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Lung ultrasound in neonatal intensive care unit, an alternative to the Chest X Ray

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ABSTRACT

Introduction. Chest X-ray (CXR) has been for decades the most practiced diagnostic tool in respiratory pathology, an available and sometimes life-saving investigation, but we must admit that it has also long-term risks. X-rays can destroy living tissues, affecting DNA and producing genetic mutations
Objective. Reducing the exposure of the newborn to ionizing radiation
Material and method. We have analyzed the diagnostic correlation between CXR and lung ultrasound (LUS) for newborns with respiratory pathology admitted to the Neonatal Intensive Care Unit (NICU) of Emergency University Hospital Bucharest. They required a chest X-ray, and we correlated the ultrasound appearance with the radiological one.
Results. Acknowledging the normal appearance of LUS, multiple neonatal pathologies can be identified and monitored by pulmonary ultrasound, avoiding chest X-ray.
Conclusions. Lung ultrasound proved to be a very useful tool, always handy, easy to perform, reproducible, provides the image promptly, and is immediately integrated clinically into the medical thinking at the patient's bedside, therefore it should become standard of care.

Keywords: ionizing radiations, lung ultrasound, chest X-ray, atelectasis, respiratory distress syndrome

INTRODUCTION

LUS is being used in adult care since 1995 and nowadays, this technique plays a significant role in the study of pulmonary pathology, becoming an acknowledged procedure [1]. LUS was also performed to evaluate newborns, but not as a routine approach, first in the assessment of neonatal respiratory disorders, using only the abdominal window in order to diagnose hyaline membrane disease.

LUS can be performed at the infant's bedside, repeatedly, with minimal discomfort for the newborn, without the irradiation risk, with a simple, easy-to-learn technical examination done by the neonatologist. A study conducted by Bedetti et al. has shown that an inexperienced doctor can get the ability to detect the presence of pulmonary interstitial syndrome after 30 min of training and only 10 clinical examinations [3].

The specific signs described in LUS are almost similar at any age, therefore it is appropriate to be used in neonatal units, for preterm and term infants [2].

Even though newborns have a smaller chest diameter, a reduced volume of lung tissue, and thin muscular and subcutaneous layers, we can still obtain good-quality images in LUS, and we can easily and quickly recognize a normally aerated lung, or contrary, an interstitial or alveolar pattern [4]. Therefore, LUS-specific images have been associated with typical neonatal respiratory disorders, respiratory distress syndrome (RDS), transient tachypnea of the neonate (TTN), pneumothorax, and meconium aspiration syndrome [5,6,7,8].

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One of the advantages of LUS is the reduction of radiation exposure, Wilson-Costello estimated that an ELBW infant needs an average of 30 CXR during NICU admission [9].

MATERIALS AND METHODS

The normal ultrasound findings in a newborn's lung are similar to the adult lung. We can perform LUS using a simple device without Doppler and a linear probe, with a frequency of 9 to 12 MHz, positioned perpendicular to the ribs. The pleura, a thin hyperechoic horizontal line, is moving continuously during respiration, and that movement is considered a normal dynamic sign, described as a "lung sliding" sign [10]. Below the pleural line, we can see parallel echogenic lines, equidistant from one another, artifacts defined by Lichtenstein et al. as 'A-lines. Vertically 'comet-tail' artifacts, 'B lines', do not appear in the normal lung [6], but indicate the absence of pneumothorax These artifacts are correlated to pathological findings and are determined by the fluid-rich subpleural interlobular septae surrounded by air, suggesting an alveolar-interstitial syndrome [7].

RESULTS

Clinical case 1: respiratory distress syndrome (RDS)

A typical sign of RDS is a bilateral "white lung" - diffuse alveolar pattern without normal areas (absent A-lines), small subpleural consolidations, and irregular pleural lines (Fig 1, a and b).

Usually, ultrasound image improves 6 hours after the surfactant administration, compared to the radiological image, which improves sooner.

Clinical case 2: pulmonary hemorrhage

Pulmonary ultrasound is useful in the diagnosis of RDS complications such as pulmonary hemorrhage, pneumothorax, or atelectasis. LUS findings in pulmonary hemorrhage include the absence of A-lines, numerous and compact B lines, shred sign/fractal sign (an irregular line between consolidated and aerated lung), pleural effusion, pleural line abnormalities, lung consolidation with air bronchograms [11].

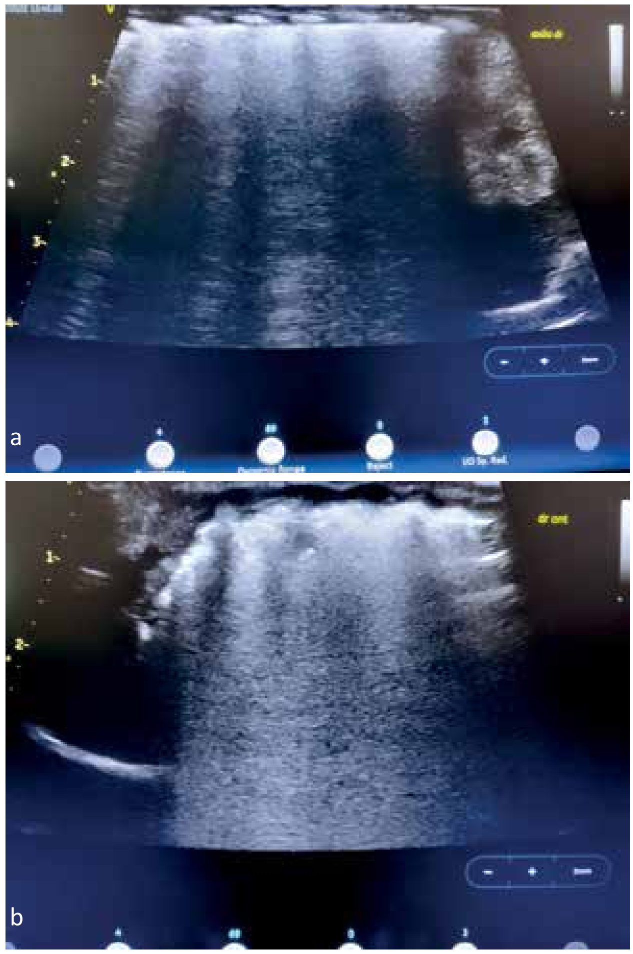
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FIGURE 2. a and b: Lung ultrasound aspect of pulmonary hemorrhage in a premature newborn at 40 hours of life (gestational age 27 weeks, female); a. right axillar view, b. right lung anterior-superior view

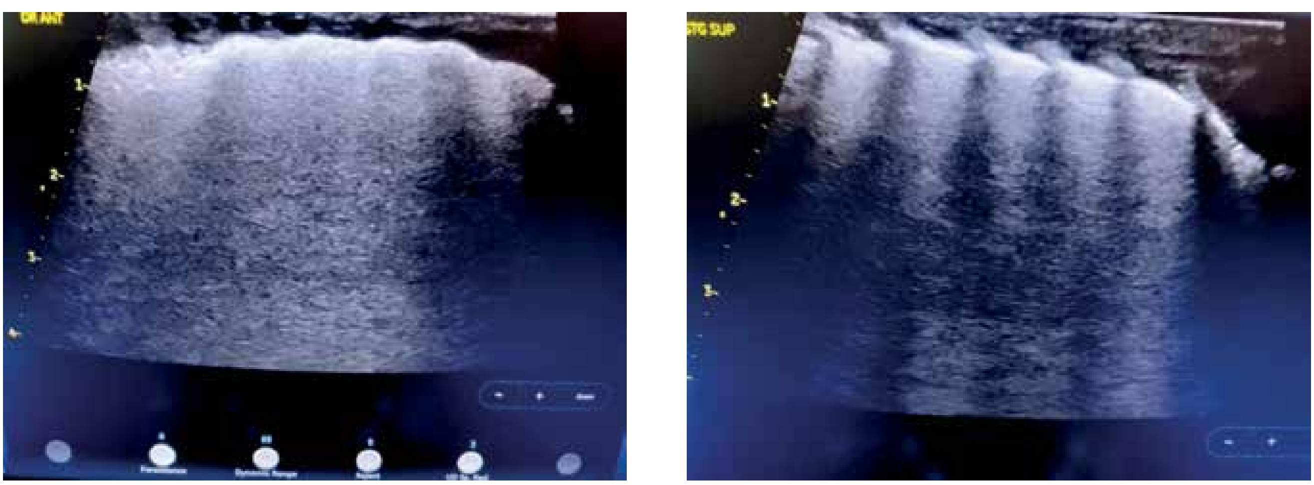
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FIGURE 1. Lung ultrasound aspect of RDS in a premature newborn (gestational age 25 weeks, birth weight 700 grams, male, Apgar score 3/6); a. right lung, anterior view, b. left lung superior anterior view

Clinical case 3: transient tachypnea

A typical sign is interstitial edema for which LUS has good sensitivity and higher specificity; depending on severity, examination revealed the presence of separate or confluent B-lines (vertical dynamic artifacts at the liquid-air interface) alternating with normal areas (A-lines) and areas with edema (B lines) predominantly in the lower pulmonary fields defined as a double long point.

Double lung point may be present but it has no 100% specificity, but it can make the difference between severe respiratory distress through surfactant deficiency and transient tachypnea.

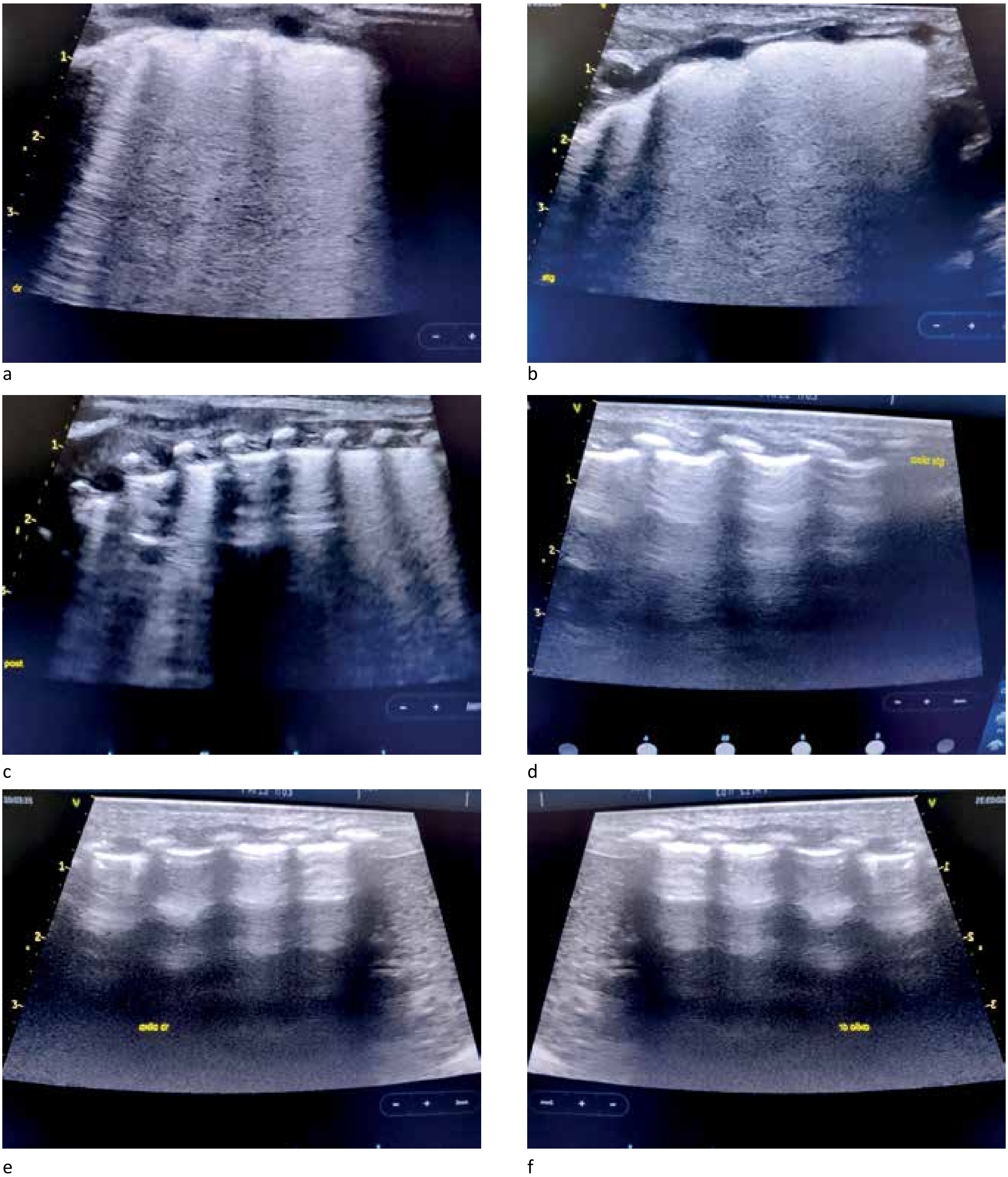
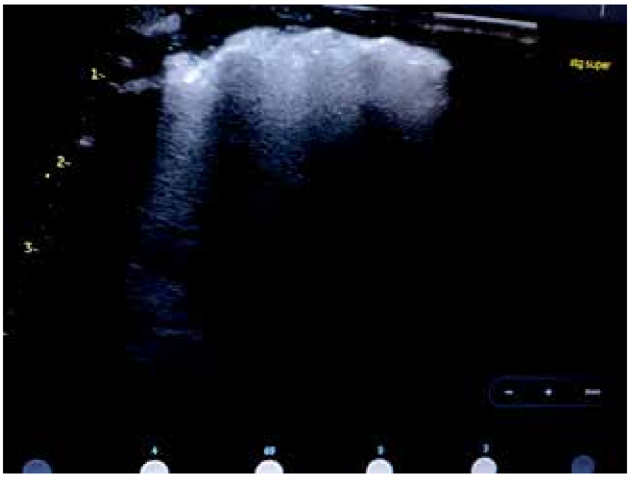


FIGURE 3. Lung ultrasound aspect of TTN in a late preterm newborn (gestational age 34 weeks, male, moderate grunting, nasal CPAP, clinically and ultrasound improvement in 12 hours); a. double lung point, b. alveolo-interstitial edema, c. confluent B-lines with the presence of few A-lines, d, e, f. LUS images after clinical improvement.

Clinical case 4: meconium aspiration syndrome

There can be present all the ultrasound signs, from normal areas to extended atelectasis or condensation, inhomogeneous images disseminated in both pulmonary fields: coalescent B lines, areas of atelectasis, condensation, and air bronchogram.

The signs change from one day to another, as the inflammation progresses and atelectasis induced by the meconium plugs may occur.



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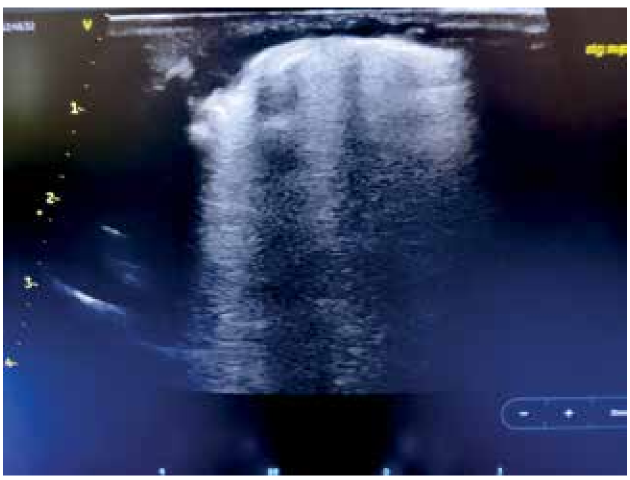

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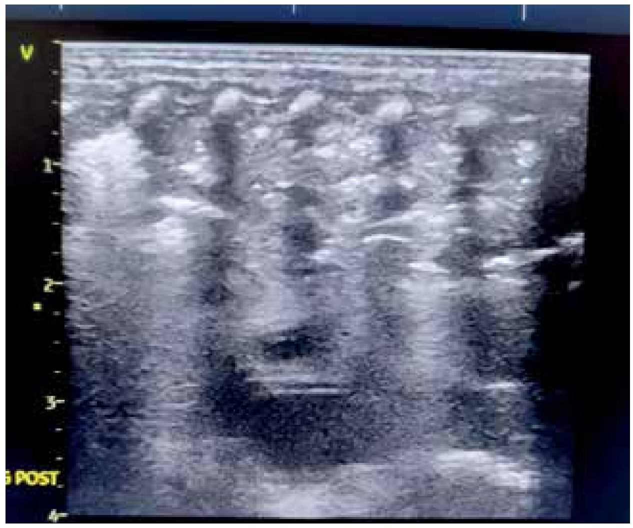
FIGURE 4. Lung ultrasound aspect of MAS in a newborn (gestational age 39 weeks, meconium stained amniotic fluid, respiratory failure requiring mechanical ventilation; a. LUS image in the second day of life, b. LUS image in the third day of life

Clinical case 5: pneumonia

Typical findings are consolidations with irregular edges and the presence of dynamic air bronchogram, associated with abnormalities of the pleural line (thickening, interruption, irregularities). B-lines are present in adjacent pulmonary fields corresponding to the extended inflammatory process, occasionally accompanied by pleural effusion.

The absence of "lung sliding", the presence of "lung-pulse" (pulsations with cardiac frequency), and the "shark sign" can also be identified in pneumonia.



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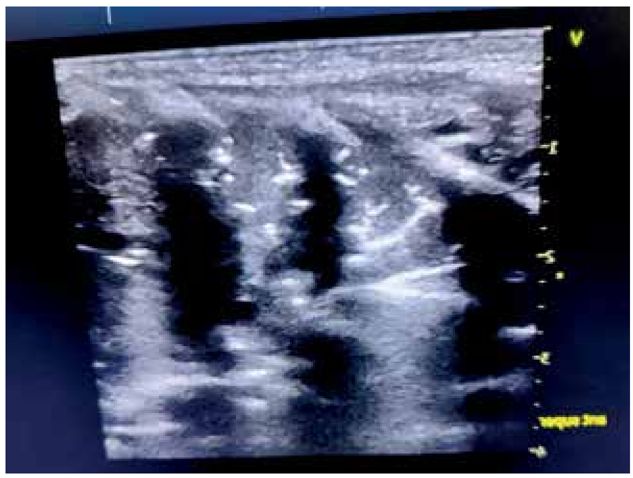

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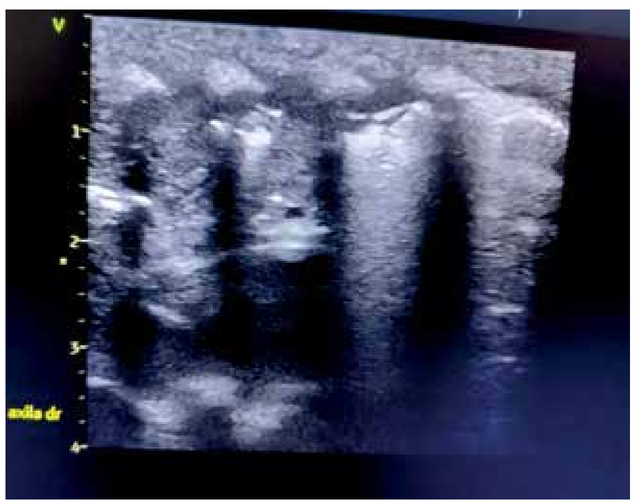

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FIGURE 5. Lung ultrasound aspect of pneumonia in a premature newborn who develops ventilation-associated pneumonia at the age of 1 month (gestational age 24 weeks, male, mechanically ventilated); a. sub-pleural consolidations, b, c. different stages of pneumonia

Clinical case 6: acute respiratory distress syndrome (ARDS)

Acute respiratory failure due to extensive inflammation of the lung tissue, endothelial injury, and secondary surfactant deficiency, both qualitatively and quantitatively.

Extensive inflammation of the lung tissue is reflected by extensive B-lines due to the presence of interstitial infiltration, consolidations, bronchogram, and occasionally atelectasis.

Although in the Montreaux definition of ARDS, pulmonary ultrasound has not been validated as the only imaging investigation, in our NICU we try to minimize the number of CXR per patient by performing LUS to appreciate the evolution of respiratory distress.

Clinical case 7: pneumothorax

LUS can establish the diagnosis in case of an emergency, until the CXR can be performed, and has superior accuracy compared to X-ray; it can also detect subclinical pneumothorax that can escape radi-

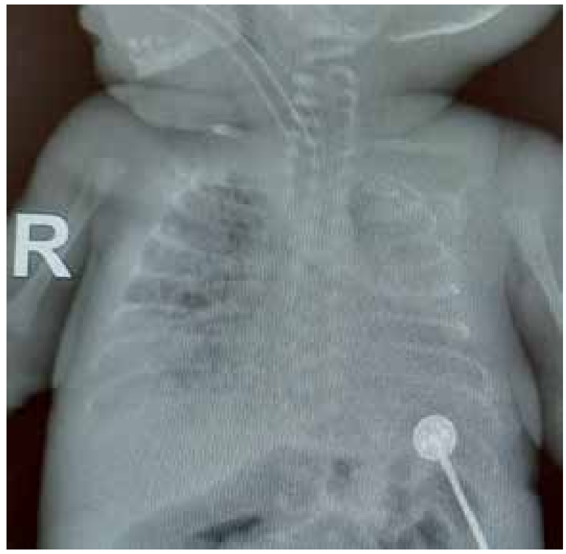

FIGURE 7. Radiography showing signs (of bilateral diffuse opacities or complete pulmonary opacification, which is not completely explained by the presence of pleural effusion, atelectasis, RDS, TTN, or congenital pulmonary abnormalities

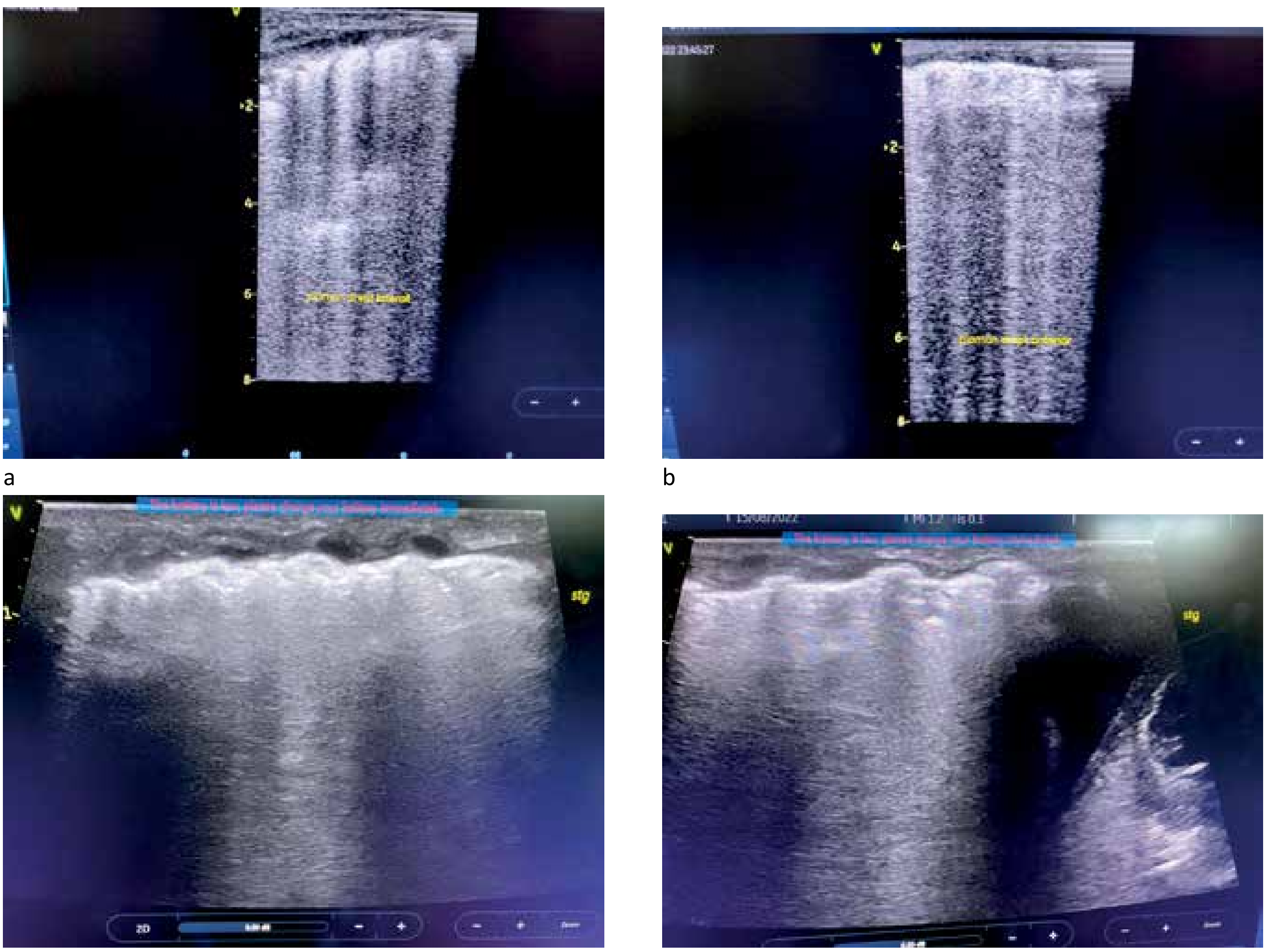
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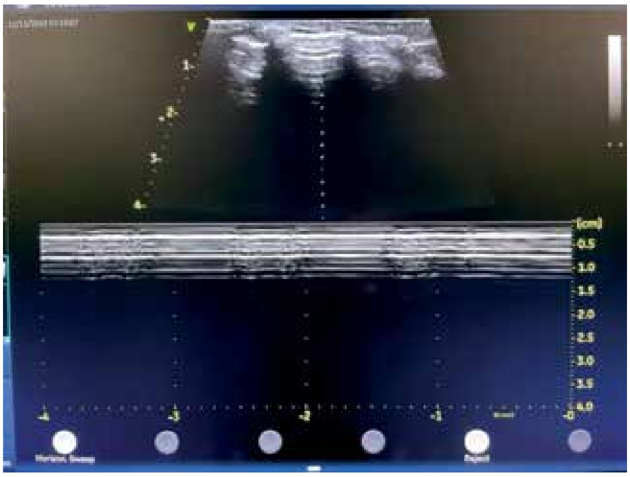
FIGURE 6. Lung ultrasound aspect of ARDS in a premature newborn (gestational age 25 weeks), who at 6 weeks develops worsening of the general condition, pallor, edema, increased oxygen requirements, important leukocytosis, positive inflammatory syndrome – healthcare-associated infection (no identified germ); a. right lung lateral view, b. right lung anterior view, c. confluent B – lines, d. subpleural consolidations



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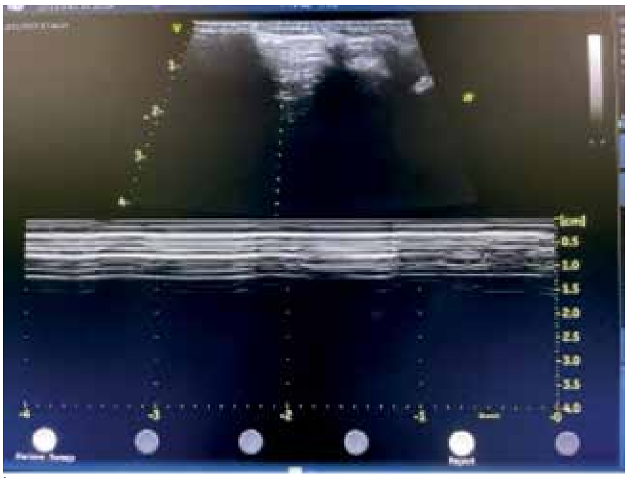

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FIGURE 8. lung ultrasound aspect of pneumothorax in a premature newborn (gestational age 32 weeks, male, birth weight 1400 grams, RDS, surfactant administration, mechanically ventilated); a. anterior-superior view, b. anterior-inferior view of the right lung, in M-mode showing barcode sign

ological detection. Typical signs are the absence of "lung sliding", the absence of B lines, the absence of lung pulse, and the presence of lung point. Switching to M mode the "barcode sign" is identified which means replacing the normal sand-like appearance with horizontal parallel lines.

CONCLUSIONS

Pulmonary ultrasound is a very useful method in the evaluation and monitoring of many pathologies frequently encountered in children, is recommended in daily medical practice, and has become a preferred investigative method that has entered the current practice of neonatologists. It does not completely replace the chest X-ray, but it can be useful in monitoring lung pathology over time. Pulmonary ultrasound is easy to learn and perform, has no risk of irradiation, can be done at the bedside, has a real-time review, provides prompt image, is clinically integrated immediately, it can be performed with any ultrasound machine, regardless of its performance.

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