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

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Abstract:

Background: The neonatal period is characterized by critical physiological transitions, especially within the respiratory system, predisposing neonates to a spectrum of pulmonary disorders. Respiratory distress remains one of the most common indications for neonatal intensive care unit (NICU) admission. Imaging is essential for early diagnosis and management. Lung ultrasound (LUS) has gained attention as a valuable diagnostic tool compared to the traditional chest X-ray (CXR), offering advantages in terms of safety and bedside availability.**Subjects and methods:** This prospective study was conducted at Benha University Hospitals between February 2024 and September 2024, involving 100 neonates diagnosed with respiratory disorders. The study compared lung ultrasound (LUS) and chest X-ray (CXR) for the diagnosis of pulmonary pathologies. Included patients were full-term or preterm neonates below 28 days of age, presenting with low birth weight and respiratory distress. Standardized protocols were used for both imaging modalities. **Results:** Lung ultrasound showed superior diagnostic performance compared to chest X-ray in identifying common neonatal respiratory conditions such as hyaline membrane disease (HMD), transient tachypnea of the newborn (TTN), pneumonia, and pneumothorax. LUS proved to be a highly valuable diagnostic tool in the neonatal intensive care setting. **Conclusions:** Lung ultrasound is a non-invasive, radiation-free, bedside tool with high diagnostic accuracy. It complements chest X-ray and may serve as a reliable alternative in many cases of neonatal respiratory distress.

Keywords: LUS; CXR; Pulmonary Disorders; Neonatal.

Introduction

The neonatal period marks the most profound physiological transition in human life. While the respiratory and cardiovascular systems undergo abrupt functional shifts at birth, other organ systems adapt more gradually, culminating in the full conversion from intrauterine to extrauterine physiology. This transitional window is pivotal, particularly due to the abrupt cessation of placental support for gas exchange, circulation, and metabolic clearance, necessitating immediate and coordinated neonatal adaptation [1]. Respiratory pathologies in neonates may stem from delayed postnatal adaptation, structural or congenital anomalies, or acquired insults such as perinatal infections. These conditions represent the leading cause of NICU admissions among both term and preterm newborns [2]. Among the most frequently encountered disorders are respiratory distress syndrome (RDS), pneumothorax, pneumonia, pulmonary hemorrhage, aspiration syndromes, pleural effusion, transient tachypnea of the newborn, meconium aspiration, persistent pulmonary hypertension (primary or secondary), congenital pulmonary airway malformation, congenital diaphragmatic hernia, tracheoesophageal fistula, choanal atresia, pulmonary sequestration, and congenital lobar emphysema [3]. Given its diverse etiologies, neonatal pulmonary disease remains a predominant cause of respiratory compromise. Escalation into respiratory failure is a major contributor to neonatal mortality globally. Therefore, heightened clinical vigilance and early therapeutic intervention by neonatologists are vital [4]. Chest X-ray (CXR), despite its widespread availability and relatively low radiation exposure, continues to be the frontline imaging modality for evaluating neonatal pulmonary and cardiovascular systems. However, lung ultrasound (LUS) has demonstrated superior diagnostic precision and consistency in detecting conditions such as neonatal pneumonia and other lung pathologies, surpassing CXR in several clinical contexts [5]. The utility of ultrasonography (USG) in emergency and intensive care settings has earned it the designation of a “third eye” for clinicians. LUS employs both anatomical landmarks (e.g., ribs, pleural lines) and ultrasound artifacts such as B-lines—distinct vertical hyperechoic reverberations arising from the pleura. The appearance of diffuse, bilateral B-lines is suggestive of interstitial syndromes including pulmonary edema, diffuse parenchymal disease, and interstitial pneumonia [6]. In neonates, LUS permits the differentiation between normally aerated lungs—characterized by a homogeneous hypoechoic pattern with pleural sliding and horizontal A-lines—and the echogenic “white lung” pattern typical of fluid-laden or inflamed pulmonary tissue. Non-invasive ventilation (NIV) is commonly utilized in moderate neonatal respiratory compromise to maintain spontaneous respiration while mitigating the risks associated with mechanical ventilation [7]. Nonetheless, the ability to predict NIV failure remains limited. Conventional radiographs often fail to correlate with the clinical grading of RDS. By contrast, the persistence of a “white lung” signature on LUS has shown strong correlation with ongoing respiratory distress in preterm infants [8]. Accordingly, this review investigates the comparative diagnostic value of LUS versus CXR in evaluating pulmonary conditions within the neonatal population, with a focus on identifying the superior modality for routine clinical implementation.

Neonatal Pulmonary Disorders

Neonatal respiratory conditions may arise due to delayed postnatal adaptation, congenital anomalies, or infections acquired around the time of birth. A comparative analysis revealed a prevalence of 2.2% in Italy and 6.7% in India, highlighting regional variability in respiratory morbidity among newborns [9].

These conditions represent the most frequent cause of NICU admissions in both term and preterm neonates. For instance, one study reported that respiratory distress was the primary diagnosis in 33.3% of neonates admitted beyond 28 weeks of gestation, while another identified signs of RD in 20.5% of cases. The global uptick in cesarean deliveries may be partially responsible for the increasing incidence of such admissions [(10)].

Respiratory Distress in Neonates

Etiologically, neonatal RD may stem from medical, surgical, congenital, or systemic origins [(11)].

Table 1. Common causes of neonatal respiratory distress [(49)].

Category	Condition
Preterm Pathology (Medical Causes)	• RDS • Pneumothorax • Pneumonia • Pulmonary hemorrhage • Aspiration • Pleural effusion (chylothorax) • Chronic lung disease
Term Pathology (Medical Causes)	○ Transient tachypnoea of the newborn ○ RDS ○ Meconium aspiration ○ PPHN ○ Pneumonia ○ Pneumothorax ○ Aspiration ○ Pleural effusion ○ CPAM
Congenital Anomalies and Surgical Conditions	○ CDH ○ TEF ▪ Choanal atresia ▪ Pulmonary sequestration ▪ CLE
Non-respiratory causes of respiratory distress (Systemic Causes)	▪ Heart failure (due to CHD) ▪ Neuromuscular disorders ▪ Hypoxic ischemic encephalopathy ▪ Metabolic acidosis (due to inborn error of metabolism)

❖ **Respiratory distress syndrome**

RDS is an acute pulmonary disorder primarily affecting neonates between 26–33 weeks' gestation, though it may also present in term infants following cesarean section, perinatal hypoxia, or in infants of diabetic mothers. The hallmark of RDS is a surfactant deficiency leading to alveolar collapse and impaired gas exchange [(12)].

Incidence correlates inversely with gestational age, and preterm neonates remain at the highest risk [(13)].

Epidemiology and Risk Factors

Surfactant deficiency is the principal factor predisposing preterm infants to RDS, with additional risk noted among offspring of diabetic mothers [(14)].

Clinical and Radiological Aspects of RDS

Clinically, RD manifests as signs of increased respiratory effort including tachypnea, nasal flaring, subcostal retractions, and expiratory grunting. The normative neonatal respiratory rate ranges from 30–60 breaths/min, with tachypnea defined as a rate exceeding 60 breaths/min [(15)]. This compensatory response may indicate hypercapnia, hypoxemia, or acidosis, yet remains a non-specific marker found in respiratory, cardiovascular, metabolic, or systemic illnesses [(16)].

Radiographically, conditions such as diaphragmatic paralysis, CPAM, pneumothorax, mediastinal mass, or CDH may be visualized, as they compromise thoracic compliance and pulmonary inflation. When tachypnea is disproportionate to physical signs of distress, metabolic causes or systemic infections like sepsis should be investigated through laboratory analysis [(17)].

RDS Management

Advancements in the treatment of RDS have markedly transformed neonatal outcomes, particularly following the introduction of exogenous surfactant therapy. Clinical improvements have also been closely tied to the prenatal administration of corticosteroids and the application of positive end-expiratory pressure (PEEP), both of which help maintain alveolar patency and mitigate atelectasis [(18)].

Pulmonary surfactant plays a critical role in stabilizing alveoli by reducing surface tension within the air sacs. In neonates with RDS, surfactant deficiency impairs gas exchange and predisposes to alveolar collapse. The therapeutic efficacy of surfactant extracts in enhancing survival has been well-established. However, the optimal timing for initiation has remained a point of clinical inquiry. A review of randomized trials comparing early selective administration (within the initial two postnatal hours) to delayed intervention demonstrated a clear benefit associated with early delivery, suggesting a time-sensitive therapeutic window [(19)].

Chronic Neonatal Lung Disease / Bronchopulmonary Dysplasia (BPD)

Bronchopulmonary dysplasia (BPD) stands as a prevalent and severe complication of prematurity, resulting from interrupted alveolar development in immature lungs subjected to mechanical ventilation, supplemental oxygen, and inflammatory stimuli before pulmonary maturation is complete. Clinically defined by the need for oxygen therapy at 36 weeks' corrected gestational age, BPD affects approximately 32% of preterm neonates and nearly half of those with very low birth weight **(Figure 1,2,3,4)** [(20)].

Full-term Infant Respiratory Distress

Though commonly associated with prematurity, RDS also occurs in term infants, primarily due to severe perinatal infections or elective cesarean deliveries. The highest risk is observed when delivery occurs before the onset of labor, as the physiologic mechanisms necessary for fetal lung fluid clearance may be underdeveloped [(21)].

Term RDS can be classified into three distinct etiologies: **ARDS**: Triggered by catastrophic insults such as birth asphyxia, sepsis, shock, or coagulopathy. **IRDS**: Often observed in neonates delivered by elective cesarean section, with earlier deliveries correlating with increased incidence. **Genetic surfactant deficiency**: A rare but serious contributor associated with inborn errors of surfactant metabolism [(22)].

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

Transient tachypnoea of the newborn (TTN) is a self-limited respiratory disorder marked by rapid breathing within the initial hours of life, typically resolving within 72 hours without the need for invasive intervention [(23).] The condition is linked to delayed clearance of fetal lung fluid, a process normally regulated by hormonal changes near term and during labor. Catecholamines and glucocorticoids activate sodium transport pathways that drive alveolar fluid reabsorption. Although vaginal birth provides some mechanical assistance, hormonal signaling is the principal mechanism. TTN is reported in approximately 10% of infants born at 33–34 weeks, 5% at 35–36 weeks, and less than 1% among term neonates [(24).]

❖ **Meconium aspiration syndrome (MAS)**

Meconium aspiration syndrome (MAS) remains a considerable source of neonatal morbidity and mortality, particularly in resource-limited settings. Historically, aggressive airway suctioning was routinely performed for all infants born through meconium-stained amniotic fluid (MSAF), regardless of their clinical vigor. However, evolving evidence has led to the abandonment of this practice, with guidelines now discouraging routine intubation and suctioning in the absence of respiratory compromise [(25).]

Clinical and Radiological Aspects of MAS

Diagnostic criteria for MAS typically include respiratory distress in a neonate delivered through MSAF, oxygen dependency within the first two hours of life that persists for at least 12 hours, oxygen saturation maintained above 92% with supplementation, and exclusion of congenital malformations of the lungs, heart, or airways [(26).]

Initial CXR often reveals streaky linear opacities that evolve into hyperinflation with patchy infiltrates (**Figure 5**). Air leaks, such as pneumothorax or pneumomediastinum, are noted in 10–30% of affected neonates. Blood gas analysis commonly shows hypoxemia and hypercapnia, reflecting ventilation-perfusion mismatch [(27).]

❖ **Neonatal pneumonia**

Neonatal pneumonia may mimic systemic infection, with presentations including respiratory distress and unstable temperature regulation. Radiological features range from initially normal to patchy consolidations and air bronchograms. In some cases, bilateral granular patterns or diffuse infiltrates with associated effusions—observed in up to 67%—are presen

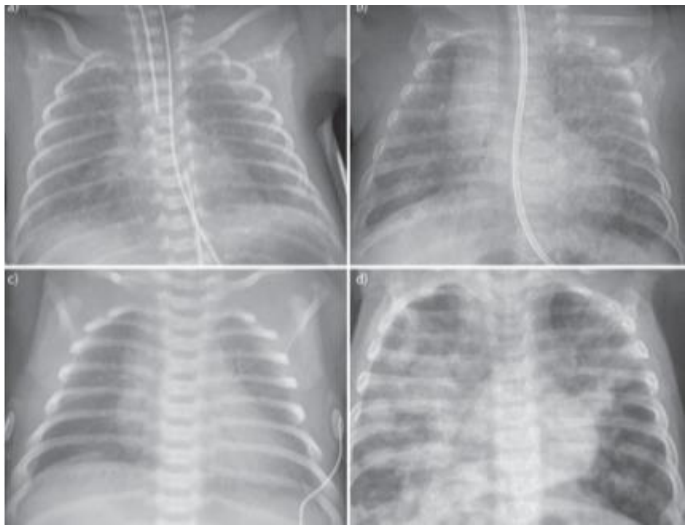

Figure 1. Chest radiograph images [(38)]

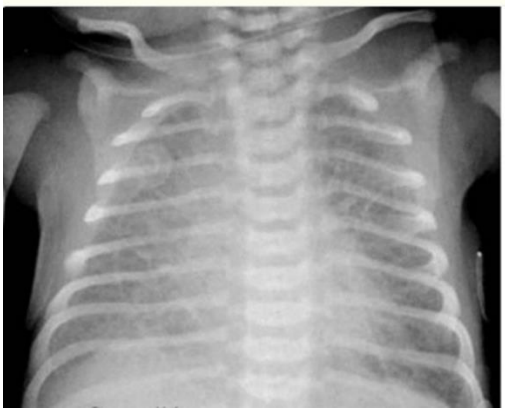

Figure 2: Transient tachypnea of the newborn is characterized by streaky, pulmonary interstitial markings and fluid in the fissure apparent on chest radiograph [(5)]

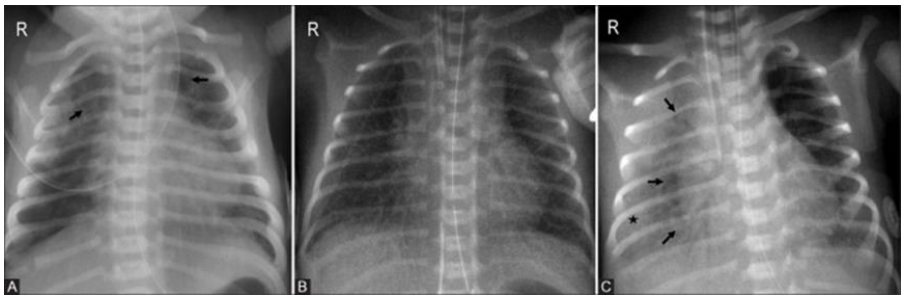

Figure 3: Post surfactant therapy changes. [(5)]

- ❖ Pre-treatment: Bilateral diffuse opacities with visible air bronchograms (arrows).
- ❖ Post-treatment: Improved lung inflation and resolution of opacities bilaterally.
- ❖ Partial response: Marked improvement on the left side, while the right lung retains granular opacities (asterisk) and persistent air bronchograms.

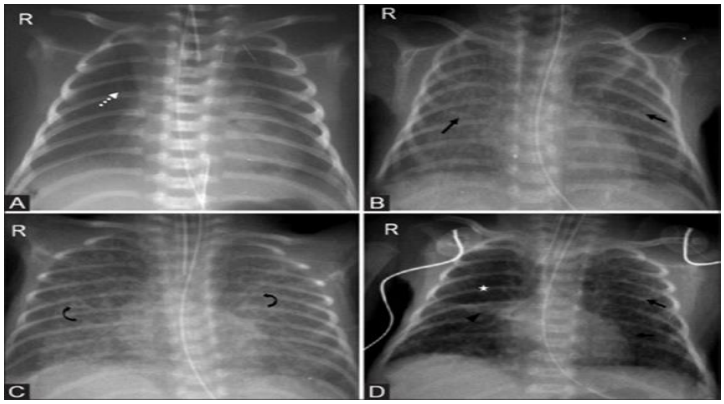

Figure 4. Radiographic transition from RDS to BPD [(5)]

(A) Early phase: Fine granular opacities indicative of RDS (dotted arrow).
(B) Day 7: Progressive bilateral opacities (arrows).
(C) Day 10: Markings become coarser with a honeycomb pattern (curved arrows).
(D) By day 30: Coarse interstitial changes, segmental atelectasis (arrowhead), and signs of hyperinflation (asterisk) consistent with BPD.

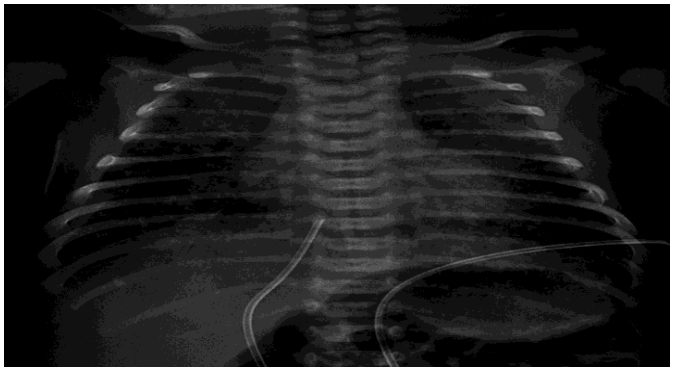

Figure 5. Chest radiography of a full-term infant with meconium aspiration [(27).]

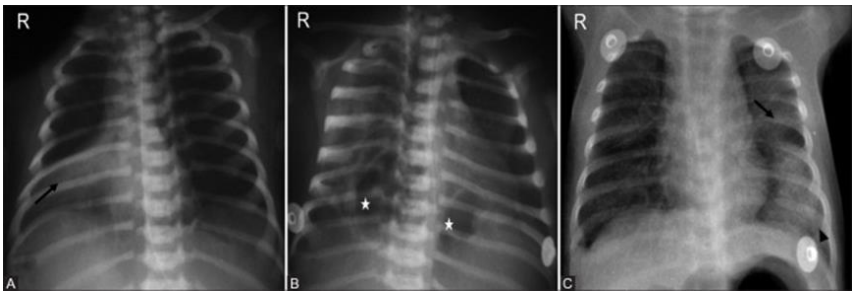

Figure 6: Neonatal pneumonia. [(5)]

❖ **Surgical causes**

Congenital Diaphragmatic Hernia (CDH)

CDH results from diaphragmatic maldevelopment allowing abdominal organs to herniate into the thorax, impeding lung growth and alveolar development. The incidence is approximately 1 in 2500 live births **(29).**

CPAM, formerly CCAM, is characterized by benign overgrowth of terminal bronchioles forming cystic lesions, usually limited to a single lobe. Antenatal ultrasound may detect hyperechoic lung areas, which are more precisely evaluated by fetal MRI. Postnatal imaging often shows cystic lucencies on CXR, but CT provides definitive characterization **(30) (31).**

Congenital lobar overinflation (CLO)

CLO, also referred to as congenital lobar emphysema, typically involves lobar hyperinflation due to bronchial obstruction. The left upper lobe is most frequently affected. Imaging may show overdistention of the affected lobe, adjacent collapse, and mediastinal shift. CT aids in diagnosis and in excluding reversible causes **(32).**

Bronchopulmonary sequestration

Bronchopulmonary sequestration is defined by nonfunctioning pulmonary tissue that lacks tracheobronchial continuity. The extralobar variant often presents in neonates. Radiographic findings may mimic CPAM or infectious processes, and CT angiography is often necessary for differentiation **(33).**

Other extrapulmonary causes of distress include anomalies such as tracheoesophageal fistula, tracheomalacia, bronchopulmonary foregut malformations, congenital cardiac defects, and structural thoracic abnormalities **(34).**

❖ **Congenital cardiac causes**

Neonatal respiratory compromise may stem from cardiac pathologies, including pulmonary edema secondary to left-sided failure or obstructed venous return. Clinical signs—cyanosis, murmurs, and acidosis—suggest underlying heart disease. Radiologic findings include cardiomegaly, pulmonary congestion, and

interstitial edema. While PDA is a common cause in preterm neonates, lesions such as VSD and atrioventricular canal defects are more typical in term infants **(35).**

Lung Ultrasonography in Neonatal Pulmonary Disorders

LUS has emerged as a valuable, radiation-free diagnostic modality for assessing neonatal lung pathology. Its effectiveness is amplified in neonates due to their small thoracic dimensions and compliant chest wall, allowing for enhanced acoustic penetration. Unlike traditional CXR, LUS offers bedside feasibility, reproducibility, and minimal training requirements, making it an ideal tool in the NICU setting **(36).**

Respiratory distress syndrome

RDS, prevalent among preterm neonates, arises from pulmonary surfactant deficiency and often necessitates surfactant replacement and ventilatory support. Characteristic LUS findings in RDS include lung consolidations, static or dynamic air bronchograms, pleural line thickening or irregularity, and compact B-lines. In more severe cases, the presence of lung pulse and pleural effusion may also be observed **(37).**

Transient tachypnea of the newborn

LUS offers superior sensitivity and specificity in distinguishing TTN from hyaline membrane disease and neonatal pneumonia. TTN typically presents with bilateral—but frequently asymmetric—distribution, a smooth pleural line, absence of significant subpleural consolidations, and diffuse B-lines reflecting pulmonary edema. While the double lung point (DLP) alone lacks diagnostic specificity, its combination with B-line patterns significantly enhances diagnostic accuracy **(38).**

Clinically, TTN manifests as mild, self-limiting respiratory distress resolving within 24–48 hours, though persistent symptoms may occur in severe cases. Pulmonary fluid retention is the hallmark feature, leading to interstitial and alveolar edema **(39).**

Pneumonia

LUS has emerged as a reliable, non-invasive modality for diagnosing neonatal pneumonia. Hallmark sonographic features include subpleural consolidations with irregular or shredded margins, dynamic air bronchograms, pleural line abnormalities, and occasional pleural effusion. Notably, LUS has demonstrated exceptional diagnostic performance, with some studies reporting 100% sensitivity and specificity when large irregular consolidations and air bronchograms were considered diagnostic criteria **(40).**

Meconium aspiration syndrome

The sonographic appearance of MAS often overlaps with that of pneumonia. Common findings include irregular subpleural consolidations, air bronchograms, patchy or confluent B-lines, loss of A-lines, and disrupted pleural contour **(41).**

Although these features are nonspecific, the distribution can be a differentiating factor: MAS typically involves bilateral lung fields, whereas pneumonia is often unilateral. This distinction aids in the differential diagnosis **(42).**

Air leak syndromes

Air leak syndromes—including pneumothorax, pneumomediastinum, and pulmonary interstitial emphysema (PIE)—result from alveolar rupture with subsequent air escape into extra-alveolar spaces, often secondary to mechanical ventilation or underlying pulmonary pathology. Pneumothorax is the most prevalent form, occurring in approximately 1%–2% of term neonates and up to 30% of those with respiratory disease or on ventilatory support. Lung ultrasound (LUS) serves as a rapid and accurate bedside diagnostic tool for pneumothorax, with typical sonographic features including the absence of lung sliding, absent B-lines, prominent A-lines, and the presence of a lung point—denoting the transition between normal and abnormal pleural interface **(43).**

Bronchopulmonary dysplasia (BDP)

BPD is a chronic lung disease predominantly affecting extremely preterm infants, with an incidence of up to 68% in neonates born before 28 weeks of gestation. It arises from a multifactorial interplay between lung immaturity, oxygen toxicity, mechanical ventilation, and inflammation. LUS findings in BPD include heterogeneous distribution of B-lines, thickened and irregular pleural lines, and patchy subpleural consolidations. Persistent retrodiaphragmatic hyperechogenicity observed on transabdominal LUS has been proposed as an early predictor of BPD development [(44)].

Neonatal Chest X-Ray in Diagnosis of Pulmonary Disorders

CXR is the primary method used to evaluate NRDS in newborns. However, frequent exposure to ionizing radiation can have long-term adverse effects, including an increased risk of cancer, especially in premature infants. Research suggests that LUS may be a useful alternative for diagnosing NRDS. Reducing the dose of ionizing radiation is one of the main objectives of pediatric radiology [(45)].

Best Practices in Pediatric Chest Radiography

Optimal pediatric CXR requires adherence to standardized imaging protocols. Proper positioning is critical, with minimal rotation and upright positioning when feasible. The ALARA principle (As Low As Reasonably Achievable) guides exposure parameters, ensuring minimal radiation while preserving image quality. Accurate placement of tubes and lines is also essential, as misplacements may mimic or obscure thoracic anomalies. For instance, a nasogastric tube misdirected into the left hemithorax may suggest diaphragmatic hernia or esophageal atresia [(46,47)].

Interpretation of Neonatal Chest Imaging

Radiographic patterns vary based on gestational age and etiology:

- RDS typically manifests in preterm neonates with low lung volumes, fine granular opacities, and air bronchograms.
- TTN, more common in term neonates, shows increased lung volume, prominent parahilar streaking, and fluid in interlobar fissures.
- MAS appears as bilateral coarse infiltrates, areas of atelectasis, and signs of hyperinflation.

Radiolucent findings are often associated with air leak syndromes such as pneumothorax, pneumomediastinum, PIE, and pneumatoceles—conditions frequently resulting from mechanical ventilation. Hyperinflation may also result from endotracheal tube malposition or as compensatory overexpansion. Congenital malformations like CPAM may present with lucent cystic areas, while congenital diaphragmatic hernia is identified by the presence of bowel loops in the thorax and a contralateral mediastinal shift [(48,49,50)].

Methods

This review combined a comprehensive evaluation of existing literature with institutional experience from Benha University Hospitals. For the literature review, electronic databases including **PubMed**, **Scopus**, and **Google Scholar** were searched for publications from **January 2015 to April 2025** using terms such as "lung ultrasound in neonates," chest X-ray," and "neonatal pulmonary imaging."

The review included clinical studies, observational reports, meta-analyses, and expert consensus statements, all focused on diagnostic imaging of neonatal respiratory disorders. Only English-language full-text articles were included.

In addition, a prospective observational study was conducted at Benha University Hospitals between February 2024 and September 2024**,** involving 100 neonates diagnosed with respiratory disorders. This part of the work was approved by the Benha Faculty of Medicine Research Ethics

Committee (Approval No. MS-7-4-2024**).** Standard imaging protocols were applied, and findings from both lung ultrasound (LUS) and chest X-ray (CXR) were compared.

Discussion

Lung ultrasound (LUS) is emerging as a highly sensitive and radiation-free imaging tool for evaluating neonatal pulmonary disorders. Compared to chest X-ray (CXR), LUS provides real-time bedside imaging, which is particularly beneficial in critical care settings. Studies consistently demonstrate the superior diagnostic accuracy of LUS in conditions such as respiratory distress syndrome (RDS), transient tachypnea of the newborn (TTN), pneumonia, and meconium aspiration syndrome (MAS) [51–53].

In RDS, LUS typically shows compact B-lines, subpleural consolidations, pleural thickening, and absence of A-lines, all of which correlate strongly with clinical severity and response to surfactant therapy[54]. These findings often precede radiographic changes, allowing earlier intervention than CXR, which may show nonspecific granular opacities [55].

TTN can be accurately diagnosed using the "double lung point" sign and diffuse B-line patterns on LUS, which help differentiate it from RDS and pneumonia[56]. CXR, in contrast, often shows overlapping signs that are less specific[57].

LUS also demonstrates high sensitivity and specificity for pneumonia through detection of irregular subpleural consolidations, dynamic air bronchograms, and pleural line abnormalities[58]. These features are more detailed than those seen on CXR, especially in early stages of infection.

In MAS, LUS allows detection of bilateral consolidations with air bronchograms and patchy B-lines, providing clearer differentiation from other pathologies than CXR[59]. Similarly, LUS is highly accurate in diagnosing pneumothorax using signs like absent lung sliding and the lung point, with performance comparable to or exceeding that of CXR[60].

Conclusions:

LUS has demonstrated substantial diagnostic utility in neonatal respiratory care and should be considered a complementary, if not alternative, modality to CXR, particularly in the evaluation of NRDS. Its non-ionizing nature, bedside applicability, and cost-effectiveness make it particularly suitable for neonatal intensive care settings, where frequent imaging is necessary. sBy reducing reliance on ionizing modalities, LUS can significantly decrease cumulative radiation exposure in vulnerable neonates. Moreover, its affordability and ease of use—without the need for complex equipment or consumables—position it as an indispensable tool in modern neonatal imaging protocols.

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