac border and the structures of the right hilum can be seen through the thymic opacity.[2]
   d. Hilia: they form water density.[6] In 97% of cases, the left hilum is taller than the right one.[2]
8. Cardiac silhouette. For the evaluation of cardiac size, the cardiothoracic index *(Figure 3)* has been used, which has

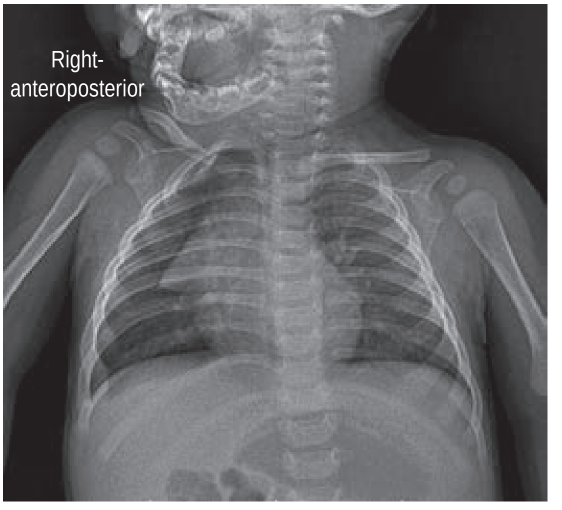

Figure 2: Sign of the thymic sail.
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different normal values by age group *(Table 1)*;[9-11] however, these measurements vary significantly between patients and in the projections since the AP projection magnifies the cardiac silhouette, giving an erroneous result, and should therefore be taken with reservation.[7,8]

9. Pulmonary parenchyma. The pathologic conditions that produce changes in the density of the lung parenchyma can be divided into those involving the alveolus, the interstitium, or both.[6] For its description, we will classify it in radiographic patterns:
   a. Alveolar pattern: the air in the alveoli is occupied by fluid, inflammatory exudate and/or cells, transudate, blood, or tissue. Radiological features include radiopaque images with a tendency to coalesce, cottony appearance at the edges, and lobar distribution.[4,6]
   In alveolar involvement, the bronchi remain aerated (radiolucent) and surrounded by consolidated parenchyma (radiopaque), and this conjunction of images evidences the bronchus and corresponds to the air bronchogram sign.
   b. Interstitial pattern: caused by diseases that affect the interalveolar septa involving the interstitial connective tissue and pulmonary capillaries without affecting the alveolar space. There are diverse ways of description through the following patterns:[7,12,13]
      - *Reticular pattern:* refers to multiple tiny radiopaque lines crisscrossing at various angles to create a lattice pattern.[13]
      - *Nodular pattern:* described as the presence of well-defined rounded radiopaque images of diffuse bilateral distribution, micronodular images are defined as those with a diameter of less than 5 mm, and macronodular images as those with a 5 to 3 cm diameter. The miliary pattern refers to diffuse bilateral symmetrical diffuse micronodular images of the same density and is generally related to tuberculosis with lymphohematogenous dissemination.[14]
      If an area of focal consolidation has well-defined borders and is larger than 3 cm, it is called a «mass». If it measures less than 3 cm, it is called a «nodule».[3]
      The reticulonodular pattern is a combination of both.
      Honeycomb pattern: it is characterized by the presence of thick reticular opacities, with interposition of clarities resembling cystic spaces. It represents the last stage of cicatrization.[12]
      - *Unpolished glass:* corresponds to a faint increase in density that does not hide the pulmonary vasculature but with poor definition of the vessel margins.[6]
   c. Atelectasis: it is described as an opacity of homogeneous character that presents a triangular image of a well-delimited border with medial or internal vertex and external base. For its identification, there are direct and indirect signs:

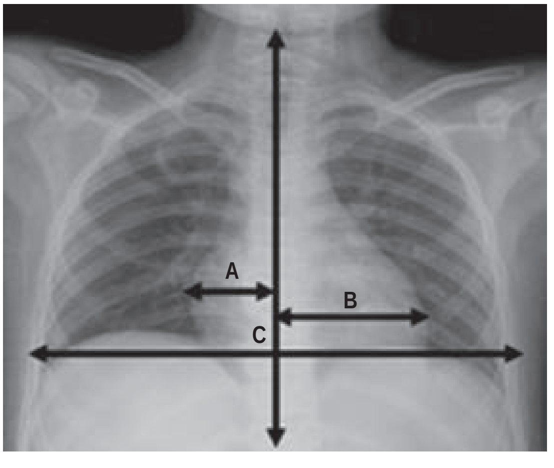

Figure 3: Cardiothoracic index measurement method. «A» is equal to the distance between the outermost part of the right cardiac border. «B» is equal to the distance between the outer part of the left heart border; the sum of A + B is divided by the diameter of the thorax at its widest point at the level of the diaphragms «C».
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Table 1: Cardiothoracic index (CT) values at pediatric ages.[9-11]

Age	CT index	Range
0-3 weeks	0.55	0.45-0.65
4-7 weeks	0.58	0.46-0.70
1 year	0.53	0.45-0.61
1 a 2 years	0.49	0.39-0.60
2-6 years	0.45	0.40-0.52
7 years	< 0.50	0.40-0.50

Direct

1. Displacement of the fissures is the most reliable sign.
2. Clustering of pulmonary vessels or bronchi.
3. Loss of aeration (radiopacity).

Indirect

1. Elevation of the hemidiaphragm on the affected side.
2. Tracheal deviation towards the affected side.
3. Retraction of the heart towards the area of injury.
4. Narrowing of the intercostal space in the affected area.
5. Hilar retraction towards the area of injury.
6. Compensatory hyperinflation of adjacent lobes.[6,12]

d. Hyperclarities: they can be generalized or diffuse and localized. They correspond to two types of involvement: an increase in the size of the alveoli or their number and the absence of lung parenchyma, constituting cystic images or cavities.[2]
Cavities are limited by an opaque ring surrounding an area in which there are no alveoli and, according to their pathogenesis, can be classified into three:
Bullae: thin-walled cavities, single or multiple, which are characterized by varying shape, size, and location from one examination to another; they appear in sequels of abscesses, caverns, pneumonia, trauma, etc.[2]
Bullous pneumonia: characterized by the formation of a type of bulla called pneumatocele, formed by air leakage with cavity formation within a pneumonic process. They lack hydroaerial levels.[2]
Blebs or subpleural bubbles: small subpleural cavities located at the apexes, whose rupture can cause spontaneous or recurrent pneumothorax.[2]
e. Caverns and abscesses: thick-walled cavities with pericavitary condensation and, sometimes, liquid level. Unlike pneumatoceles, they are produced by necrosis of lung parenchyma, either from liquefaction (lung abscess and necrotizing pneumonia) or caseous (tuberculous cavern) and subsequent emptying of the cavity, for which they have a drainage bronchus. Pericavitary condensation happens because they always occur within pneumonia. The tuberculous cavern usually has a smooth internal border and low liquid level, and the abscess has an irregular inner border with a notable hydroaerial level.
f. Cysts: cavities of thick and uniform walls, surrounded by healthy parenchyma, and that do not vary in time or do so very slowly. If they have suffered complications, they may be empty or have a hydro-aerial level. If they are filled with liquid content, they have the appearance of a mass. They can be congenital, like the bronchogenic cyst, or acquired, like the hydatid cyst.

10. Radiological signs of pleural alteration.
a. Pleural effusion: free pleural fluid in the standing position tends to be in the posterior and lateral costophrenic angles, so they are more evident in the lateral projection; they lose their normal shape and are effaced *(Figure 4)*.[3]
If there is more fluid ascending through the pleural space, a meniscus is formed. Pleural fluid is often seen ascending through the greater fissure in the lateral projection; requesting a lateral decubitus projection with a horizontal beam is recommended, remembering that the affected side should be down.[3]
If a radiopaque hemithorax is found displacing the mediastinal structures, it is a pleural effusion or a tumor. If there is no displacement, it may be atelectasis.
b. Pneumothorax: radiological findings are peripheral hyperlucency (intrapleural air), visceral pleural line or border, and absence of peripheral vascular raster.[3] Pneumothoracic tension compromises pulmonary venous return and is a medical emergency. The three radiographic signs that indicate a tense pneumothorax are collapsed lung, descent of the hemidiaphragm, and contralateral mediastinal shift. The intercostal spaces on that side may be separated.[3]
There is no unification on the method for quantifying the size of the pneumothorax. Some established definitions are: small pneumothorax when the distance between the pulmonary apex and the thoracic dome is less than 3 cm.[15] On the other hand, the British Thoracic Society differentiates pneumothorax into small or large based on the presence of a band of air < 2 or > 2 cm, respectively, between the pulmonary border and the thoracic wall.[16]
The Rhea and Light criteria, illustrated in *Figure 5*, have been described in numerical terms to quantify pneumothorax.[17,18]

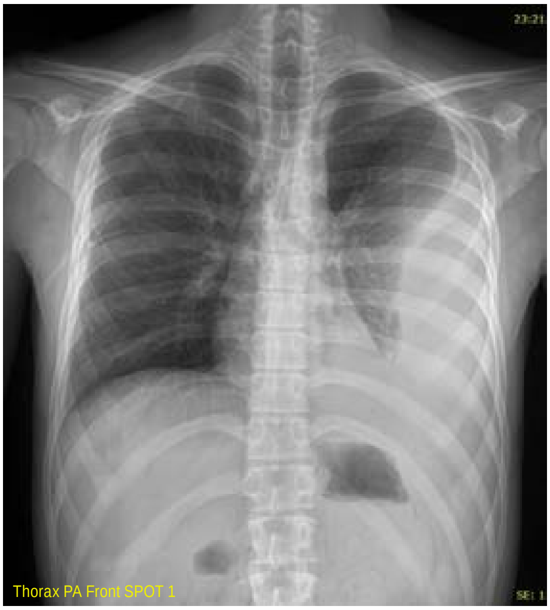

Figure 4: Left pleural effusion. Homogeneous radiopacity is observed in the left basal region, with erased costodiaphragmatic and cardiophrenic angles. Image property of the author.

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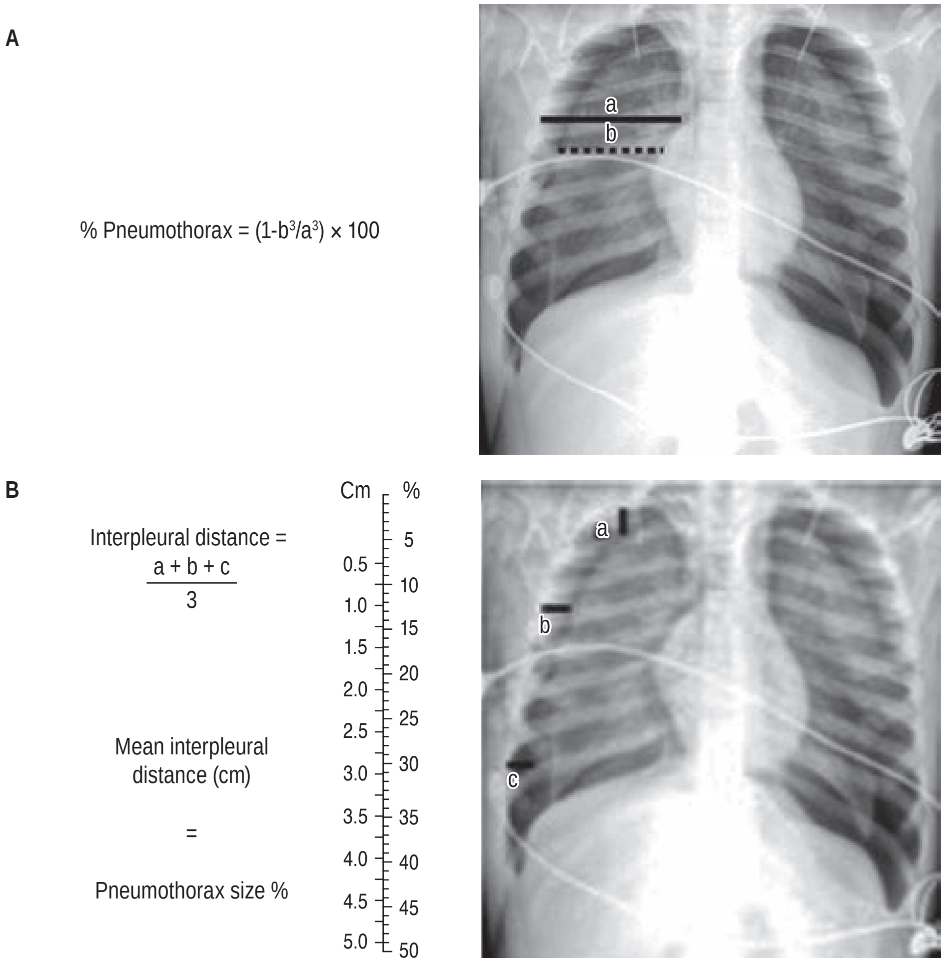

Figure 5:

Methods for calculating the size of the pneumothorax. **A)** Light's method. **B)** Rhea's nomogram.[17,18] The results represent the percentage of pneumothorax.
Images modified by the author.

CONCLUSIONS

Chest radiography is a particularly useful tool in the study of many pediatric pathologies and is part of the initial evaluation. Its proper interpretation can be the starting point in the suspected diagnosis. It is essential that it is performed systematically and that the differences inherent to the pediatric age are considered.

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