43 Neonatal Chest X-Ray

Introduction

The chest X-ray is the most frequently ordered radiological investigation in NICUs. It should ideally be performed in the ICU using a portable X-ray equipment. In most cases, an anteroposterior view of the chest would provide sufficient diagnostic information. Lateral chest and abdomen views should be included only when there is a clinical indication.

Indications

The indications for ordering a chest X-ray include:

1. For evaluating the initial cause of respiratory distress
2. For suspected cardiac or pericardial disease
3. To check position of endotracheal tube, umbilical venous or arterial lines, peripherally inserted central catheters or chest tubes
4. For evaluating the cause of worsening respiratory distress in a ventilated neonate after ruling out mechanical problems (tube block/secretions/dislodgement) or ventilator dysfunction

Some conditions where X-rays are *not* indicated include:

1. Routine / daily X-rays in ventilated neonates
2. Routine pre/post extubation X-rays
3. After re-intubation in a neonate where the optimal "tip-to-lip" distance is known based on initial X-ray
4. Evaluation of an isolated episode of desaturation/ apnea
5. Routinely before/after giving surfactant
6. Transient / mild respiratory distress (<4 hr) after birth

Interpretation

While describing an X-ray, the following observations need to be made:

- Projection (AP vs PA film)
- Exposure (hard vs soft films)

- Rotation
- Soft tissue/bones
- Lungs:
  - Expansion
  - Parenchymal appearance – lucency, nature of opacities, fissure
  - Cardiac and diaphragmatic margins
- Cardiac:
  - Cardio thoracic ratio/ cardiac size
  - Pulmonary vascular markings
  - Specific chamber enlargement

Projection

The following features distinguish AP from a PA film:

- In PA films, the scapulae lie postero-laterally and are away from the lung fields, whereas they tend to overlap the lungs in AP films
- Due to its anterior placement, the heart appears larger in AP rather than a PA film
- The cervico-thoracic vertebral end plates are tangential to the AP projection beam, making them prominently seen in AP view, while the lamina appear more prominent in PA view
- The ribs appear to be more horizontally placed in AP view

Practical tip: Most neonatal chest X-rays are AP films, unless the baby is made to lie prone

Exposure

- Lucency of soft tissue shadow - darker the soft tissue, more is the exposure
- Ease of visibility of retrocardiac vertebrae – if the retrocardiac vertebrae are easily seen, the film is over exposed
- Relative lucency of lung fields
- When long bones appear to disappear, it is over-exposed film

Rotation

The chest X-ray is rotated if

- The distance of the anterior ends of ribs from the midline of spine are unequal on either side. The film is rotated to that side on which the distance appears greater
- Medial end of clavicles are not equidistant from the midline

The first criterion is usually more helpful as the lower chest tends to be rotated more commonly than the upper chest, as the latter is usually stabilised at the time of taking X-rays.

Usually the side to which the chest is rotated appears more hyperlucent than the other and hence should be interpreted with caution.

Soft tissue/bone

The importance of carefully looking at the bones cannot be over-emphasised, especially for picking up changes of osteopenia and fractures.

Thymus - normal and abnormal

The thymus may create some challenges in the interpretation of neonatal chest X-rays. One needs to differentiate its normal from abnormal appearance.

Normally, thymus appears as a bilateral smoothly outlined superior mediastinal shadow blending with the cardiac silhouette. Some normal variants of thymus:

- "Notch sign" - uniform enlargement of thymus on both sides with prominent notch on inferior left border (corresponding to the junction of inferior aspect of normal thymus gland and cardiac silhouette)
- "Sail sign"- Characteristic sail like border of normal thymus, more commonly seen on right side
- "Wavy thymus sign"-Undulating waviness of the lateral border of thymus due to indentation of ribs

Interpretation of lung fields

Lung expansion

Normal lung expansion: Up to 6 ribs anteriorly and 8 ribs posteriorly. This follows the normal position of the diaphragm

between 5th and 7th anterior ribs
The radiological features of hyper-expansion are:
1. Presence of more than 6 ribs anteriorly and 8 ribs posteriorly
2. Flattening of diaphragm
3. Increased lucency of lung fields (blackness)
4. Air under the heart/ herniation of lung to opposite side
5. Ribs more horizontal

However, the evaluation of lung expansion by counting the number of ribs (or intercostal spaces) above the diaphragm can be tricky in newborns due to two reasons:
1. This technique represents the expansion in two dimensions only. But newborns, unlike older infants and children, have highly compliant thoracic cage, which can easily expand in the antero-posterior dimension as well.
2. Lesser diaphragmatic excursions occur during inspiration in neonates as compared to older children

Characteristic appearance of common disease conditions

Respiratory distress syndrome (RDS)

The condition is caused by the deficiency of surfactant production by type II alveolar cells, which results in alveolar collapse with overinflation of larger alveoli and resultant transudation of proteinaceous fluid into alveoli, creating the classical hyaline membranes. The radiological features of the condition are
- Under-aerated lungs
- Reticulo-granularity (presence of air in the distended terminal bronchioles and alveolar ducts against a background of alveolar atelectasis)
- Air bronchograms-with progress of disease, more and more distal airways collapse, leaving the proximal bronchi standing out as air bronchograms. Note that air bronchograms may be absent in an expiratory film
- Diffuse granularity
- In severe cases or in expiratory films, these findings may be replaced by white-out lungs due to diffuse alveolar atelectasis

The severity of RDS has been classified based on radiological findings as follows:

Mild: Normal/ decreased aeration, reticulo-granularity

Moderate: Decreased aeration, air bronchograms and indistinct diaphragm and heart borders

Severe: Confluent opacification of lungs with loss of mediastinal and diaphragmatic borders ('white-out')

RDS mimickers: A few congenital heart disorders such as total anomalous pulmonary venous connection (TAPVC), pulmonary vein atresia and hypoplastic left heart syndrome by producing interstitial pulmonary edema can mimic the granular pattern seen in RDS.

Transient tachypnea of newborn (retained fluid syndrome)

This is a condition resulting from the delayed clearance of fetal lung fluid, overloading the interstitium, lymphatics and cardiovascular system. X-ray picture is characterised by

- Prominent hilum with perivascular streaky shadows
- Prominent interlobar fissure (horizontal fissure)
- Small pleural effusion
- There may be mild cardiomegaly
- Normal to increased lung volume

Radiographic findings usually resolve in 12-24 hours

Pulmonary interstitial emphysema (PIE)

It is caused by the dissection of air from alveoli into the parenchyma and interstitium of lungs and perivascular sheaths of vessels, tracking towards the hilum. X-ray appearance is characterised by

- Radiolucent streaks- linear or irregular, branching/ cystic spaces (honeycomb like) or pneumatoceles; seen radiating from the hilum towards the periphery of the lung
- PIE may present with linear or cystic changes. Linear lucencies of PIE may be differentiated from air bronchograms in that the latter are generally smooth and branching, in contrast to interstitial air which is coarser and non-branching

Pneumothorax

This results from the dissection of extra-alveolar air to the hilum, followed by rupture into pleural space. Increased radiolucency of the ipsilateral lung and sharpness of mediastinal border are the earliest signs of pneumothorax. The characteristic X-ray findings are:

- Clear border of collapsed lung
- Absent lung markings beyond the collapsed lung border (this differentiates pneumothorax from vertical skin folds)
- May or may not be accompanied by mediastinal shift
- Herniation of the pneumothorax bounded by parietal pleura into the contralateral side

Pneumomediastinum

Presence of air adjacent to the heart outlining the thymus and elevating it. The thymus is compressed by pneumothorax, whereas it is elevated by pneumomediastinum.

Meconium aspiration syndrome (MAS)

The radiological appearance may range from hyperexpansion to collapse:

- Gross hyperexpansion of lungs
- Bilateral coarse patchy nodular opacities (this represents areas of focal alveolar atelectasis with focal alveolar overdistension in between)
- Sometimes, a large piece of meconium can obstruct the bronchus leading to emphysema of one lung/lobe and compression of the other lung

Pneumonia

- The radiological picture is variable and may range from reticulo granularity to lobar or segmental consolidation
- Asymmetry of reticulogranular pattern with air bronchograms may be seen
- Coarse granular patchy infiltrates with irregular areas of hyperinflation

Pleural effusion

- Detected by the blunting of lateral costophrenic angle (only

in erect film)
- In supine radiographs, there is decreased transradiancy of the lung with preserved pulmonary vascular markings
- If enough fluid is present, it is seen as a peripheral band separating the lung and lateral chest wall

Bronchopulmonary dysplasia (BPD)

The radiological appearance is variable and depends on the postnatal age (Northway, et al):

Stage I (2-3 days)-Air bronchograms, reticulo-granularity (similar to RDS)
Stage II (4-10 days)- Opacification; coarse irregular densities
Stage III (11-20 days)- Small generalised radiolucent cysts
Stage IV (1 month)- Dense fibrotic strands, generalised cystic areas, hyper-inflated lungs

Three types of bubbles in chest X-ray

***Type I bubbles*:** Seen in RDS
Small and uniform, rounded
1-2 mm in diameter
More prominent in lung bases
Due to overdistension of the terminal airways
Become less pronounced on expiration

Type II bubbles: Seen in pulmonary interstitial emphysema (PIE)
Nodular and tortuous in shape
2-3 mm in diameter
Peribronchial and perivascular in location
Do not empty on expiration

Type III bubbles: Larger than the first two types of bubbles
Irregular shaped
Seen in focal hyperaeration syndrome, eg. bronchopulmonary dysplasia
Also become less pronounced on expiration, like type I bubbles

Congenital diaphragmatic hernia: Bochdalek defects present with a well defined dome shaped soft tissue opacity usually on the left chest. They are dynamic in nature and may "come and go" in serial films. Importantly, intestinal loops may be gasless in the first few hours of life with the herniated abdominal contents appearing as an opaque mass with ipsilateral lung hypoplasia and contralateral mediastinal shift. The classical appearance of gas filled loops in the chest may appear only few hours after birth.

Morgagni hernias are seen as opacities adjacent to the right costophrenic angle.

Tracheoesophageal fistula (TEF)

A soft rubber tube is better than an infant feeding tube for the radiological diagnosis of TEF. The X-ray shows coiling of the tube in the upper esophagus. If one desires to delineate the extent of gap between the upper and lower pouch, a lateral X-ray is preferable. Absent stomach gas suggests associated esophageal atresia.

Interpretation of the cardiac shadow in X-ray

The most important features to be noted are:

- Cardiac size
- Pulmonary vasculature
- Shape and size of different chambers/ cardiac situs

Cardiac size

This may be assessed simply by measuring the cardiothoracic ratio (CT ratio). CT ratio is the largest transverse diameter of the heart divided by the maximum internal diameter of the chest.
A CT ratio of more than 0.6 suggests cardiomegaly in newborns.

Pulmonary vasculature

Normally it is difficult to appreciate pulmonary vascular markings in the lateral third of the lung fields as well as in the lung apices.

Increased pulmonary vascularity is said to be present when the pulmonary vessels are seen in the lateral third of the film, or in

the lung apices, or if the right pulmonary artery which is visible in the right hilus appears wider than the trachea.

Decreased pulmonary blood flow/PBF (oligemia) is diagnosed by the relative blackness of lung fields with small lung hilum.

Causes of decreased PBF	Causes of increased PBF
Tricuspid atresia Ebstein's anomaly Pulmonary stenosis (PS) Tetralogy of Fallot Pulmonary atresia Persistent truncus (type IV) Eisenmenger syndrome	Acyanotic: Ostium primum/ secundum ASD Ventricular septal defect Patent ductus arteriosus Cyanotic: Admixture lesions without PS Transposition of great Total anomalous pulmonary venous drainage Persistent truncus arteriosus Single ventricle

Specific chamber enlargement

In an AP view, the right heart border is formed from above downwards by superior vena cava (SVC), ascending aorta (AA), right atrial appendage (RAA), and the right atrium (RA). The left heart border is formed by the aortic arch (AoA), main pulmonary artery (PA), left atrial appendage (LAA), and the left ventricle (LV). This forms the basis for diagnosing various chamber enlargements. Note that the right ventricle (RV) does not contribute to either of the borders and usually presents with an upturned apex, when enlarged. Left atrial enlargement results in splaying of the carina, straightening of left heart border and double left heart border appearance.

Specific x-ray picture in congenital heart lesions

Heart lesion	X-ray picture
Ventricular septal defect	Prominent pulmonary vascular markings, left atrial and ventricular enlargement
Patent ductus arteriosus	Prominent main pulmonary artery, left atrial and ventricular enlargement
Coarctation of aorta	"Reverse 3 sign" along the upper left heart border-hypoplastic aortic knob along with left ventricular prominence; inferior rib border notching

contd....

Tetrology of fallot	"Coeur en sabot" (boot shaped) heart – caused by a small pedicle (atretic PA) with a upturned apex due to RV hypertrophy; pulmonary oligemia
Transposition of great arteries	"Egg on side" appearance due to the narrow pedicle created by the parallel orientation of aorta and pulmonary artery
Truncus arteriosus	Narrow pedicle, frequently accompanied by absent thymus
Total anomalous pulmonary venous connection (supracardiac)	"Snowman" appearance caused by the dilated vertical vein, innominate vein and SVC, pulmonary plethora

Line positions

Umbilical arterial line

- High: Between T6 and T9 thoracic vertebrae
- Low: Between L3 and L4 vertebrae

Umbilical venous line: 0.5 cm to 1 cm above the diaphragm

Endotracheal tube tip: T1 or T2; atleast 2 cm above carina (Note: position of the baby's head and neck may alter ETT position)

Percutaneous central line (PICC): When inserted from upper limb, the line must have crossed the first rib and passed medially, with the tip lying between T3 and T6 vertebrae.

Practical tips

While doing an X-ray

- Follow aseptic precautions. Adequate hand hygiene is a must for all including the radiographer
- Always make note and discuss the exposure settings with the radiographer in order to optimise image quality. A rough guide is to use 30-50 kV and 4-10 mA
- Avoid direct contact of the X-ray plate with the baby to prevent hypothermia. Always place the X-ray plate in the separate tray meant for that purpose
- In small babies, beware of hypothermia as the radiant warmer is tilted away during the X-ray and provide extra

heat source if necessary. X-ray can be done through an incubator safely

- Instruct health care providers to wear lead apron themselves and use gonad shield for the baby. Safe distance for health care professionals when a x-ray is being filmed in order to prevent radiation hazard is not clear
- Expose only the area of interest and remove chest leads, tubings, etc. from the field
- Make sure the baby is not rotated
- As far as possible, quieten the baby to avoid swings in respiratory depth

While reading an X-ray

- Read schematically; jumping to the diagnosis may entail the risk of missing additional details
- Correlate findings with clinical details
- Make note of age in hours/ days, serial sequence number and interventions done before (such as surfactant administration) and after the X-ray (pulling out a deeply placed endotracheal tube)
- Use of a view box and magnifying glass is ideal

References

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