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# Neonatal Lung Ultrasound - Personal Practice Guideline with Illustrative Case Reports and Inferences

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## Abstract

Lung ultrasound (LUS) is gaining increasing adaptation in neonatal units worldwide for the evaluation and management of neonatal respiratory disorders. Neonatologist performed lung ultrasound (NPLUS) is a bedside, repeatable, cost effective, safe and quick modality of understanding and managing neonatal respiratory disorders. In some neonatal units in Europe and China who have the requisite level and spread of expertise, NPLUS has eliminated the need for routine X-Ray (XR) Chest examinations in the neonatal unit. LUS must be compared to as a provision of a 3-dimensional computerized tomography (CT) lung scan equivalent imaging technique by the bedside. As the confidence and experience of the neonatal team in NPLUS matures, NPLUS will lead to minimizing XR chest requests with the resultant benefits of significant cost savings, reduction of radiation risk and a reliable real time bedside objective guide towards identification prognostication and targeted management of neonatal respiratory distress.

***Keywords:*** *Lung Ultrasound; Respiratory Diseases; Prematurity; Neonate; Artefacts*

## Abbreviations

CLD: Chronic Lung Disease; CT: Computerized Tomography; LNU: Local Neonatal Unit (BAPM Definition); LUS: Lung Ultrasound; MAS: Meconium Aspiration Syndrome; MRI: Magnetic Resonance Imaging; NICU: Neonatal Intensive Care Unit; NIV: Non-Invasive Ventilation; NPLUS: Neonatologist Performed Lung Ultrasound; PACS: Picture Archiving and Communication System; RDS: Respiratory Distress Syndrome; TTN: Transient Tachypnoea of Newborn; XR: X-Ray

## Introduction

Medical application of Ultrasound waves in the interrogation of human organs and cavities revolutionized modern medicine in many ways. But lungs remained an orphan to the application of sonar interrogation due to the traditional wide belief that the scatter attenuation of air prevents such. Focussed researchers nevertheless continued their analysis of reverberation artefacts from reflections from the pleural air interface, the horizontal A waves (We can say A stands for Air pleural interface) and the vertical comet tail like diving and moving B lines [1,2]. In a sentinel publication it was reported pneumothorax leaves a signature pattern in lung ultrasound in neonates and it is now accepted that it is more sensitive than a XR Chest and 100% specific [3,4]. Further clinical research has confirmed the usefulness of LUS as a diagnostic, prognostic and management tool in neonatal respiratory disorders. LUS is gaining increasing acceptance and adaptation in the neonatal units worldwide as the clinician's bedside quick and easy access tool in diagnosing and management of neonatal lung disorders. Neonatologist performed lung ultrasound (NPLUS) is proposed as a new terminology to define this competency and along with the terminology neonatologist performed echocardiography (NPE) constitute an essential skill within neonatal point of care ultrasound (Neo-POCUS) [5].

In this article, we present and discuss LUS on these headings:

1. The physiological principles of LUS.
2. Expand on to discuss the common LUS pattern recognition in the common neonatal respiratory disorders and pleural space collections.
3. How to do LUS?: An illustrated guidance from personal practice.
4. Should XR chest examination remain the Hobson's choice in evaluating neonatal respiratory disorders? Illustrative case reports of LUS:

I believe this article shall serve as a beginner or standard level LUS operator and reporting guidance. For neonatologists with more experience, recent articles reporting international and expert consensus guidelines on NPLUS are recommended for additional reading [6-8].

## Physiological principles of LUS

LUS is basically interpretation of reverberation artefacts generated by reflection and dispersion of sound waves at the pleural interface and the abutting lung surface. If the underlying lung is well expanded with air, then there we get A lines or horizontal reverberation artefacts marking the intercostal space pleural lining and if the lung is fluid laden or unexpanded then the ultrasound waves dive deep vertically across the more denser lung parenchyma and its septae creating B lines that move with breathing movements (sliding). The B lines that are discrete and few can progress to confluent and later homogeneously Sono-opaque and be hepatized as well with increasing severity of the lung disease [1].

We can say that LUS is the intelligent extrapolation of the:

1. 2 common artefactual patterns A waves and B waves along.
2. The pleural line sonic reflection characteristics (regularity, thickness).
3. The real USG images of consolidation or solid lung surface or abscess adjacent to pleural surface (sub pleural consolidations micro < 0.5 cm or large > 0.5.
4. Real USG images of fluid collection within the pleural space displacing the lung.
5. The shred lines a USG linear separation of real USG images mentioned at point 3 above from the artefactual images mentioned at point 1.
6. Sliding, an adapted slang that describes the respiratory movements of lung surface underneath the intercostal acoustic windows (a see saw movement of the A and B lines). Absence of sliding is a strong marker of pneumothorax.

## LUS pattern recognition in the common neonatal respiratory disorders and pleural space collections

The theoretical principles of LUS as applied to diagnose and manage the neonatal lung disorders [1,4,9]:

1. Since the common neonatal lung disorders are usually generalized pathologies extending up to the pleural surface, LUS is useful by way of pattern recognition of reverberation artefacts (horizontal pleural reflections the A lines and the perpendicular interstitial fluid compartment reflections the B lines).
2. In pathologies wherein the air within lung tissue is entirely replaced by fluid or is consolidated densely, effusions, pneumonia or when pleural space is filled in with fluid, the ultrasonic waves do penetrate such tissues and LUS images become real images as in any other USG examination and must be interpreted as such.

3. In pneumothorax the lung is displaced by air filled in pleural space that splays the visceral and parietal pleural opposition, and, in such cases, the Horizontal A pleural line artefacts are generated against the parietal pleura and air in pneumothorax and so we have an unusually well-defined stacking of A lines with absence of sliding as lung is not opposed to the pleural surface. These are more elegantly defined as Bar code sign on an M mode interrogation line applied.
4. In contrast M mode interrogation of the A lines generated across a sliding pleural lung interface will be a seashore pattern due to the preserved sliding. With careful LUS imaging a Lung point or the transition between normal A lines and Pneumothorax zone A lines is delineated and this can quantify the extent of pneumothorax and in following the course.
5. The common neonatal lung disorders respiratory distress syndrome or surfactant deficient lung disease, transient tachypnoea of newborn, meconium aspiration syndrome and chronic lung disease are identifiable, and their severity graded by the intermix of A and B lines, absence of A lines and density of B lines.
6. Focal pathologies like lung abscess and consolidation extending or abutting pleural interface are detected by LUS by true images as these allow interrogation by ultrasound waves. Deep lying focal pathologies that do not extend to pleural interface cannot be identified by LUS if overlying lung is expanded with air as the sonic waves will get refracted before they reach the zone of interrogation.

A unique opportunity provided by LUS is accurate and early detection of pneumothorax by the absence of sliding and the characteristic lung point transit between non waving A wave pattern without sliding and sliding diseased or normal lung. This has been the first and most recommended indication for LUS in neonatal units of all levels including neonatal transport services [4,8,10-12].

## The guideline for neonatologist performed lung ultrasound (NPLUS)

### Indications and uses of NPLUS:

The current recommendations on the role of NPLUS as presented in NeoFOCUS- UK forum [6] is as follows:

1. As a real time diagnostic tool: To help identify the cause of respiratory compromise (Transient tachypnoea of newborn, respiratory distress syndrome, meconium aspiration syndrome, pneumothorax, pneumonia, atelectasis, effusion...) and optimise treatment (like surfactant therapy).
2. As a prognostic tool: To assess the need for admission, monitoring disease progression and response to treatment.
3. As a bedside tool to identify the need for and to guide procedures like chest drain insertion.

Due to logistical reasons that include lack of expertise and experience in NPLUS, XR chest examinations cannot be entirely substituted by LUS at this juncture in many neonatal units that includes ours [13,14]. Nevertheless, there are strong and compelling arguments on why LUS should replace XR chest requests in neonatal units [15].

## The operational guidance for performing LUS in the neonatal unit

For better understanding of the knobology and principles of using ultrasound machine advanced expert level readers are referred to additional references [16,17]. Portable or beside USG machine with high frequency ultrasound probes (>10 mHz) and preferably the hockey stick linear neonatal adapted probes. Nevertheless, any linear ultrasound (USG) probe with high frequency like the existing L12 - 3 mHZ probe bundled in with our neonatal unit onsite Philips Affiniti 70G USG machine will suffice. For diaphragmatic views our neonatal cardiac S12-4 cardiac probe is adequate. More advanced compact gadgets like pocket-sized “iViZ” wireless ultrasound scanner (Fujifilm Sonosite Inc., Bothell, WA, USA) with a linear probe (13 MHz) are available in units that are specializing in LUS research [18]. With training and experience, a complete NPLUS examination as per the reporting format incorporated in badgernet should take less than 10 to 15 minutes to complete. (see later section on training and competency certification requirements).

### The steps of performing NPLUS as we do in our unit:

1. The standard images will be acquired in the standard 6 lung zones (R1, R2, R3/4 and L1, L2, L3/4) as defined in Badgernet and set in by consensus international guidelines (see pictorial representation at Figures 1and 2). Where possible and feasible posterior lung zone images shall also be acquired (R5/6, L5/6). A video recording of the demonstration of LUS zones and probe application is available upon personal requests to this author.
2. The patient should be correctly identified, and a request placed and transmitted on to the neonatal unit USG Machine matching the patient identifiers for uploading on to the PACS.
3. Clean the machine interface and the probes with disinfectant wipes provided and follow aseptic patient handling throughout the procedure.
4. Ensure the neonate is optimized with stable vital signs for the duration of the procedure with good thermal control and monitoring and wiping out the gel and cleaning the skin after completing the procedure. Take the nurses caring for the baby into confidence and request support during the procedure.
5. Select the probe L12-3 and choose Lung ultrasound. You can use the general settings or soft tissue software protocol included until a proper LUS software is embedded on the machine.
6. For diaphragmatic views change the probe to S12-4 as done for cardiac scans.
7. Adjust the gain settings using gain button and or the I-scan button to optimize the image settings as to see the ribs as darkest objects (to equal the bat wing hangers), the pleural line interface lying underneath the intercostal spaces as bright white and the intermediate intercostal space above the pleural line as grey.
8. Adjust the depth button to set the focal zone about 1 to 2 times the distance of pleural reflection line from the probe.
9. Acquire the LUS images in loop recordings of 6 to 10 seconds with appropriate labelling of zones or description of location. Complete your exploration with M mode and colour doppler and diaphragmatic views as required.
10. After the images are acquired, complete the vetting and labelling of the images and then end the examination to save the images.
11. Return the USG machine to the procedure room attaching to the charger plug and to the ethernet port for transmission of images on to the PACS systems of the hospital.

### Reporting the LUS images:

1. A sequential approach as per the badgernet reporting proforma shall be followed and images further reviewed in peer review or consultant approved in case it is performed by trainees.

2. The sequential steps of reporting LUS are as follows.

   a. Batwing sign: Identification of batwing sign establishes that image acquisition location is appropriate and optimized.

   b. Sliding: This is due to breathing movements (natural or mechanically aided) which represent the lung covered with visceral pleura sliding beneath the parietal pleura fixed to the overlying intercostal muscles and ribs. Absent lung sliding is 100% sensitive for diagnosis of pneumothorax but not 100% specific as massive lung consolidation, atelectasis are few other pathologies wherein lung sliding may be absent.

   c. The lung images:

      i. These can be artefactual as discussed above the horizontal pleural reflection artefacts or A lines that are stacked in equidistant

rows (2 or 3) and the perpendicular B lines that emanate from the pleural interface and dive deeper. A lines are air pleural surface reverberation artefacts whereas B lines are interstitial fluid artefacts.

ii. The subpleural consolidations can be micro (< 0.5 cm size) or macro (> 0.5 cm size). Subpleural consolidations are present in RDS pathologies and increasing size consolidations eventually coalesce to develop a true consolidation pattern mimicking pneumonia.

iii. Real USG images arise if the pleural adjacent lung pathologies allow ultrasonic waves transmission like consolidation, abscess, pleural effusion or a space occupying echo dense lesion.

iv. Applying colour doppler can differentiate air bronchograms within the consolidated lung tissue v. An M mode interrogation as discussed earlier in the theoretical basis paragraph will reliable identify define and quantitate the pneumothorax (lung point).

3. Report the images and apply the relevant scores as per the scoring systems provided The BRAT scoring system is to quantitate the severity of the RDS pattern and distinguish between RDS and delayed clearance of lung fluid [19]. It has to be noted that BRAT is not an acronym, but it goes by the name of the person who presented this scoring system in 2015 [19].

4. In a 6-point scoring system (3 zones as defined each on both lungs), a score above 8 is consistent with RDS rather than TTNB or delayed clearance of lung fluid and consideration for surfactant should be given at scores above:

a) A lines only no B lines or less than 3 isolated B lines in an intercostal space are scored 0 (normal lung image pattern).

b) 3 discreet B lines (with A lines) is scored 1.

c) Confluent B lines and absent A lines that may extend to white out lung is scored 2.

d) Consolidation pattern with shred sign (grey hepatization of lung) is scored 3 (note this is true sonographic image not artefact).

5. An illustration of this scoring is appended (Figure 3). The UK NHS Neonatal Patient Data Management electronic patient record system, (BadgerNet version 69.0. 194) has a LUS reporting sheet designed incorporating this sequential analysis.

6. The captioned examples of LUS findings in common neonatal lung disorders other than RDS and CLD are appended (Figure 4-8):

1. Pneumothorax (Figure 4,5).
2. Pneumonia (Figure 6,7).
3. Transient Tachypnoea of newborn (Figure 8).

7. Further knowledge and information on RDS and other neonatal respiratory diseases can be gathered by reading the illustrated case reports (case reports 1 to 7) presented later (Figure 9-32).

## Parental information and consent process

Wherever possible parents shall be informed of the procedure scheduled to be performed for their baby. A routine consent need not be taken as we don't require consent for any XR examinations on the neonatal unit and compared to XR examinations, LUS is technically easy, radiation free and adds more information than that can be derived from X ray examinations. Over a period, LUS may phase out the need for routine X-ray examinations. Nevertheless, parental consent shall be obtained wherever possible as LUS data shall be useful as academic material for publications and presentation in regional and national neonatal networks.

### Training and competency requirements

Competency in LUS can be achieved by attending formal LUS courses and practising LUS and images reporting thereby creating a logbook of NPLUS with supporting LUS reporting proformas that are accepted my trained mentors with the adequate expertise. LUS is not included in the RCPCH trainee curriculum currently and NPLUS skill competency acquisition is entirely voluntary and is an out of working hours activity for the trainee doctors. The trainees and middle grade residents can reach out to consultants interested in LUS to have hands on practice if they have a specific learning or academic requirement. Focused Ultrasound in Intensive Care (FUSIC) and Children ACute Thoracic UltraSound (CACTUS) are two programmes that are currently recommended for interested clinicians in UK until a curriculum is approved by RCPCH.

### Should XR chest examination remain the Hobson's choice in evaluating neonatal respiratory disorders? Illustrative case reports of LUS

The author has published his experience of neonatal ventilation (78 neonates over a 20-month period from January 1999 to August 2000) from a district general hospital in Saudi Arabia [20]. XR chest findings were the gold standard distinguishing the neonatal respiratory disorders as reported then and until this day XR remains the standard for respiratory care of neonates in many units [14]. But should XR chest remain the Hobson choice in evaluating and deciding management of neonatal respiratory disorders? The advent of neonatal LUS in recent years has been now being adapted into my clinical practice and LUS may well phase out XR chest requests once training and competency levels of the team increases [15]. I present the following case scenarios from my clinical practise.

### Case Reports

#### Case report 1: LUS in managing respiratory distress in neonates born through meconium-stained liquor (See figure 9-12)

In 2012 I have managed a term neonate with respiratory distress in the setting of Meconium-stained liquor in whom inconclusive XR chest findings required a CT chest to diagnose a clinically unidentified pneumothorax that was successfully managed. Herein shared are the XR Chest and the corresponding CT chest images. Absence of clinical signs of pneumothorax and suspicion of a left congenital lobar emphysema prevented a diagnostic pleural aspiration. CT chest was therefore the decision facilitating investigation. The lung which was seemingly innocuous in XR chest images (Figure 9) was displaying florid signs of meconium aspiration syndrome in the CT images (Figure 10) which in addition identified the left lung hyperinflation as left pneumothorax (arrow). A pleural drain was inserted, and the neonate made an uneventful recovery in 3 days. The need for CT scan with its logistic difficulties in transport, radiation and cost that was then required for effective and safe patient care could in current times obviated by the availability of LUS by bedside. As we discussed earlier LUS has 100% specificity is far superior to XR chest in diagnosing pneumothorax.

In 2025, LUS can distinguish true Meconium Aspiration Syndrome in babies born through Meconium-stained liquor from transient respiratory morbidities like transient tachypnoea of newborn. We recently presented our experience of LUS in the evaluation of respiratory distress in a term neonate born through meconium-stained liquor with insights and inferences derived thereto (Gengaimuthu K, Egbeama A. Lung Ultrasound predicting respiratory course in a term neonate born through meconium-stained liquor - A Case report with Insights and inferences. E poster presented in British Association of Perinatal Medicine (BAPM) April 2025).

This neonate had a harsher looking XR Chest (Figure 11), but LUS was consistent with delayed clearance of lung fluid and predicted early uneventful recovery (Figure 12) LUS can predict and help in appropriate and targeted management of respiratory disorders in neonates.

#### Case reports 2 and 3: LUS to objectively assess the severity of RDS to decide surfactant therapy and to follow on

LUS scoring provides objective guidance to surfactant therapy that XR chest imaging may not provide in clinically equipoise situations

that are encountered during management of preterm babies less than 30 weeks. [21]. Persistence of high LUS BRAT scores at 7 days of age has good predictive value towards progression to chronic lung disease [21,22]. The BAPM tool kit for management of Chronic Lung Disease states that with appropriate training and expertise lung ultrasound might be a more sensitive predictor of CPAP failure and surfactant requirement than $FiO_2$ cut- off in the neonatal unit [23].

### Case report 2 (Figure 13-15)

29 weeks preterm stabilized on face mask CPAP in delivery room transferred and continued nasal CPAP in the level 3 neonatal unit on $FiO_2$ 24% at 4h and expanded lungs in XR chest awaiting step down transfer to Local neonatal unit (level 2). LUS identified RDS with subpleural consolidations and a severity of BRAT score 12 supports decision to give surfactant by LISA before transfer. The baby stayed on NIV in LNU without requiring any escalation thereafter. Note how XR appearances that are more benign looking on left contrasting the corresponding L1 LUS.

### Case report 3 (Figure 16-18):

26+5 weeks neonate intubated and received first dose of surfactant at 7h in NICU remains ventilated on day 2 $FiO_2$ 0.32 and discordance between XR image (Figure 16) and LUS (Figure 17 and 18). The clinical team decision for second dose of surfactant at 29h is objectively supported by a LUS BRAT score of 14 and the neonate steps down to NIV within the first week of age and is transferred to a level 2 LNU.

### Case report 4 and 5: LUS as a guide to extubating and step down to Non-invasive ventilation by identifying tube related harm to lungs

Right upper lobe atelectasis and in more severe cases unilateral widespread collapse consolidation picture due to tube malposition or migration is a frequent event in preterm neonates on invasive ventilation for RDS. LUS provided objective evidence to support attempts to extubate to NIV in such situations despite the baby requiring higher oxygen requirements on invasive ventilation. Early extubation with good chest physiotherapy will facilitate resolution of tube related lung atelectasis as restoration process for the mucociliary blanket protection mechanism starts once the offending intruder of the trachea, the endotracheal tube is removed.

### Case report 4 (Figure 19 and 20)

Herein we share the LUS images from 30 weeks ventilated preterm neonate the right sided LUS planes R1, R2. The R2 images are much better than the R1, the latter showing grade 3 consolidation type picture. These support tube related atelectasis and collapse consolidation as the reason for ventilator dependency and provide valuable supporting objective evidence to the clinical team to extubate and initiate NIV with chest physiotherapy. This approach was proved right as baby stayed on NIV and was repatriated to an LNU.

### Case report 5 (Figure 21-24):

This 27+6 weeks/1kg neonate was uplifted from LNU to our NICU for continuing invasive ventilation on day 4 of life. He had received 2 doses of surfactant in LNU first by LISA while on CPAP and the 2$^{nd}$ dose when he was intubated for invasive ventilation. His LUS on day 10 (6$^{th}$ day of care in NICU) was suggestive of extensive right sided changes disproportionate to the left side LUS findings. Although oxygen requirement was 60% on invasive mechanical ventilation a considered clinical decision was made to try Nasal Intermittent Positive Pressure Ventilation which combined with chest physiotherapy was successful. He was and soon stepped down to CPAP and repatriated back to his LNU.

### Case report 6: LUS as a useful modality of interrogation of unexplained or incidental XR Chest opacity (Figure 25-27)

LUS being a bedside tool with operational ease, it is very useful for evaluation of extrapulmonary and pulmonary aberrations in sick

preterm neonates. Its value has been described in the evaluation of congenital diaphragmatic hernia recently [18]. We recently have done LUS in the following setting for evaluation of incidental unexplained XR chest opacity. This is in addition to occasions wherein LUS is used to confirm a widened superior mediastinum and cardio thymic silhouette in XR images as thymus by the characteristic sonographic pattern.

This 24-week extreme preterm neonate after intubation and surfactant administration a right middle zone opacity is noticed in XR chest taken after inserting umbilical lines in the NICU (Figure 25). The opacity persisted in subsequent XR images and baby cannot be transferred to CT or MRI console. Parents are worried and we did LUS on day 4 (Figure 26) by bedside and identified it as an echo opaque colour non enhancing homogenous mass with grade 3 BRAT scoring lung segments underlying. On follow up LUS imaging (Figure 27), the mass was shown to have reduced in size with improved lung LUS scoring that aided the decision to extubate to NIV. An elective CT chest is planned to confirm the provisional diagnosis of Congenital Cystic Adenomatoid Malformation with parental consent.

### Case report 7: LUS in guiding intercostal drainage tube drainage of pneumothorax and evaluation of underlying lung condition (Figure 28-32)

LUS is invaluable in early and accurate identification of pneumothorax and can guide drainage of air [10,12]. With the pig tail catheter that remains coiled inside the chest the status of expanded lung is not clearly seen in XR images. Whereas LUS provides valuable guidance on assessing the status of underlying expanded lung and facilitates objective decision making. XR chest images that are shared below is from a 35-week ventilated neonate with difficult airway who blew up a right pneumothorax during intubation which has been drained with a pig tail catheter (Figure 28 and 29). LUS performed bedside to confirm lung expansion showed B lines in all lung planes imaged and a consolidation pattern in right lower zone that was not discernible in XR image initially (Figure 30-32). Later this was treated as pneumonia as the chest drain tip showed significant bacterial growth and a patch was clearly seen in XR image as well.

## Discussion and Conclusion

From the case reports discussed, we can infer that LUS is here to stay as a useful and superior adjunct to XR Chest evaluation of neonatal respiratory diseases. With increasing competency levels and confidence and trust in LUS, this may eventually lead to a major reduction if not near elimination of need for XR imaging for respiratory diseases in the neonatal unit a process that was achieved in 3 years in a major LUS focussed Chinese centre [24]. Lack of expertise is cited as the major current barrier resisting the implementation of LUS in the neonatal residency training programmes in Canada [14]. Acquisition of LUS skills are required not only for the tertiary neonatologists but is required even more importantly for those working in less privileged sites. This is because a 24h radiology imaging services may not be available outside of teaching level 3 units. LUS machines and NPLUS are a valuable addition to neonatal transport services for the reasons mentioned earlier on [25]. A neonatal LUS simulator SIMUNEO has been developed, and this facilitates LUS learning by professionals [26]. This by providing training opportunities may contribute to improving the currently low penetration of LUS and NPLUS in many geographic domains.

### Annexure 1: Figures (1 to 32)

### The scanning zones for neonatal lung ultrasound (Figure 1 and 2)

The usual 6 Lung zone (3 on either side) supine imaging is depicted below. Anterior superior L1, Anterior inferior L2 and Lateral L3, L4 (L3, L4 are reported as a single Lateral zone). The marking lines displayed are parasternal, anterior axillary, posterior axillary lines that define the zones as anterior and lateral with the nipple line further subdividing these into upper and lower (Figure 1).

LUS can also be completed with prone position imaging as a standalone or addition (12 zone imaging) depending on the clinical status of the neonate. Prone imaging provides 2 additional zones for each lung, Posterior superior L5 and Posterior inferior L6. Usually Lateral

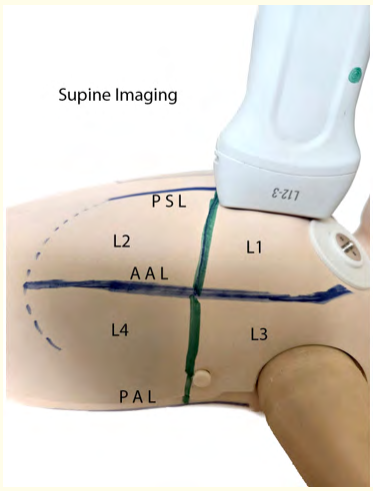



***Figure 1:*** *Supine position imaging.*

*PSL: Parasternal Line, AAL: Anterior Axillary Line, PAL: Posterior Axillary Line, the horizontal line is across the landmark of nipple. These 4 lines subdivide the anterior and the lateral chest into anterior LUS zones 1 and 2 and the lateral LUS zones 3,4.*

zones L3, L4 also can be imaged in Prone position in addition with the nipple horizontal line extending posteriorly (Figure 2).

## LUS findings in neonatal respiratory disorders (Adapted from Reference-7 with permission)

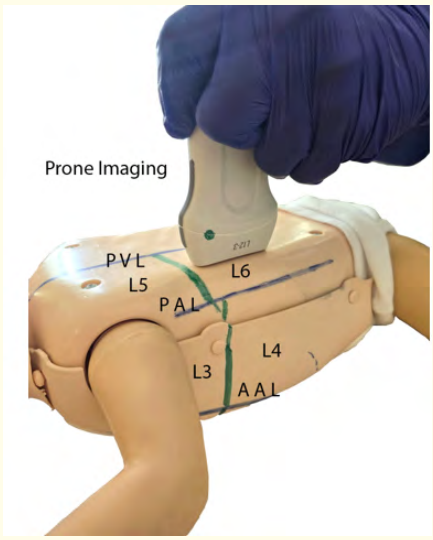



***Figure 2:*** *Prone position imaging.*

*PVL: Para Vertebral Line, PAL: Posterior Axillary Line, AAL: Anterior Axillary Line.*

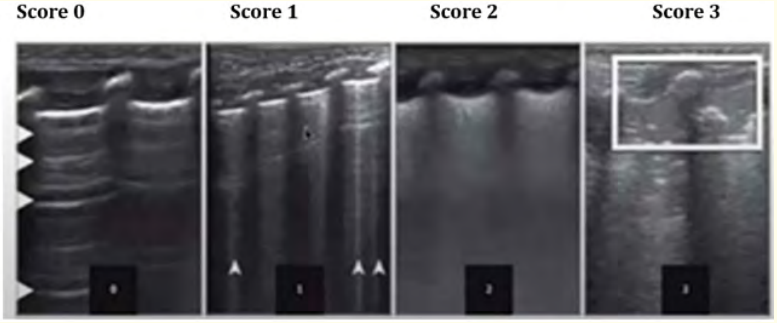



***Figure 3:*** *The interpretative scoring of lung images (used for RDS) BRAT score.*

**LUS images in neonatal pneumothorax (Figure 4 and 5)**

**Pneumonia USG shred sign and consolidation (true USG Image) (Figure 6 and 7) with captions within**

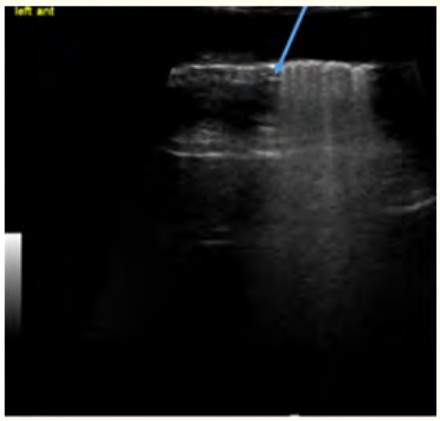


***Figure 4:*** *B mode. Blue arrow points to lung point.*

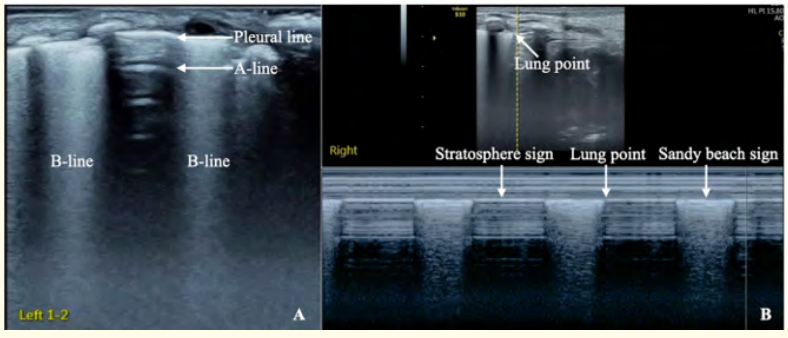



***Figure 5:*** *M-Mode across the non-sliding A line pattern in pneumothorax (The Barcode sign or the stratosphere sign) in another example of mild pneumothorax: Sandy beach sign is normal lung sliding M mode pattern.*

While consolidation is true sonographic image and not artefact and is alternately termed hepatization of lung, shred sign represents irregular shreds of air pocket at the junction of consolidated lung with rest of the lung.

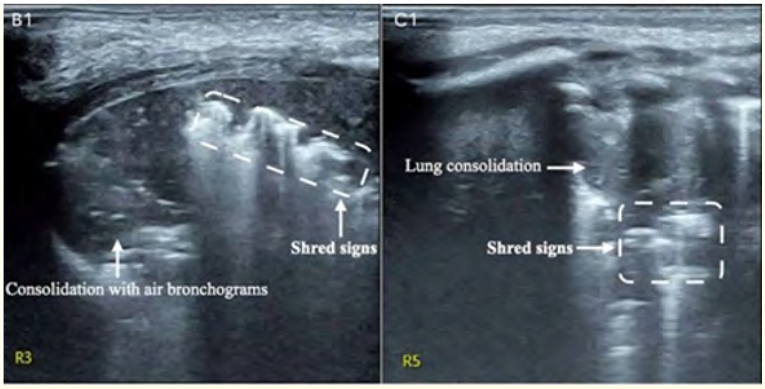



***Figure 6 and 7***

## Transient tachypnoea of newborn or delayed clearance of lung fluid

Interstitial pattern with B lines interspersed or confluent in severe cases occasionally with additional small subpleural consolidation, regular pleural line. The characteristic double lung point represents abrupt transitions between a severer grade 2 to grade 1 or grade 0 in more than one zone.

***Figure 8:*** *Transient tachypnoea of newborn or delayed clearance of lung fluid.*

## Case report 1 (Figure 9-12)

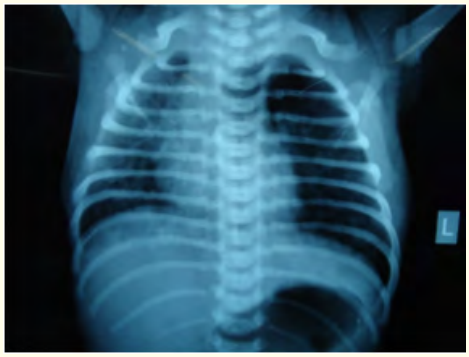



***Figure 9:*** *XR left hyperinflation.*

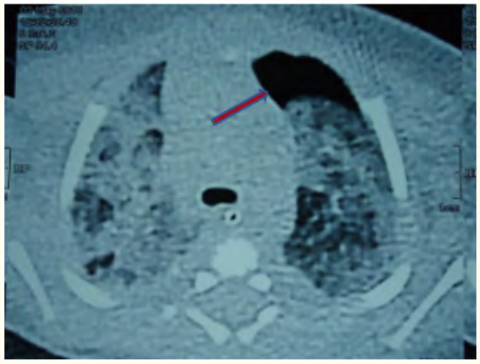


***Figure 10:*** *CT image with arrow pointing to pneumothorax and pneumonitis.*

***Figure 11:*** *XR at 6h.*

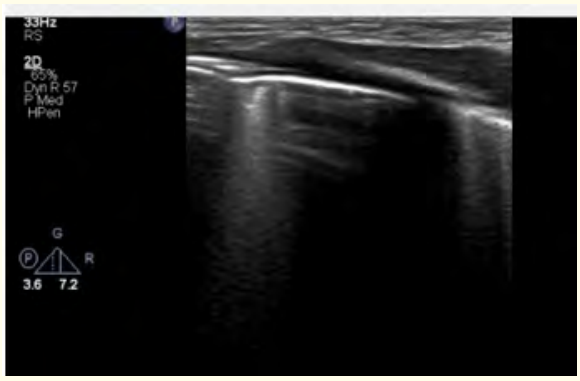



***Figure 12:*** *LUS at 6h with double lung point.*

## Case report 2 (Figure 13-15)

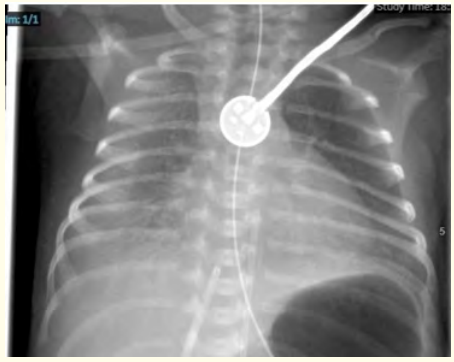


***Figure 13:*** *XR on nasal CPAP at 5h.*

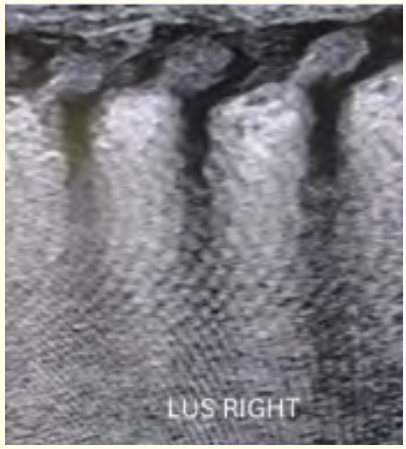



***Figure 14:*** *LUS RT grade 2 RDS.*

***Figure 15:*** *LUS L1 grade 2 RDS.*

**Case report 3 (Figure 16-18)**

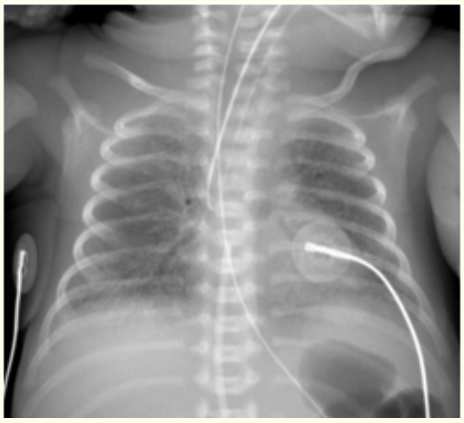


***Figure 16:*** *XR image expanded lungs.*

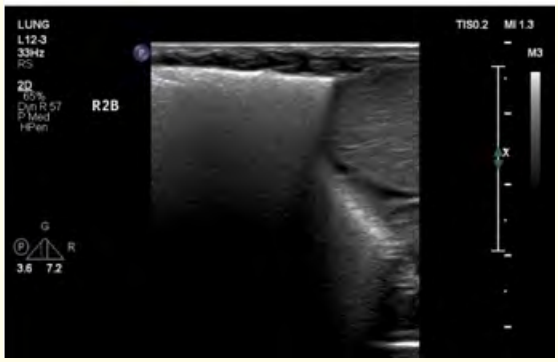



***Figure 17:*** *LUS R2 grade 2 RDS.*

***Figure 18:*** *LUS L1 grade 2 RDS.*

**Case report 4 (Figure 19 and 20)**

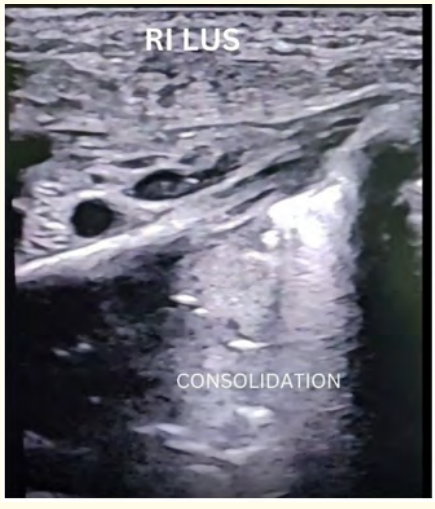



***Figure 19:*** *LUS R1 (grade 3).*

***Figure 20:*** *LUS R2 (grade 0 -1).*

## Case report 5 (Figure 21-24)

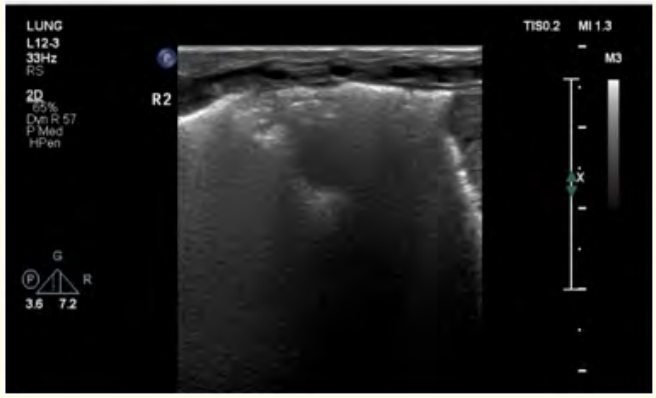



***Figure 21:*** *LUS R2 zone grade 3.*

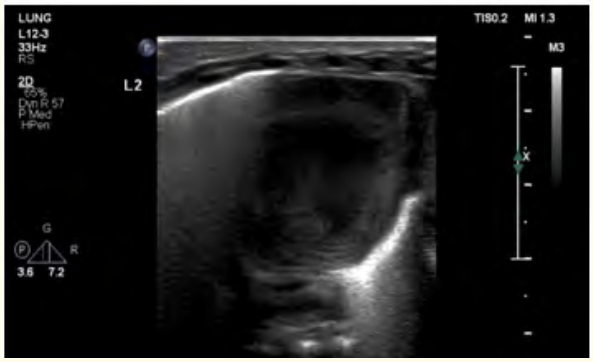



***Figure 22:*** *LUS R2 zone grade 2.*

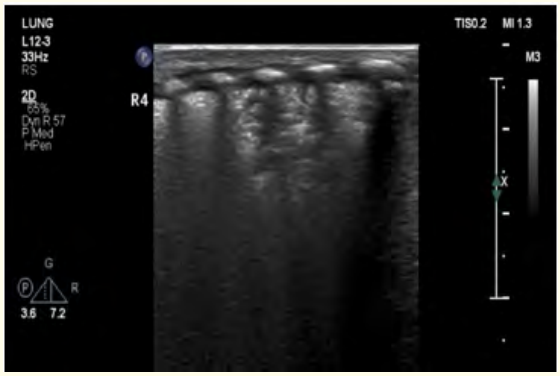



***Figure 23:*** *LUS R4 zone grade 3.*

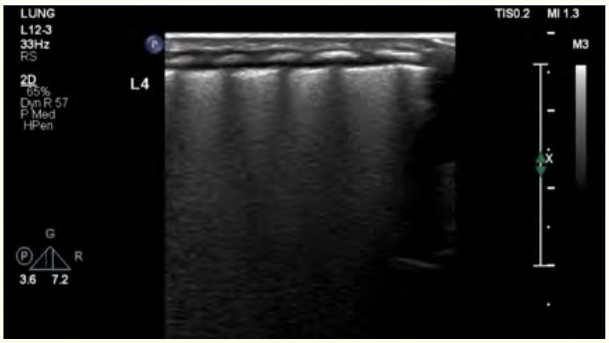



***Figure 24:*** *LUS L4 zone grade 2.*

## Case report 6 (Figure 25-27)

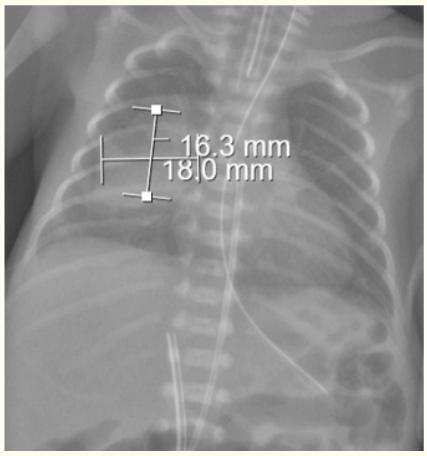



***Figure 25:*** *XR chest with right midzone opacity day 1.*

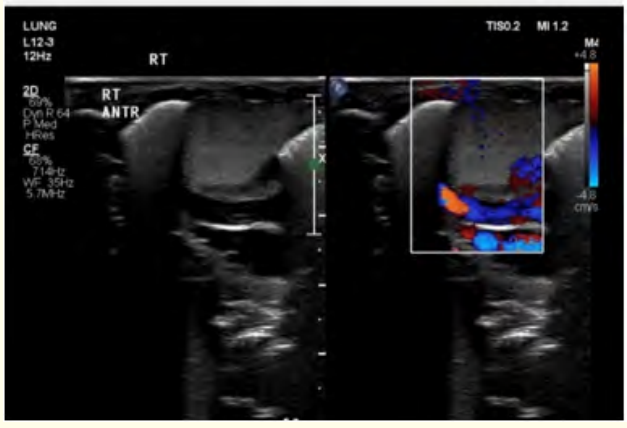



***Figure 26:*** *LUS on day 4 colour non enhancing homogenous mass with consolidated lungs.*

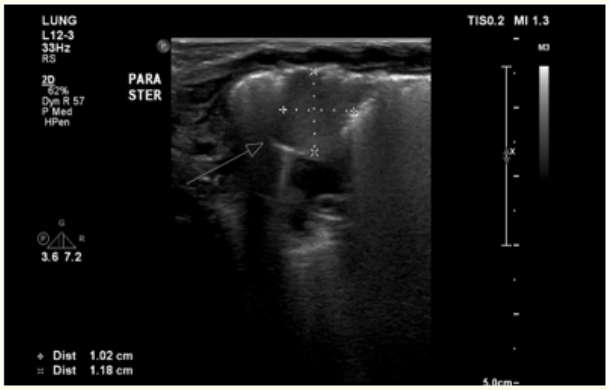



***Figure 27:*** *Follow on LUS day 45 less dense and smaller mass with improved lung.*

## Case report 7 (Figure 28-32)

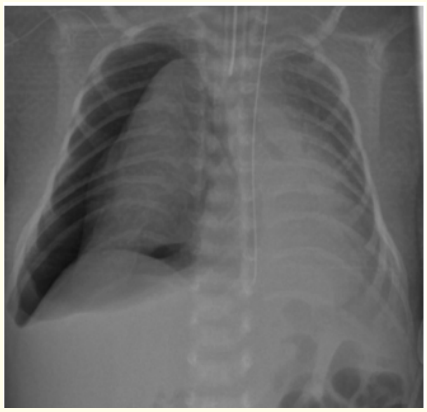


***Figure 28:*** *XR tension pneumothorax.*

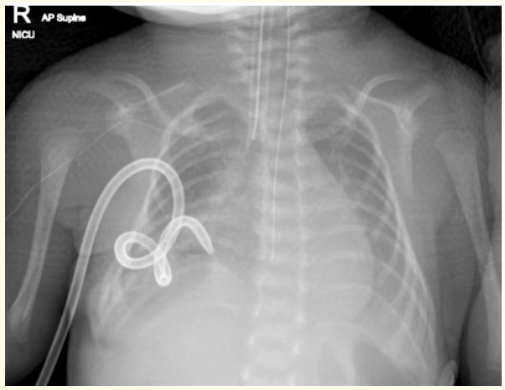



***Figure 29:*** *XR pigtail ICDT drain in situ.*

**Case report 7: Figures 30-32: The LUS with Pigtail ICDT *in situ*:** There was sliding demonstrated on all zones on the right side and B lines plus some focal consolidation.

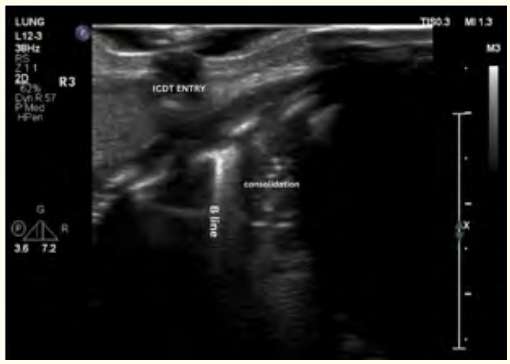



***Figure 30:*** *LUS R3 consolidation.*

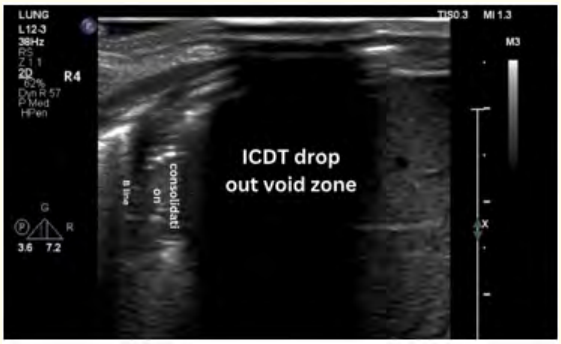



***Figure 31:*** *LUS R4 midzone consolidation.*

***Figure 32:*** *LUS R4 Anterior sweep with labels drop out zone due to dressing.*

## Annexure 2

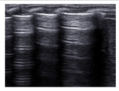
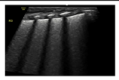
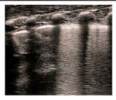
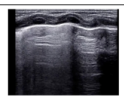
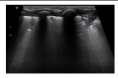
| Lung Pathology | | Lung Sliding | A-Lines | B-Lines | Consolidation | | M-Mode |
|---|---|---|---|---|---|---|---|
| | | | | | Microconsolidations <5 mm | >5 mm | |
| Normal lung |  | Present | Yes | <3/intercostal space | No | No | Seashore sign |
| RDS |  | Present | No (minimal) | >3/intercostal space Confluent "White lung" | Usual | Unusual | Seashore sign |
| TTN |  | Yes | Yes | Yes | Sometimes | Unusual | Seashore sign |
| Pneumothorax |  | Absent | Yes | No | No | No | Stratosphere sign |
| Meconium aspiration syndrome |  | Variable | Variable | Yes | Yes/no | Yes | Seashore sign |

***Table 1:*** *Reproduced from 7 with permission.*

## Acknowledgements

First and foremost, I am extremely thankful for the parents who consented for sharing the images of their babies for the benefit of professionals and advancement of care for babies in the neonatal unit. I am thankful for my consultant colleagues and the neonatal nursing team for their valuable help. Special thanks are due to Natallie Cartmell Neonatal Clinical facilitator of our neonatal unit for her valuable help and assistance in designing the neonatal baby manikin for LUS zones photography and video recording. I am indebted to Dr Richa Gupta, Research Lead and Dr Aubrey Makhalira Clinical Director of Lancashire Teaching Hospital neonatal services for their support in introducing LUS services in our unit. I express my sincere thanks to Dr Yogen Singh, Professor of Paediatrics at the University of California Davis Children's Hospital, California and the Chair for ESPNIC POCUS Working Group for his valuable support and permission to use LUS images and table from his publications.

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