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Lung Ultrasound versus Chest X-ray for Diagnosing Pulmonary Disorders in Neonatal Age Group: Review Article

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ABSTRACT

Background: Neonatal respiratory conditions can arise for several reasons: delayed adaptation or maladaptation to extra-uterine life, existing conditions such as surgical or congenital anomalies, or acquired conditions such as pulmonary infections occurring either pre- or post-delivery. Respiratory conditions are the most common reason for admission to a neonatal unit in both term and preterm infants. The most common respiratory disorders include respiratory distress syndrome, pneumothorax, pneumonia, pulmonary hemorrhage, aspiration, pleural effusion, transient tachypnoea of the newborn, meconium aspiration, primary or secondary persistent pulmonary hypertension, congenital pulmonary airway malformation, congenital diaphragmatic hernia, tracheoesophageal fistula, choanal atresia, pulmonary sequestration, and congenital lobar emphysema.

Objective: This review article aims to evaluate the role of lung ultrasound (LUS) versus chest X-ray (CXR) for diagnosing pulmonary disorders in the neonatal age group, with a focus on identifying the most effective imaging modality.

Conclusion: Chest imaging with X-ray (CXR) has high diagnostic potential in some disorders, such as respiratory distress syndrome in neonates. This technique also has the potential to assess the treatment response and evaluate the complications following treatment. No single imaging modality is superior for all neonatal respiratory conditions. CXR remains the standard for initial evaluation, while LUS is becoming a preferred choice for dynamic, bedside assessment. CT is valuable for complex or congenital cases where detailed imaging is crucial. The integration of these modalities ensures optimal care, guided by clinical context and radiological expertise.

Keywords: Lung Ultrasound; Chest X-ray; Pulmonary Disorders; Neonatal.

INTRODUCTION

Respiratory distress is the most frequent cause of neonatal intensive care unit (NICU) admission, requiring individualized management strategies as a primary focus. Significant respiratory morbidity occurs in 15% of term infants and 29% of late preterm infants admitted to NICU, with even higher rates in those born before 34 weeks' gestation [1].

Respiratory distress, characterized by signs such as tachypnea, nasal flaring, retractions, bilateral and equal air entry, abnormal breath sounds, and cyanosis, should be carefully evaluated through inspection, auscultation, and non-invasive pulse oximetry as recommended by the American Heart Association. Although chest X-ray plays a key role in diagnosis, it exposes neonates to ionizing radiation, putting their sensitive tissues at greater risk. Lung ultrasound (LUS) has emerged as a promising, safer diagnostic tool, providing accurate detection of neonatal respiratory distress syndrome (RDS) and other pulmonary diseases. Increasingly used in critical care, ultrasonography enables real-time visualization of chest anatomy and artifacts like B-lines, indicative of interstitial lung diseases, while differentiating between dry, aerated lungs (A-lines) and inflamed, edematous lungs (white lung pattern) [2].

Given that non-invasive ventilation (NIV) is widely used to manage moderate respiratory disease while avoiding invasive complications, reliable predictors of NIV failure are crucial, as clinical assessment and chest radiographs often offer discordant grading of disease severity. Notably, the persistence of a "white-lung" pattern on ultrasound correlates strongly with clinical respiratory distress [2]. This review aimed to evaluate the role of lung ultrasound (LUS) versus chest X-ray (CXR) in diagnosing pulmonary disorders in neonates, focusing on identifying the most effective imaging modality.

1. Neonatal Pulmonary Disorders

The newborn's ability to adapt to the extra-uterine environment is critical for survival, especially the lungs. In utero, oxygen, nutrients, and carbon dioxide are managed via the placenta, and the lungs are filled with fluid to promote growth. Preterm neonates, especially those born before 37 weeks, face challenges due to immature lungs. Extremely preterm (≤28 weeks) and late preterm (≤32 weeks) neonates lack sufficient alveolar development, which typically starts after 32 weeks [2].

- **Respiratory Distress in Neonates**

Respiratory distress in neonates can arise from medical, surgical, congenital, or systemic causes. Medical causes in preterm infants include respiratory distress syndrome, pneumothorax, pneumonia, pulmonary hemorrhage, aspiration, pleural effusion, and chronic lung disease, while in term infants, transient tachypnea, meconium aspiration, persistent pulmonary hypertension, and similar conditions are common. Congenital anomalies such as congenital diaphragmatic hernia, tracheoesophageal fistula, and pulmonary malformations, along with systemic causes like heart failure, neuromuscular disorders, hypoxic-ischemic

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encephalopathy, and metabolic acidosis, also contribute. Medical causes typically lead to diffuse lung changes, with the neonate's gestational age guiding differential diagnosis based on imaging patterns [3].

Clinical and Radiological Aspects of RDS

Signs of respiratory distress appear soon after birth. Chest radiographs show poorly inflated lungs with a "ground-glass" appearance and air bronchograms. Respiratory distress worsens in the first 2–3 days, stabilizes for 2–3 days, then improves, often with a diuretic phase. Radiographic findings include small lung volumes, vertically oriented ribs, a bell-shaped thorax, granular lung appearance, and air bronchograms extending from the hilum to the periphery. In severe cases, a "white-out" lung appearance may occur. A normal radiograph at 6 hours post-birth excludes RDS [4] **(Figure 2)**.

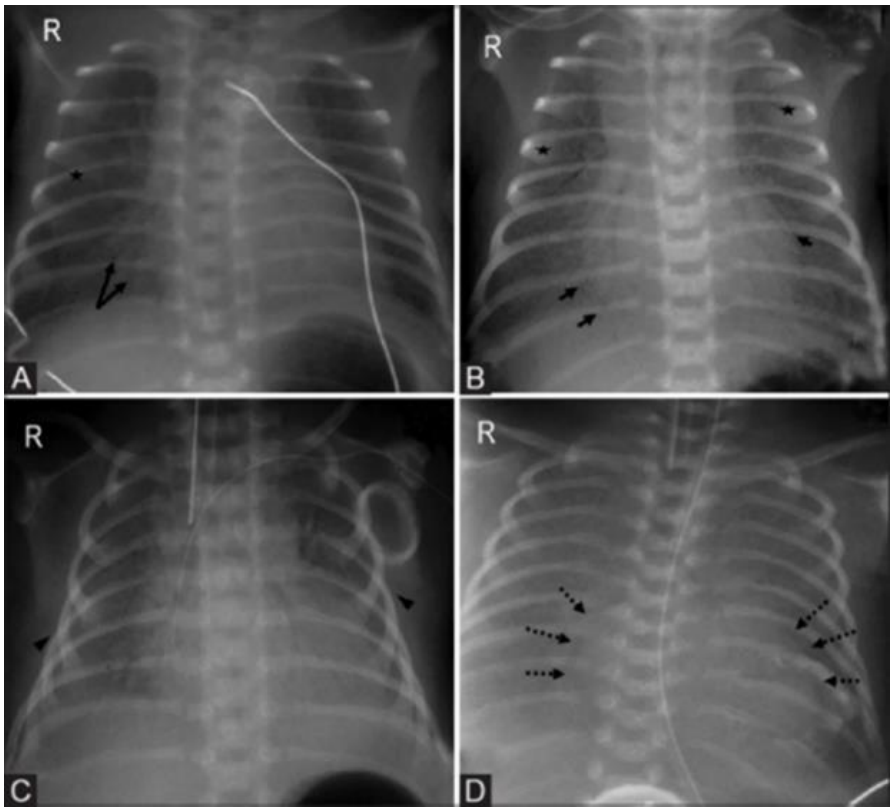

Figure 1. Progression of radiographic findings in respiratory distress syndrome [5].

(A) Stage 1: Fine granularity (asterisk) with few air bronchograms (arrows).
(B) Stage 2: Coarse, distinct granularity (asterisks) with extensive air bronchograms (arrows).
(C) Stage 3: Increasing opacity with decreasing air bronchograms and granularity. Note the vertical orientation of ribs (arrowheads) with bell-shaped thorax.
(D) Stage 4: "Whiteout lung"-Diffuse bilateral opacification with lack of apparent heart borders (dotted arrows) and loss of all air bronchograms.

RDS Treatment

Respiratory support and exogenous surfactant therapy improve RDS, often clearing granular opacities and increasing lung volumes. Partial or no radiographic improvement indicates a poor prognosis. Positive pressure ventilation, with or without surfactant therapy, can cause complications, especially in preterm lungs. Barotrauma may lead to air leaks, such as pulmonary interstitial emphysema (PIE), pneumothorax, pneumomediastinum, and others. Other complications include pneumonia, pulmonary hemorrhage, bronchopulmonary dysplasia, and rare systemic air embolism [6].

Untreated form of respiratory distress syndrome presents with recovery towards the end of the first week. Secondary surfactant deficiency can be treated by administering surfactant [7].

- **Chronic Neonatal Lung Disease / Bronchopulmonary Dysplasia (BPD)**

BPD is a chronic lung disease in premature infants caused by prolonged mechanical ventilation and high oxygen exposure. It primarily affects infants with birth weights <1000 g and is rare in those >32 weeks gestational age. Radiographic manifestations of BPD are classified into stages **(Figure 2)** [8].

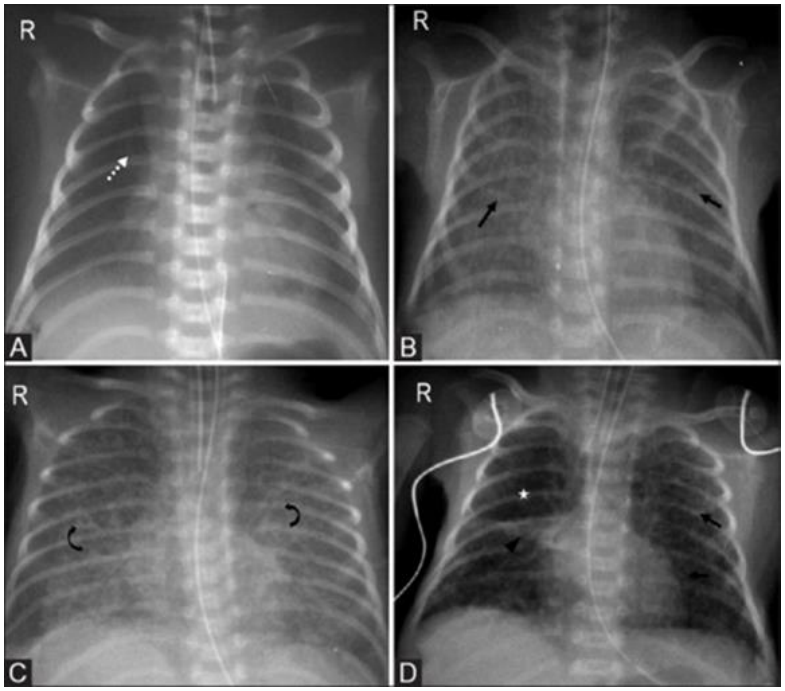

Figure 2. Progression from respiratory distress syndrome to bronchopulmonary dysplasia [5].

(A) Stage 1: Initial radiograph depicting fine granular opacities (dotted arrow) of respiratory distress syndrome.
(B) Stage 2: Radiograph taken on day 7 reveals bilateral increased opacities (arrows).
(C) Stage 3: Day 10 radiograph with coarsening of markings (curved arrows) and honeycomb appearance.
(D) Stage 4: Coarse interstitial markings (arrows), area of atelectasis (arrowhead) with hyperexpansion (asterisk) on day 30 radiograph are characteristic of bronchopulmonary dysplasia.

- **Full-term Infant Respiratory Distress**

Full-term or post-term infants, despite having mature alveoli and surfactant-producing cells, can experience respiratory distress due to factors like cesarean delivery, meconium-stained amniotic fluid, gestational diabetes, chorioamnionitis, or structural lung abnormalities [9].

- **Transient Tachypnoea of the Newborn (TTN)**

TTN is the most common respiratory issue in full-term infants, often linked to delayed lung fluid absorption, particularly following cesarean sections. It's considered part of the same disease spectrum as RDS, with similar surfactant deficiency but different clinical courses and radiographic findings**.** Risk factors include maternal diabetes, asthma, male sex, low birth weight, and macrosomia [10].

Clinical and Radiological Aspects of TTN

TTN presents with mild respiratory distress shortly after birth. It typically resolves within 72 hours with supportive oxygen therapy. The condition results from retained fetal lung fluid, especially in cesarean deliveries. Radiographs show hyperinflated lungs, airspace opacification, fissural fluid, and cardiomegaly (**Figure 3)** [11].

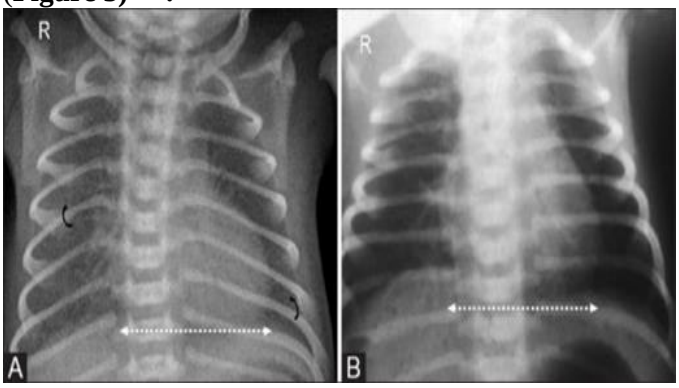

Figure 3. Transient tachypnea of term infant with respiratory distress [5].

(A) Radiograph taken at 6 hours after birth reveals coarse interstitial markings (curved arrows) with mild cardiomegaly (dotted arrow).
(B) Repeat radiograph after 3 days reveals clearing of opacities with normalization of cardiac size (dotted arrow).

- **Meconium aspiration syndrome (MAS)**

Meconium-stained amniotic fluid is common after 37 weeks gestation, affecting 10% of deliveries, but only 10% of these neonates develop respiratory distress due to MAS [12].

Clinical and Radiological Aspects of MAS

MAS presents with respiratory distress, often soon after birth, and may include signs of hypoxic-ischemic encephalopathy. Radiographs may show patchy lung changes [13].

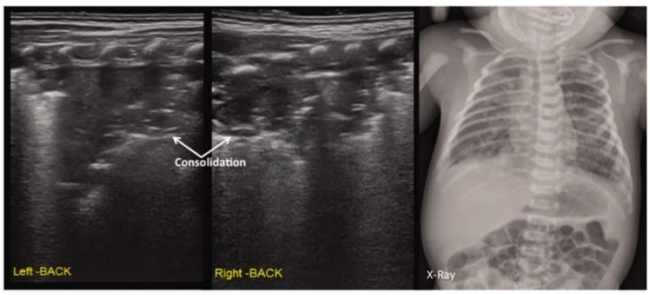

Figure 4. Newborn with meconium aspiration syndrome (MAS) [5].

Neonatal pneumonia

Pneumonia is more common in preterm neonates and can be early (≤7 days) or late onset (>7 days). Congenital pneumonia risk factors include chorioamnionitis and prolonged rupture of membranes [14].

- **Surgical causes**

Congenital Diaphragmatic Hernia (CDH)

Surgical causes of neonatal respiratory distress include congenital diaphragmatic hernia (CDH), congenital pulmonary airway malformation (CPAM), congenital lobar overinflation (CLO), and bronchopulmonary sequestration. CDH involves herniation of abdominal contents into the chest due to diaphragmatic defects, most commonly Bochdalek hernia, and is diagnosed antenatally or postnatally with imaging. CPAM, a hamartomatous proliferation forming cysts, is classified into five types and diagnosed via ultrasound or CT. CLO results from bronchial obstruction causing lobar hyperinflation, while bronchopulmonary sequestration involves non-communicating lung tissue seen as lower lobe opacity. Other congenital anomalies like tracheomalacia, tracheoesophageal fistula, congenital heart defects (causing metabolic acidosis, pulmonary edema, or cyanosis), and chest wall abnormalities may also contribute to respiratory distress. Systemic causes include metabolic disorders (acidosis, hypoglycemia) and infections like sepsis or TORCH infections, requiring thorough clinical and sometimes radiologic evaluation [15].

- **Normal neonatal LUS appearance**

Point-of-care lung ultrasound (LUS) is increasingly utilized in neonatal intensive care units (NICUs) as a non-invasive, real-time diagnostic tool for pulmonary disorders. Using high-frequency linear transducers, LUS enables the bedside assessment of neonatal lung regions through longitudinal and transverse scans, showing high diagnostic concordance with chest X-rays within the first 24 hours. In normal neonates, the pleural line appears as a smooth echogenic line with synchronous "lung sliding," and horizontal reverberation artifacts known as A-lines are visible. Early postnatal B-lines, reflecting residual lung fluid, may be seen but typically resolve as the lungs aerate. LUS has become a valuable "modern stethoscope" in NICU practice for the early diagnosis and management of respiratory distress [16].

- **Neonatal LUS in diagnosis and description of specific lung diseases**

Respiratory distress syndrome

Neonatal respiratory distress syndrome (RDS), common in premature infants, is caused by surfactant deficiency. Severe cases require surfactant administration and mechanical ventilation. On lung ultrasound (LUS), RDS shows lung consolidation, air bronchograms, thickened pleural lines, and compact B-lines. In severe cases, lung pulse and pleural effusion may be present [17].

Lung ultrasound (LUS) has high sensitivity, specificity, and predictive values in diagnosing neonatal RDS, consistently above 90%. It reliably assesses RDS severity and predicts NICU admission. LUS reduces unnecessary radiation and aids in identifying neonates needing surfactant therapy. LUS scores can predict surfactant needs and evaluate treatment efficacy. However, further multicenter studies are needed before LUS scores become routine in RDS management [18].

Transient tachypnea of the newborn

As another causative factor for dyspnea in neonates, transient tachypnea of the newborn (TTN) or "wet lung" results from delayed lung fluid clearance. In normal conditions, LUS video recordings show that substantial liquid clearance occurs within the first 20 min, and complete clearance is accomplished within the first 4 hours after birth. Compared with vaginal delivery, an elective cesarean section may lead to delayed fluid clearance within the first 3 h of birth [19].

In most cases, TTN presents as mild or transient respiratory distress, which will improve within 24–48 h. However, symptoms may persist for a long time in some severe cases. As a result of fluid retention in the lung tissues, pulmonary edema is the common characteristic of TTN. By evaluating the distribution of B-lines, the primary LUS characteristics of TTN, which are related to its severity, include the double lung point (DLP), AIS, or white lung. The DLP means that there is a sharp change in echogenicity as a result of the abundance of B-lines between the upper and the lower lung fields **(Figure 5)** [20].

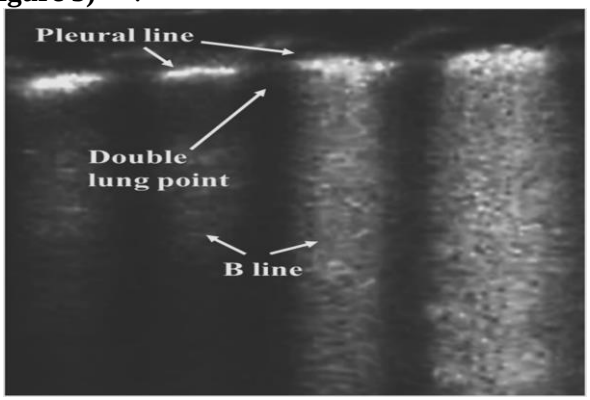

Figure 5. Transient tachypnea of the newborn on lung ultrasonography [21].

Lung Ultrasound in Neonatal Pulmonary Disorders

Neonatal pneumonia, often caused by bacterial, viral, or fungal infections, presents with respiratory distress but shows nonspecific radiographic features; lung ultrasound (LUS) improves diagnosis by revealing subpleural consolidations, dynamic air bronchograms, and pleural abnormalities with high sensitivity and specificity. Meconium aspiration syndrome (MAS), mainly affecting term or post-term neonates, also demonstrates irregular consolidations and B-lines on LUS, but typically with bilateral findings, aiding differentiation from pneumonia. Air leak syndromes such as pneumothorax can be rapidly diagnosed with LUS by detecting absent lung sliding, clear A-lines, and lung points. LUS also assists in diagnosing bronchopulmonary dysplasia (BPD) through uneven B-lines, pleural thickening, and subpleural consolidations, and is useful in identifying congenital anomalies like CDH and CPAM [22].

Neonatal Chest X-Ray in Pulmonary Disorders

Chest X-ray (CXR) remains a fundamental imaging tool in neonates but must be performed carefully, considering unique pediatric airway anatomy and minimizing radiation exposure. Radiopaque findings such as granular opacities are typical in respiratory distress syndrome (RDS), while parahilar streaking characterizes transient tachypnea of the newborn (TTN), and coarse opacities with air trapping suggest MAS. Radiolucent findings often indicate air leak syndromes or congenital anomalies like CPAM or diaphragmatic hernia. Proper tube placement assessment is crucial during chest radiography, as misplacements can hint at serious underlying anomalies [23].

Imaging Modalities for Evaluating Neonatal Respiratory Disorders

Imaging is critical for the diagnosis and management of neonatal respiratory disorders, with chest X-ray (CXR), lung ultrasound (LUS), and computed tomography (CT) being the primary tools. CXR is accessible and effective for initial diagnosis but is limited by radiation exposure and lack of dynamic evaluation. LUS offers a radiation-free, bedside alternative with high sensitivity for many conditions, although it is operator-dependent. CT is reserved for complex or unclear cases requiring detailed anatomical visualization but is limited by high radiation doses and the need for sedation [24].

CONCLUSION

Chest imaging with X-ray (CXR) has high diagnostic potential in some disorders, such as respiratory distress syndrome in neonates. This technique also has the potential to assess the treatment response and evaluate the complications following treatment. No single imaging modality is superior for all neonatal respiratory conditions. CXR remains the

standard for initial evaluation, while LUS is becoming a preferred choice for dynamic, bedside assessment. CT is valuable for complex or congenital cases where detailed imaging is crucial. The integration of these modalities ensures optimal care, guided by clinical context and radiological expertise.

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