REVIEW ARTICLE

What is POCLUS ? - Point of Care Lung Ultrasound

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ABSTRACT

Lung ultrasonography (LUS) is becoming a bedside point of care technique in critical care. Lung ultrasound recently has seen an explosion of interest in neonatal care and the evidence about its usefulness is constantly growing. And the added advantage is, it is non-invasive, radiation free, bedside and ideal for the extreme low birth weight neonates and can be interpreted by the neonatologist himself with a little training. Neonatal lung diseases often cause confusion for clinicians due to the non-specific nature of respiratory distress in neonates. Lung ultrasound is a new tool for detecting lung diseases in clinical practice and exhibits high sensitivity and specificity. The various lung ultrasound findings and their interpretation in relation to common neonatal lung conditions like transient tachypnea of newborn (TTN), Respiratory distress syndrome (RDS), Pneumonia, Pleural effusion and Pneumothorax are discussed. Lung ultrasound provides valuable real-time information, which makes it particularly promising for further applications in NICUs. The usefulness of the new Lung Ultrasound (LUS) score in relation to RDS and decision taking on surfactant administration is being delineated. Lung ultrasound scores can be used to guide early surfactant replacement in extremely preterm neonates with RDS & avoid unnecessary harmful x-rays. However, lung ultrasound should not to be performed in isolation; it should be combined with the clinical findings.

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WHAT IS POCLUS ?
POINT OF CARE LUNG ULTRASOUND

INTRODUCTION

Lung disease is one of the most common cause of neonatal respiratory distress, resulting in respiratory failure and death in severe cases. Traditionally, chest X-ray has been considered as the most valuable imaging modality for the diagnosis of lung diseases, but it unavoidably causes radiation damage to the infant. Neonates are susceptible to radiation because they have rapidly dividing cells that cannot repair mutated DNA.

Lung ultrasound (one of the latest among imaging techniques) is the point-of-care tool the clinician can use at the bedside. Several studies have demonstrated that lung ultrasound is an accurate and reliable technique for the diagnosis of neonatal

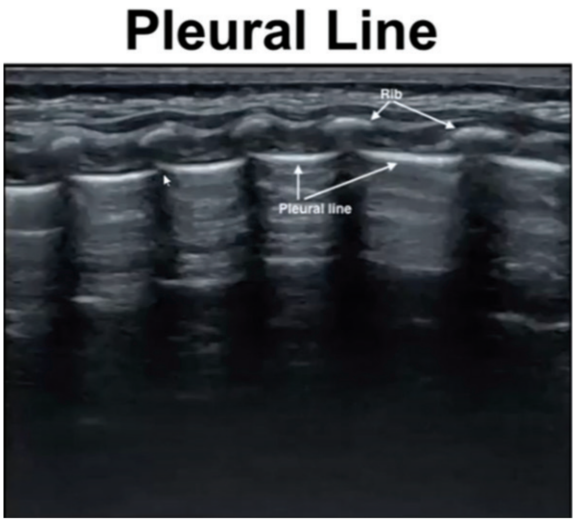

Figure 1a. Normal, Regular, Hyper-echoic Pleural line
Courtesy: DrPradeepSuryawanshi (Ref 11,12)

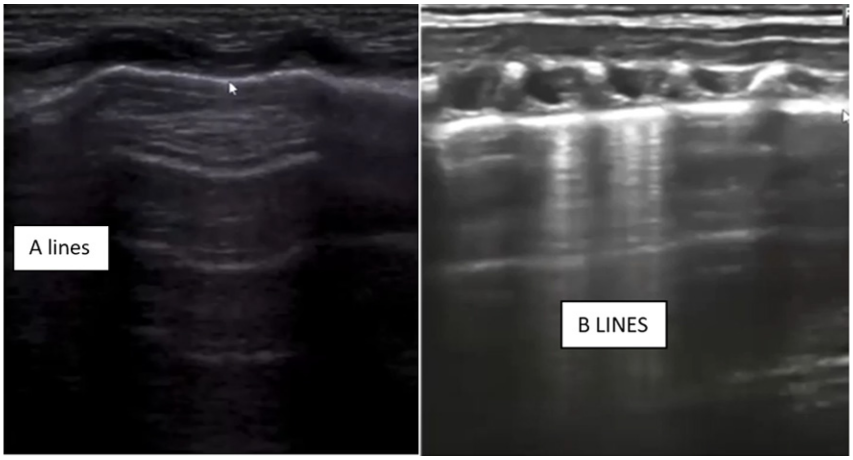

Figure 1b,c. Lung Ultrasound showing A & B lines
Courtesy: DrPradeepSuryawanshi (Ref 11,12)

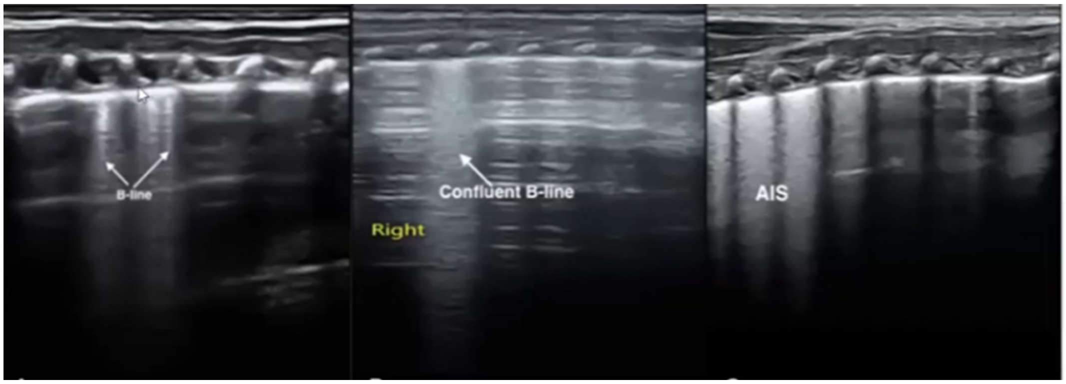

Figure 1d. B lines, Confluent B lines & Alveolar Interstitial Syndrome (AIS)
Courtesy: Ref 8

lung diseases.[1] Other advantages of lung ultrasound include that it is non-invasive, radiation-free, can avoid harmful x-rays, inexpensive in the long run, easy-to-learn and operate, bedside, quick & repeatable technique and the imaging is performed in real-time, thus making it a potential tool to be used in neonatal intensive care units (NICUs).[1] It can be performed immediately at the bedside and interpreted by the frontline Neonatologist himself.[2] In another 5-10 years the clinicians will soon be carrying a portable ultrasound in their white coat pockets instead of the Stethoscope.

Lung ultrasound in various neonatal lung diseases:

In normal aerated lungs, ultrasound is limited, because no acoustic mismatch occurs in the ultrasound beam when it encounters air.[3] When the air content decreases with subpleural interstitial edema, the ultrasound beam generates an acoustic mismatch between the fluid interfaces surrounded by air. Thus lung ultrasonography (LUS) makes an easy and quick recognition of a normal aerated lung in contrast to an interstitial or alveolar pattern.[1,3,4] Recognition of these patterns may be even easier in neonates owing to the small patients' size and the absence of obesity or heavy musculature.[1,3] Characteristic LUS images[5-9] have been described for several common neonatal respiratory conditions such as transient tachypnea of the neonate (TTN), Hyaline membrane disease (Respiratory distress syndrome [RDS]), Meconium aspiration syndrome (MAS), Pneumothorax, Pleural effusion and Atelectasis.

The 12 common neonatal lung ultrasound findings:[5-12]

1.The pleural line: The pleural line is a normal, smooth and regular hyperechoic line that moves to-and-fro during respiration, which is called lung sliding **(Figure 1a).**

2. "BAT Sign": the appearance of the hyperechoeic pleural line below the ribs in the intercostal area

3. Sea shore sign or the Sandy Beach sign: In M mode ultrasonography, two separate areas are seen due to normal pleural movement- a series of wavy line high echoes above the pleural line (like waves on a beach) and the uniform granular dot echo generated by lung sliding below the pleural line (like sand on a beach) together form a beach like picture known as Sandy beach or Seashore sign

4. A Lines: The A-lines are a series of parallel lines at regular intervals below the pleural line. They represent the large change in acoustic impedance at the pleura-lung interface and generate horizontal artifacts **(Figure 1b)**

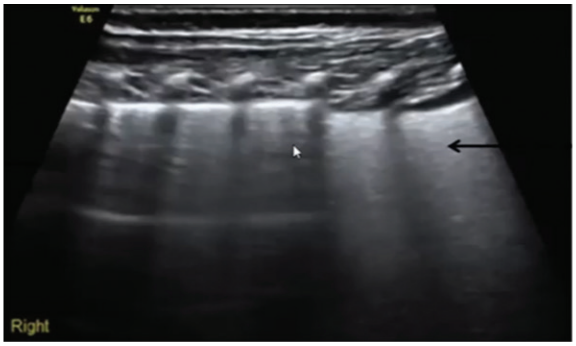

Figure 2a. Double Lung Point (TTN)
Courtesy: PradeepSuryawanshi (Ref:11,12)

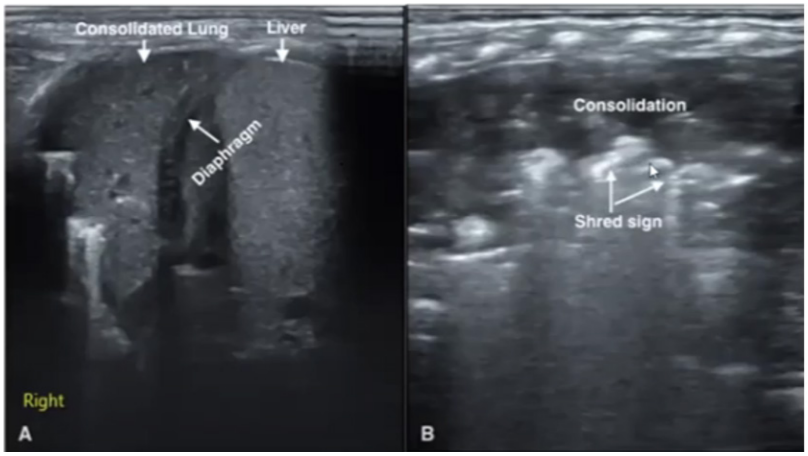

Figure 2b. Features of consolidation
Courtesy: Ref:8

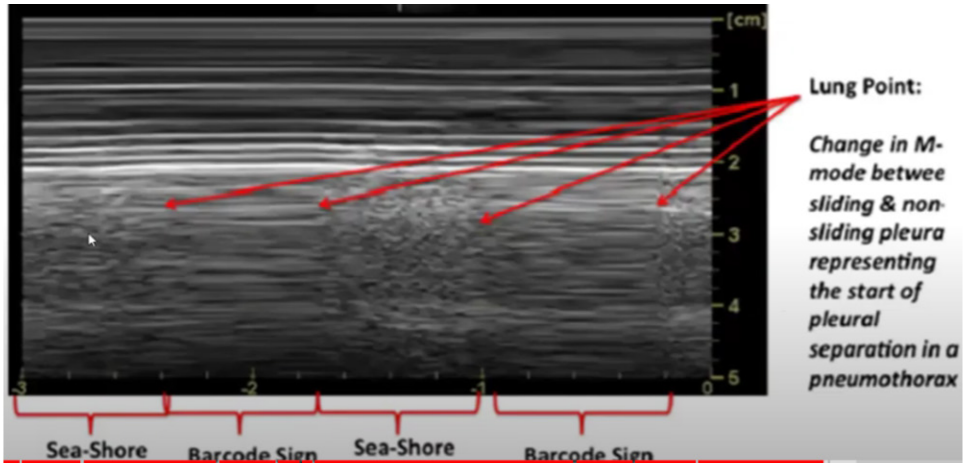

Figure 2c. Showing lung point, bar code and seashore sign
Courtesy :Dr Pradeep Suryawanshi (Ref 11,12)

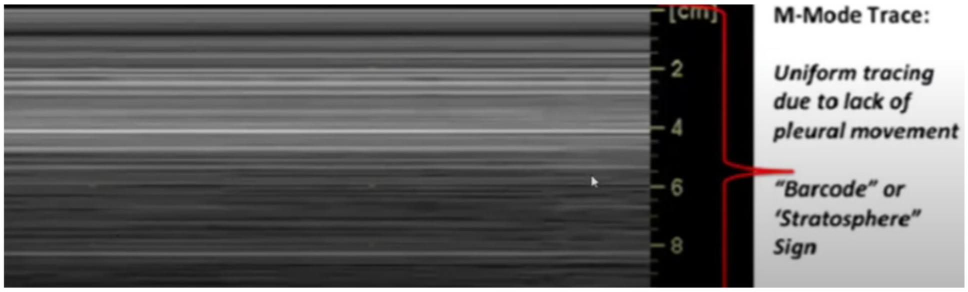

Figure 2d. Bar code or Stratosphere sign (Pneumothorax)
Courtesy :Dr PradeepSuryawanshi

A-lines represent reflection of pleura due to ultrasound diffusing through an air-filled lung. In fact, they are reverberation artifacts caused by the pleural line. They are echogenic, horizontal and parallel to straight solid pleural line and equidistant from each other.

5. B lines: arise from the pleural line perpendicular to it. They are vertical, laser-like, hyper-echoeic and erases the A lines. The accumulations of fluid in subpleural interstitial and alveolar spaces alter air-fluid ratio and produce characteristic artifact called B-lines When the air content decreases with sub-pleural interstitial edema, the ultrasound beam generates an acoustic mismatch between the fluid interfaces surrounded by air and reflects repeatedly at the deeper zones. This phenomenon creates vertical reverberation artifacts called B-lines. B-lines are hyperechoic, laser-like images that originate from the pleural line, perpendicular to it and reach the edge of the screen, moving with respiration **(Figure 1c).** Thus, B-lines are correlated with lung interstitial fluid content, and their number increases with decreasing air content. Multiple B-lines indicate alveolar-interstitial syndrome. B lines move synchronously with lung sliding and respiratory movements.

6. Confluent B lines: Confluent B lines occur when the entire inter-costal space is full of intense B lines but the acoustic shadow of ribs will still be clearly displayed. The presence of multiple B-lines is the sonographic sign of lung interstitial syndrome **(Figure 1d)**

7. Alveolar interstitial syndrome (Figure 1d): When more than 2 B lines are present in each lung field, it is called alveolar interstitial syndrome.[5,10,11]

8. Double lung point (Figure 2a): There will be a clear difference between upper and lower lung fields; the sharp cutoff between the upper and lower lung field is known as a "double lung point", the upper lung fields showing A lines and

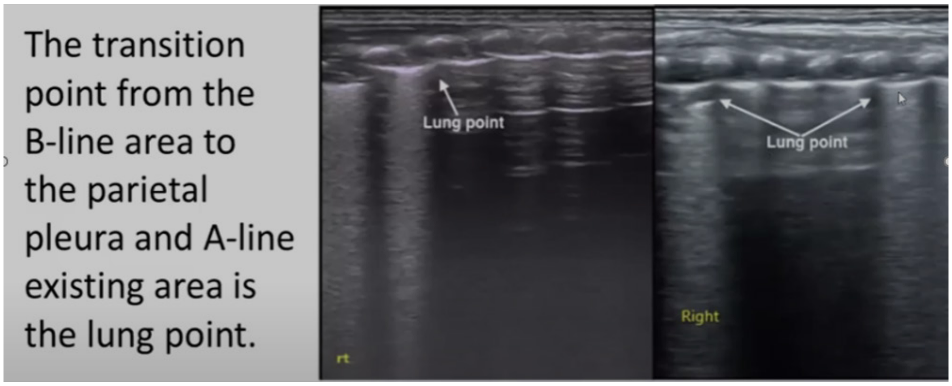

Figure 2e. Showing the lung point
Courtesy :Dr PradeepSuryawanshi (Ref 11,12)

the lower lung fields showing the B lines. This is very typical of Transient tachypnea of newborn (TTN).[5,9]

9. Hepatization of lung/ shred sign /tissue like sign are all features of lung consolidation. When the boundary between consolidated lung tissue and the aerated lung tissue is unclear and the ultrasound picture formed between the two areas is irregular and shredded is called the shred sign or tissue like sign **(Figure 2b)**

10. Lung Point: Point of transition between an area of presence and an area of absence of lung sliding. In M-mode ultrasound, the change between sliding and non-sliding pleura represent the start of pleural separation in pneumothorax and is a very specific sign of pneumothorax **(Figure 2c).**

11. Barcode sign or Stratosphere sign: specific for pneumothorax. The M mode tracing, in the absence of pleural movement looks like a barcode. Above and below the pleural line look exactly the same. When lung sliding disappears, the granular dot echoes are replaced by a series of horizontal parallel lines (absence of seashore sign). This type of ultrasonographic sign is called the barcode sign or Stratosphere sign (like a smoke emitted by a jet plane in the stratosphere) **(Figures 2 b,c,d)**

12. Quad sign or Sinusoid sign: suggestive of pleural effusion. Fluid between the parietal and visceral pleura takes a quadrangular shadow with rib margin. In between inspiration and expiration, the visceral pleura moving in and out gives the sinusoid pattern with fluid in between the pleural lines.

ULTRASOUND FINDINGS IN MAIN RESPIRATORY CONDITIONS IN NEONATES

Transient tachypnea of newborn (TTN):[5,9] Lung ultrasound enables the detection of pulmonary fluid and thus can effectively diagnose TTN. The main characteristic of TTN is fluid in the lung which primarily presents as double lung points, alveolar interstitial syndrome or white lung. The pleural line is normal, well-defined and regular in bilateral lungs. The double lung point sign refers toa sharp boundary found between relatively aerated superior lung fields and coalescent B lines (representing interstitial oedema) in the basal lung fields with a reported sensitivity of 45.6% to 76.7% and a specificity of 94.8 to 100%. In diagnosing TTN. The double lung point is a demarcation point for echogenic differences in the lung field. Ultrasound images show compact B-lines in the inferior lung field and A-lines in the superior lung field **(Figure 2a).**

Pneumonic consolidation: The ultrasonographic findings of pneumonia include lung consolidation with irregular margins and surrounding multiple B-lines. The lung consolidation is shown by hepatization of the lungs (the lung architecture looks exactly like that of liver surface), shred sign or tissue sign with irregular subpleural consolidations. **(Figure 2b)** and air bronchograms. The pleural line is not visible in the area, and lung sliding is absent. Dynamic air bronchograms are visible in large consolidations and represent bronchial patency, which excludes atelectasis.

Atelectasis: The ultrasonographic features of atelectasis include large lung consolidation with well-defined borders, pleural line abnormalities, and the absence of lung sliding

Pneumothorax:[7] There is collection of air between visceral and parietal pleura in pneumothorax. This results in the absence of lung sliding. Ultrasound images of pneumothorax exhibit the absence of lung sliding, absence of B-lines, absence of seashore sign, and presence of a lung point **(Figure 2c,d,e),** barcode sign or the stratosphere sign. The absence of lung sliding and B-lines is caused by air accumulation in the pleural cavity, resulting in a lack of movement of the visceral pleura. The lung point is a specific sign of pneumothorax. In a meta-analysis, LUS had sensitivity, specificity, positive predictive value and negative predictive value of 100% for the diagnosis of pneumothorax. LUS accurately rules in and also rules out the diagnosis of pneumothorax than supine anterior chest radiography. The sonographic signs in ruling in pneumothorax are: absence of lung sliding, absence of B lines, absence of Seashore sign and presence of Barcode sign or Stratosphere sign and the Lung point **(Figures 2c,d,e)**

Meconium Aspiration Syndrome: The following dynamic LUS signs are seen in MAS: (1) B-pattern (interstitial) coalescent or sparse; (2) consolidations; (3) atelectasis; (4) bronchograms. LUS is a useful and promising tool in the diagnosis and management of MAS, providing real-time bedside imaging, with the additional potential benefit of limiting radiation exposure in sick neonates.

Vol 2 | Issue 1 Jan - Jun 2022

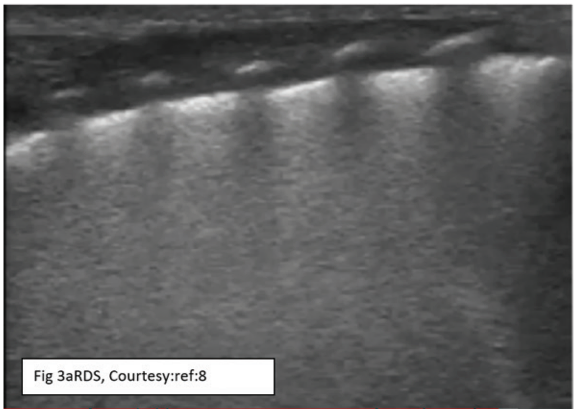

Figure 3a. 3A showing usg typical of RDS

Respiratory Distress syndrome (RDS) (Figure 3a)

The typical LUS appearance of RDS consists of : Bilateral white lungs + 'Sub-pleural' small consolidations +Pleural abnormalities like irregular thickened pleural line. Absence of spared areas (with A-lines) will be a most noticeable sign

The three signs –Bilateral diffuse white lung appearance, with no spared areas and thickened irregular pleural line with sub-pleural consolidations show almost 100% sensitivity and specificity for RDS

The ultrasonic features of RDS are compact B-lines with an echo graphic white lung appearance, the presence of a thickened and irregular pleural line, and multiple subpleural lung consolidations indicating alveolar collapse **(Figure 3a).** These signs were confirmed by Copetti et al. to have sensitivity and specificity of 100% for the diagnosis of RDS.[8]

The LUS score:[11-15] A recent meta-analysis of six single-center studies concluded that a lung ultrasound score (LUS) can be used accurately to determine the need for surfactant replacement treatment in infants with respiratory distress syndrome treated with nasal CPAP support. LUS is a reliable predictor of the need for surfactant administration, and its accuracy increases when combined with oxygen saturation to FiO2 ratio, regardless of the degree of prematurity.

Methodology: Basically, each lung is divided into 3 areas (upper anterior, lower anterior, and lateral). For each lung area, a 0- to 3-point score is given (total score ranging from 0-18). The LUS score encompasses signs typical of TTN and RDS5,6 and describe the total spectrum of possible conditions (a normal aerated lung, an interstitial pattern, an alveolar pattern, and consolidation). The LUS score is assigned as follows: 0 indicates A-pattern (defined by the presence of the only A-lines); 1, B-pattern (defined as the presence of ≥3 well-spaced B-lines); 2, severe Bpattern (defined as the presence of crowded and coalescent Blines with or without consolidations limited to the subpleural space); and 3, extended consolidations.

LUS has been demonstrated to be useful to guide surfactant replacement in several single-center and diagnostic accuracy studies, and in RCTs.[13] Use of ultrasound scanning to predict surfactant replacement allows the physician to administer the drug within 2 hours of life in most cases, between 24- and 34-weeks gestation and seem independent from gestational age.

Lung Ultrasound Protocol: Lung ultrasound is done soon after NICU admission and before surfactant administration (within 2hrs of delivery). All attending physicians should be trained. The LUS score is calculated on the basis of 3 chest areas for each side (upper anterior, lower anterior & lateral). A score of 0 to 3 points is given for each area. Total score ranges from 0 to 18, inversely correlating with lung aeration

LUS score can be used to accurately predict the need for the first surfactant dose and also the need for surfactant redosing.

LUS score for Surfactant[12,13,15]**:** A LUS score can be used to accurately predict need for 1st surfactant dose & reveals fair accuracy in predicting surfactant re-treatment. A LUS score cutoff value between 6 &8 provides optimal sensitivity and specificity for predicting the need for 1st surfactant dose, whereas a cutoff value of 10 predicts need for surfactant re-treatment. LUS score has good reliability to predict surfactant Rx in preterms less than34 wksesp ELBW infants with RDS on nasal CPAP.

CONCLUSION

In recent years, neonatal lung ultrasound has been widely used in clinical practice. Ultrasound findings combined with clinical information are useful for the diagnosis of neonatal lung diseases. In addition, lung ultrasound is safe, no risk of radiation, and easy to operate tool that can be repeatedly and rapidly performed at the bedside without anesthetic drugs. At present, lung ultrasound is not only used for the diagnosis of neonatal lung diseases but also plays a positive role in real-time monitoring and assessment. It shows good reliability for predicting the need for surfactant administration in extreme premature infants with RDS on CPAP. LUS Score 0 means normal aeration (A-lines or no more than two B-lines); score 1, moderate loss of aeration (three or more well-spaced B-lines); score 2, severe loss of aeration (coalescent B-lines); and score 3, complete loss of aeration (tissue-like pattern)

LUS is a useful criterion for surfactant administration regardless of GA and, in combination with oxygen saturation to F_iO_2 ratio, provides the highest accuracy.

Lung ultrasound scores can be used to guide early surfactant replacement in extremely preterm neonates with RDS & avoid unnecessary harmful x-rays. However, lung ultrasound should not to be performed in isolation; it should be combined with the clinical findings.

Vol 2 | Issue 1 Jan - Jun 2022

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