Original article

Lung ultrasound: diagnostic and therapeutic issues

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Abstract. *Background*: Lung ultrasound (LUS) is becoming more and more utilised in the clinical field in adults, children and neonates in course of respiratory diseases. It can be done at bed side and repeated as much is needed without risks (namely irradiation). *Methods*: The technique of LUS execution and the normal and pathologic patterns of LUS in neonates are described. *Results*: The LUS findings in the different respiratory neonatal diseases are peculiar and consistently repeatable. *Conclusion*: The use of LUS in neonates may indicate in real time the diagnosis of the respiratory disease. Should be considered as an extension of the clinical exam and must be done by the clinician in charge of the patient. (www.actabiomedica.it)

Key words: lung ultrasound (LUS), respiratory neonatal diseases

Introduction

Neonatal respiratory diseases are often a diagnostic dilemma for the clinician due to the poor sensitivity and specificity of the signs and the symptoms. Not always the chest x-ray solves this dilemma since the inter- and intraobserver variability is wide. In the last twenty years the use of lung ultrasound (LUS) became more and more common in adult patients (1-4) and recently has been applied also in neonatal age (5-7). This paper points out technical and diagnostic issues on the use of LUS in neonates suffering for respiratory diseases.

Materials and metods

A high resolution linear probe 10 MHz or more is used for lung examination. The exam is performed in the incubator for the neonates and in supine and sitting position for the older patients. Longitudinal and transversal sections of the anterior, lateral and posterior wall were obtained. Each hemithorax is divided into 3 areas: one anterior area delimited by parasternal and anterior axillary line, one lateral area between anterior and posterior axillary line, and one posterior area beyond posterior axillary line.

Normal echographic lung appearance

In a normal lung the pleura appears as a regular echogenic line moving continuously during respiration. Beyond the pleura, the lung is filled with air and does not allow further visualization of normal lung parenchyma. The large change in acoustic impedance at the pleura-lung interface results in horizontal artifacts, defined as A-lines, that are seen as a series of echogenic parallel lines distally and are equidistant from one another (Fig. 1). Vertically oriented artifacts, called B-lines, indicate an abnormality in the interstitial or alveolar compartment and correlate with lung interstitial fluid content. B-lines project from the pleural line to the edge of the screen, erase A-lines, and move with respiration (Fig. 2). Because the fetal lung has a high fluid content, B-lines can be seen in the first day of life also in neonates without respiratory distress.

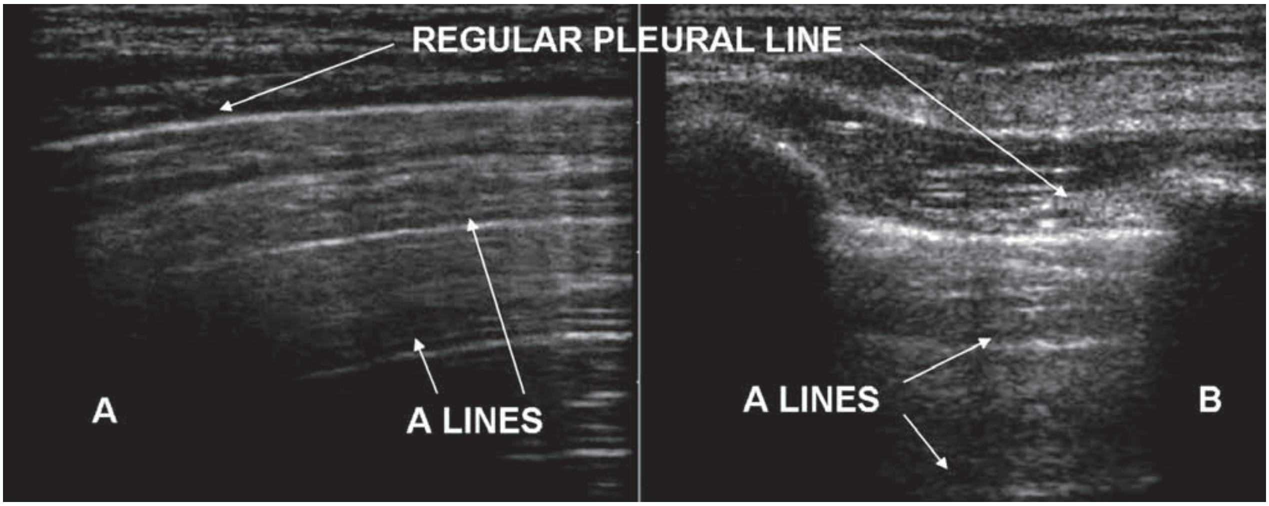

Figure 1. Normal lung appearance (panel A transversal scan, panel B longitudinal scan), note the hyperechoic pleural line and the regularly distributed A lines.

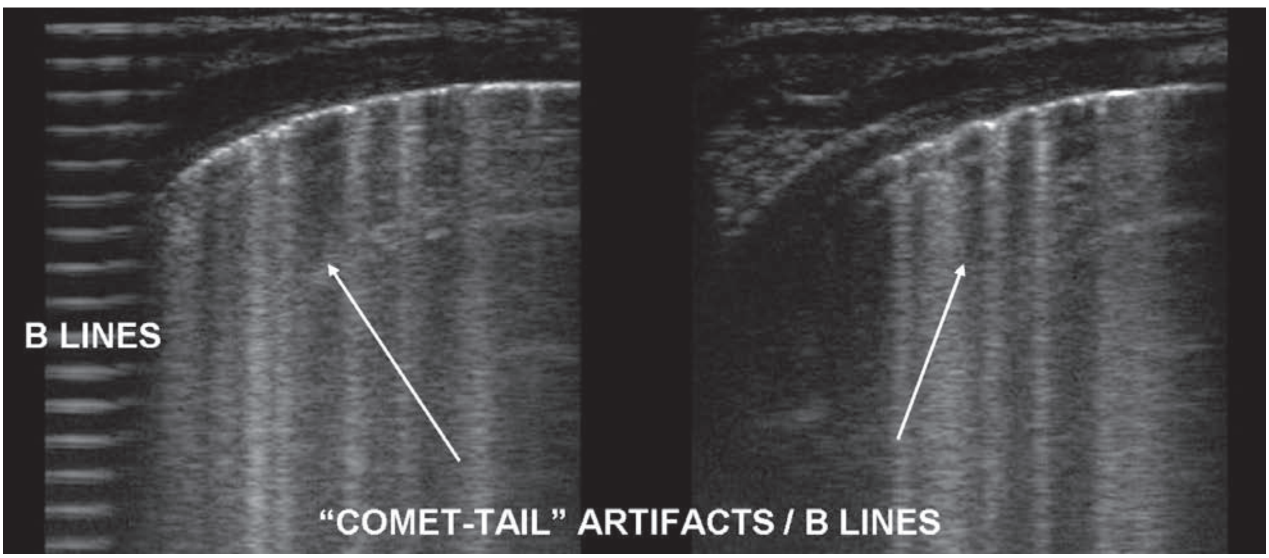

Figure 2. Vertical artifacts expression of alveolar interstitial syndrome

LUS appearance can simplified as follows: the normal lung is "black", moderately diseased lung (with interstitial water) is "black and white" (with white lines corresponding to B lines) and markedly diseased lung (with alveolar edema) is "white" (diffusely bright) (Fig. 3).

Fetal lung is very rich in fluids and therefore vertical artifacts can be seen also in healthy term newborns whether born vaginally or by caesarean section. Usually are more represented in the latter. They are not compact, rarely numerous, mainly in the right side but without a typical localization, and disappear completely within 12-24 hours of life.

Transient tachypnea of the newborn

Transient tachypnea of the newborn (TTN) represents a common form of neonatal respiratory

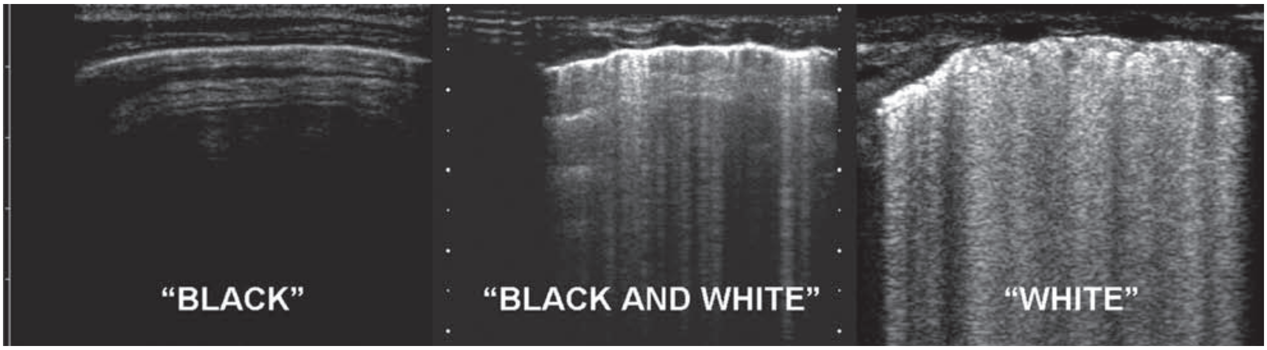

Figure 3. Differential diagnosis and lung ultrasound appearace. Black = normal, Black and White = degree of interstitial syndrome (fluid in to the septae and in to the alveoli), White = lung flooded by fluid

distress which has similar frequency all over in the world. About 33-50% of all neonatal respiratory distress are consistent with TTN (5). It has low morbidity, but often causes a severe respiratory burden that must be differentiated from other pulmonary or cardiac diseases (pneumothorax, pneumonia, sepsis, respiratory distress syndrome, congenital heart disease, etc.). TTN derives from a delayed clearance of fluid from alveoli and interstitium. In vivo studies demonstrated that pulmonary epithelium secretes Cl^- and fluids during all the pregnancy. The ability to reabsorb Na^+ and fluids appears only late in the pregnancy. After birth mature lung absorb Na^+ and fluid instead of secrete fluid and Cl^- . These changes are mediated by circulating catecholamines, steroids, vasopressin and by the increased oxygen tension. The concept of lung immaturity at birth depends largely by the inability to activate these mechanisms. TTN is more frequent in infants born by caesarean section for the lower levels of catecholamine present in respect to the infants vaginally delivered, and for the absence of thoracic compression which is applied during vaginal delivery.

The infants suffering for TTN show at the first ultrasound examination, constantly, more and very compact B-lines in the inferior pulmonary fields while in the superior fields the B-lines were present, but not compact (Fig. 4). This finding is evident in both lungs, even tough not always symmetrically. The border between the inferior pulmonary fields, where the artifacts are compact, and the superior ones is so sharp that the lung picture is peculiar. We defined "double lung point" this finding that is diagnostic for this disease. The pleural line is well defined, not thickened and hyperechogenic. Ultrasound evolution consists in progressive disappearance of compact pattern in the base with B-lines still well represented. At the same time also in the superior fields a reduction in B-lines number is noted. The double lung point disappears with coincident clinical improvement in 72-96 hours.

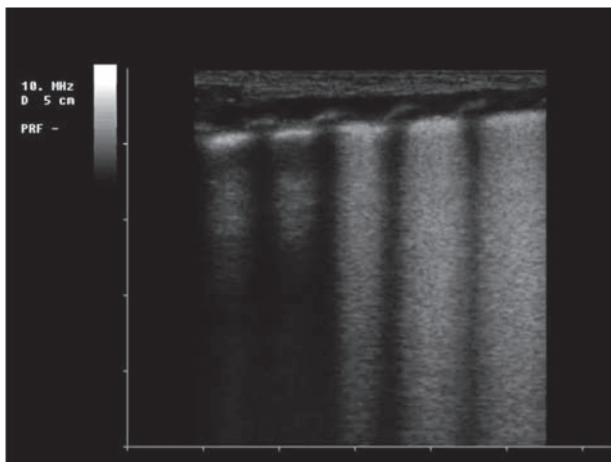

Figure 4. Transient tachypnoea of the newborn (TTN). Note the presence of "double lung point

Respiratory Distress Syndrome

Respiratory distress syndrome (RDS) of the newborn is defined as a surfactant deficiency disease causing insufficient aeration or collapse of the alveoli resulting in highly non homogeneous regional ventilation leading to development of progressive respiratory insufficiency. Both, surfactant

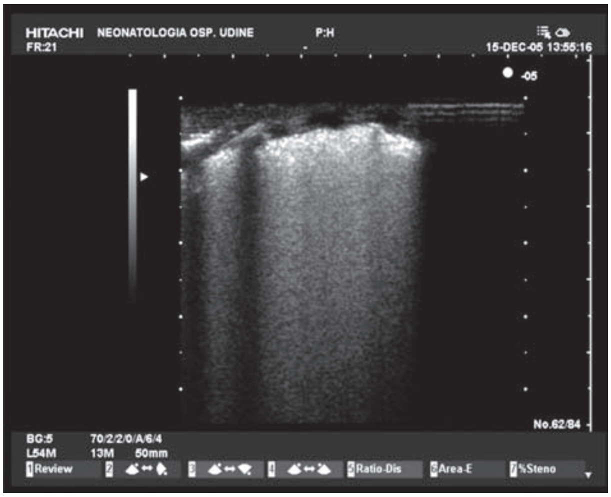

Figure 5. RDS. "White lung" with changes of pleural line that appears thickened, irregular and coarse

administration and mechanical ventilation were shown to reduce early mortality rate of the premature newborns due to RDS, but were not shown to reduce its long term consequence like bronchopulmonary dysplasia (BPD). It is well known that the surfactant administration rapidly and significantly improves lung X-ray images showing increased lung aeration even though the clinical conditions of the newborns are not always equally improved, but require the maintenance of mechanical ventilation sometimes for several days.

In the infants suffering for RDS we found at lung ultrasound consistently B lines who were compact, diffuse and symmetrically widespread distributed in both lungs. This pattern determined a picture of echographic "white lung" (Fig. 5). The pleural line was always extensively involved being thickened, irregular, not well defined and coarse. Multiple subpleural hypoecoic areas, generally small, were observed, mainly in the posterior and lateral scans, expression of lung consolidation (Figg. 6, 7). Larger consolidations with tissue pattern and with evidence of air or fluid bronchograms may be observed more frequently in posterior fields. In the infants studied before and after surfactant administration, the ultrasound lung picture did not substantially change in the first 48 h.

No correlation was found between ultrasound appearance and different radiological stages of RDS.

The echographic evolution is very heterogeneous, in some infants areas of "white lung" persist for several weeks, in other the alveolar interstitial syndrome is less severe, but, in any case, at 36 weeks of post-conceptional age, it is present with different degree in all the infants. In the neonates who developed BPD a picture of non homogeneous alveolar-interstitial syndrome is observed, but always with diffuse changes of pleural line that is thickened with multiple small subpleural consolidations.

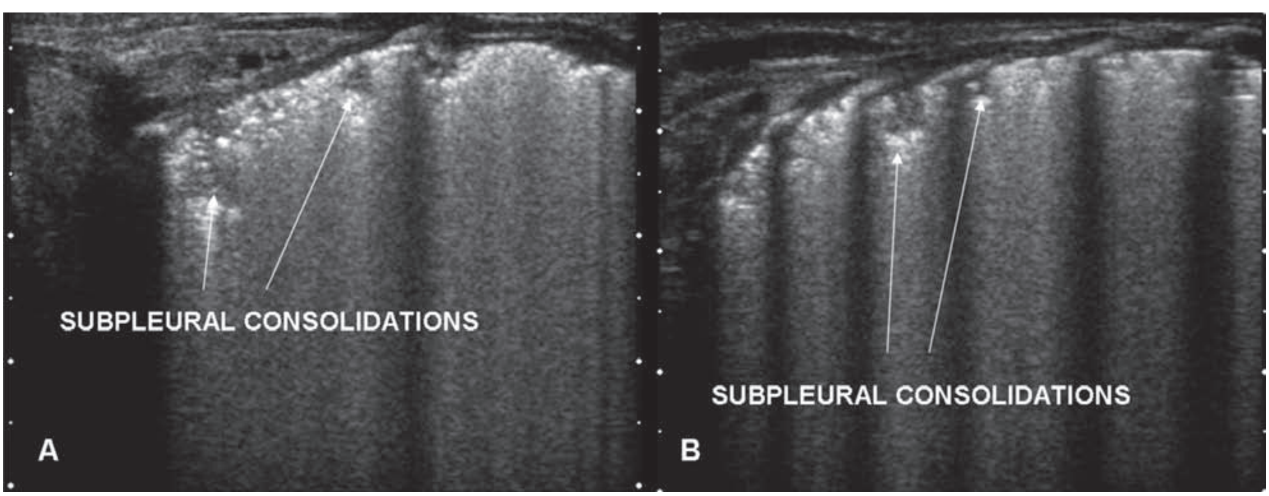

Figure 6. RDS. Subpleural consolidations seen in RDs are expression of lung collapse

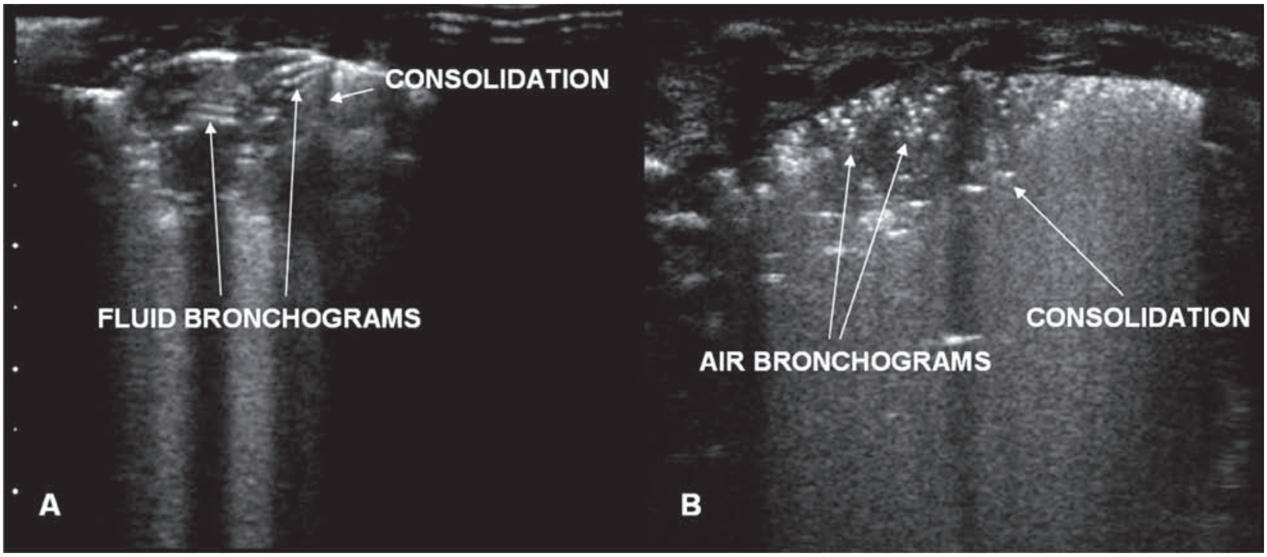

Figure 7. RDS. Subpleural consolidations in RDS, note the presence of fluid brochograms

Conclusion

In summary, on clinical ground, we point out the following issues:

1. Our findings support the validity of lung ultrasound to follow the dynamics of interstitial lung fluid clearance in the postnatal hours. This diagnostic approach represents a non aggressive and highly informative, easily repetitive, non harming tool performable at the bed side. As far as practical aspects of our findings are concerned, we strongly suggest the use of lung ultrasound in neonatal age as a first line imaging technique.
2. Lung ultrasound detects precisely the presence of interstitial and/or alveolar fluid in RDS and the images are in full concordance with clinical course of RDS, but not x-ray.
3. Surfactant does significantly improve gas exchange but not lung fluid clearance.

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