Reflections of the Newborn Lung

Neonatal lung Ultrasound in practice

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Faculty disclosures

	No, nothing to disclose
X	Yes, please specify:

Company Name	Honoraria/ Expenses	Consulting/ Advisory Board	Funded Research	Royalties/ Patent	Stock Options	Ownership/ Equity Position	Employee	Other (please specify)
Chiesi	x	X	X					
Mindray, Samsung, Sonoscanner, Philips, GE, Sonoscanner								loan of ultrasound machines
Radiometer		X						
Emergensim								Discussions, slides

Lung POCUS

- Goal/problem oriented
- Performed by the clinician
- At the point-of-care
- Repeatable
- Qualitative (or semi-quantitative)
- Interpreted in the clinical context
- Adjunct to clinical examination and monitoring tools

The newborn baby

- Echogenic
- Small thorax
- Few co-morbidities

- Specific diseases
- Radiation linked risk
- No satisfactory “gold standard”

Intensive Care Med (2012) 38:577–591
DOI 10.1007/s00134-012-2513-4

CONFERENCE REPORTS AND EXPERT PANEL

Hôpitaux universitaires Paris-Sud
Antoine-Béclère Bicêtre Paul-Brousse

International evidence-based recommendations for point-of-care lung ultrasound

- Pneumothorax
- Interstitial syndrome
- Lung consolidation
- Pediatrics and neonatology

ASSISTANCE PUBLIQUE HÔPITAUX DE PARIS

Singh *et al. Critical Care* (2020) 24:65
https://doi.org/10.1186/s13054-020-2787-9

Critical Care

espnic
European Society of Paediatric and Neonatal Intensive Care

RESEARCH Open Access

International evidence-based guidelines on Point of Care Ultrasound (POCUS) for critically ill neonates and children issued by the POCUS Working Group of the European Society of Paediatric and Neonatal Intensive Care (ESPNIC)

Neonatal lung POCUS

Singh *et al. Critical Care* (2020) 24:65
https://doi.org/10.1186/s13054-020-2787-9

Diagnosis of pneumothorax

Diagnosis of pleural effusion

Diagnosis of RDS / TTN / MAS

Recognition of lung atelectasis and pneumonia

Evaluation of lung aeration and recruitment

Recognition of lung edema

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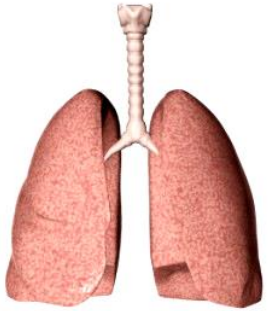
European Society of Paediatric and Neonatal Intensive Care

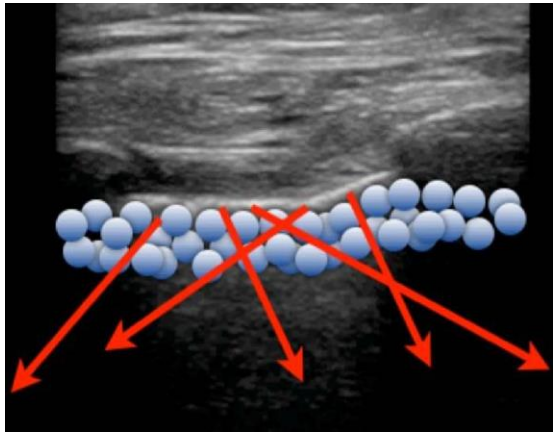
« Air is the enemy of ultrasound … »

+



= ?

Principles of lung ultrasound



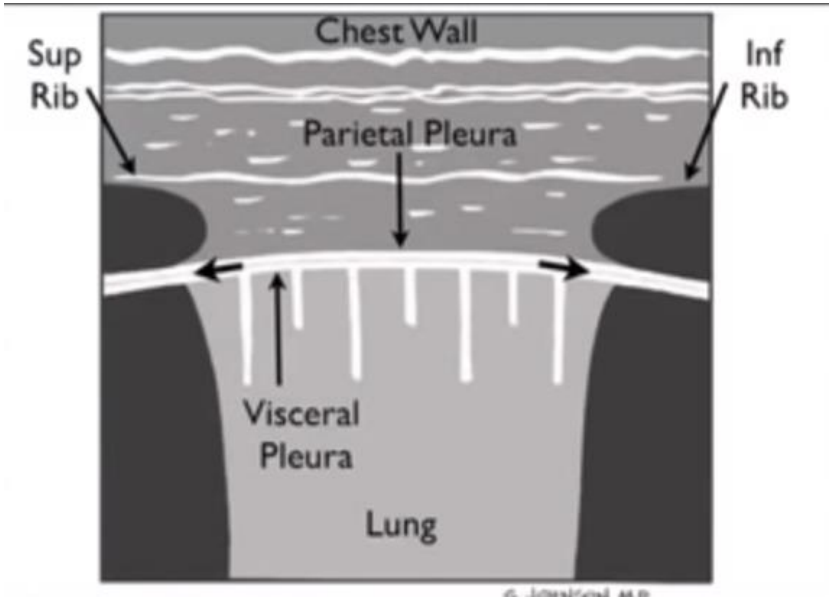
- Based on the analysis of artifacts (air/fluid ratio)
- Artifacts are dynamic
- Most lesions are in contact with the surface

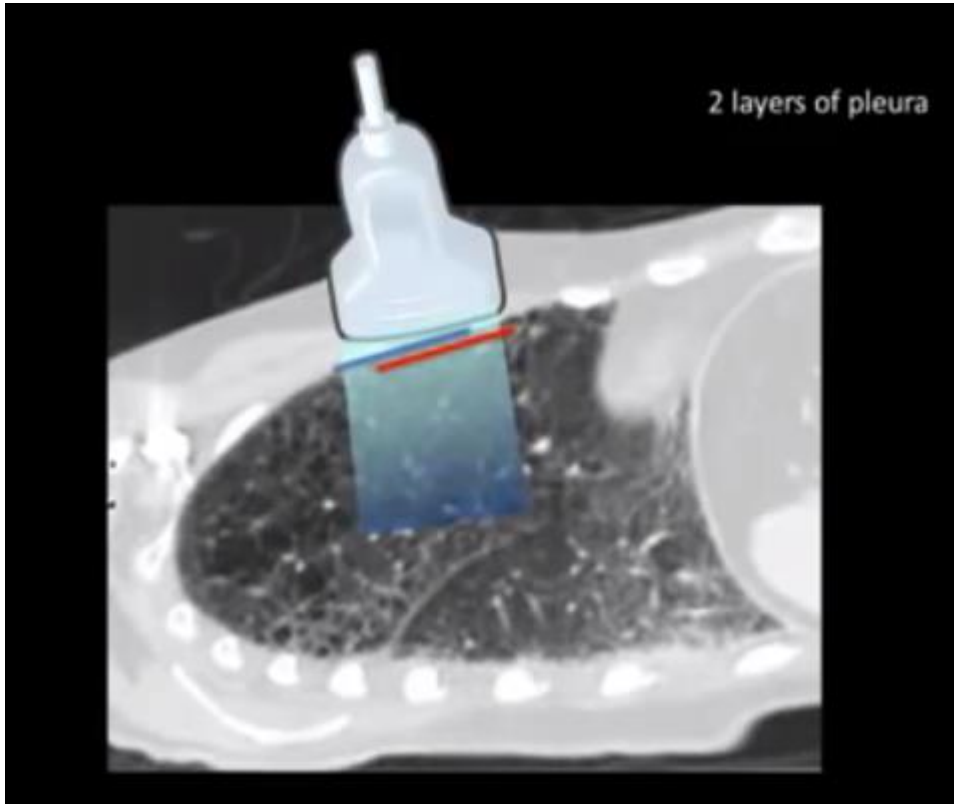
LIMITATIONS

- Lesions must be in contact with the lung surface
- Not possible to evaluate overdistension
- Systematic examination

The pleural line

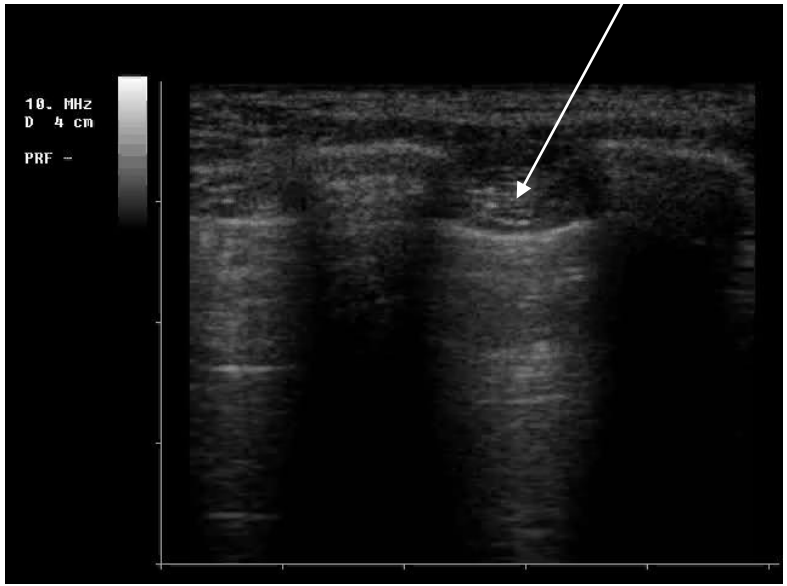
- Regular
- LUNG SLIDING
- « Starting point »

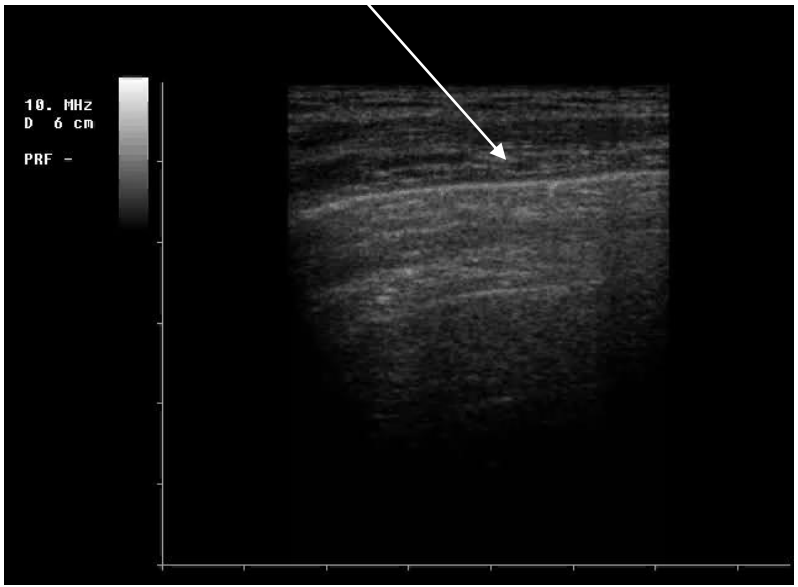




Normal lung

Lung sliding





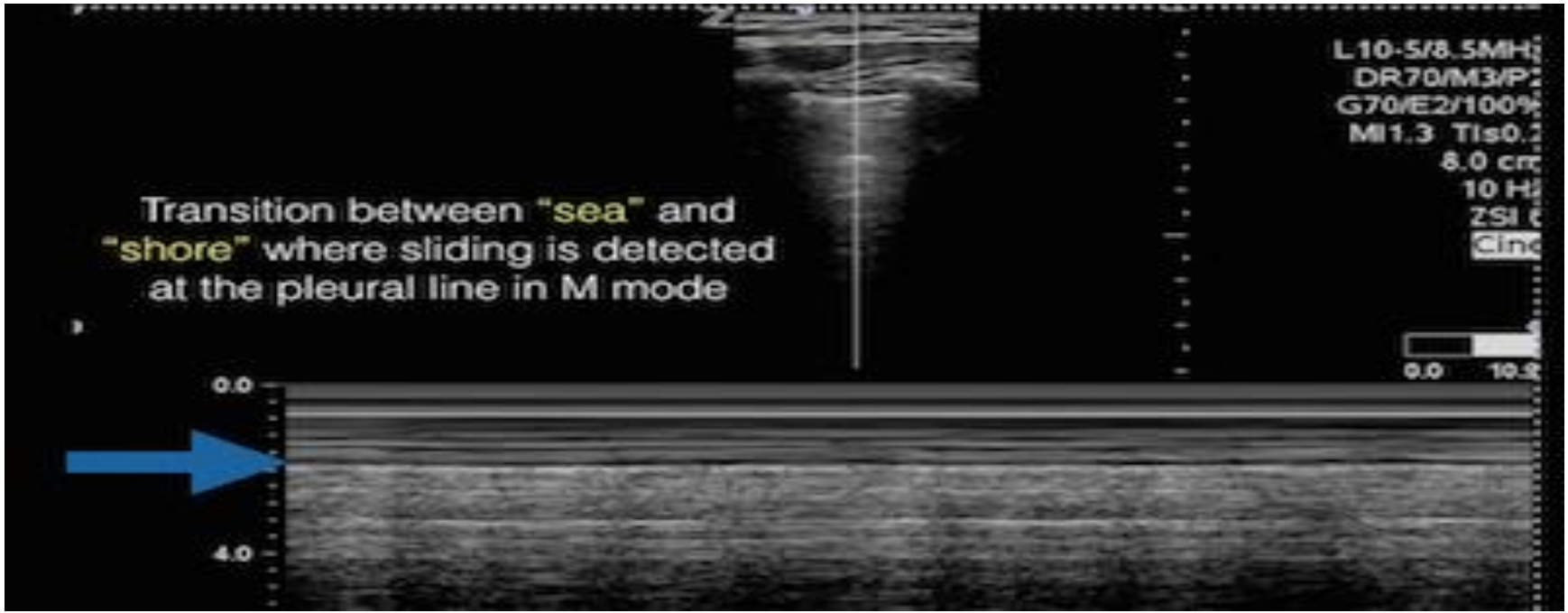
A- lines

A regular pleural line

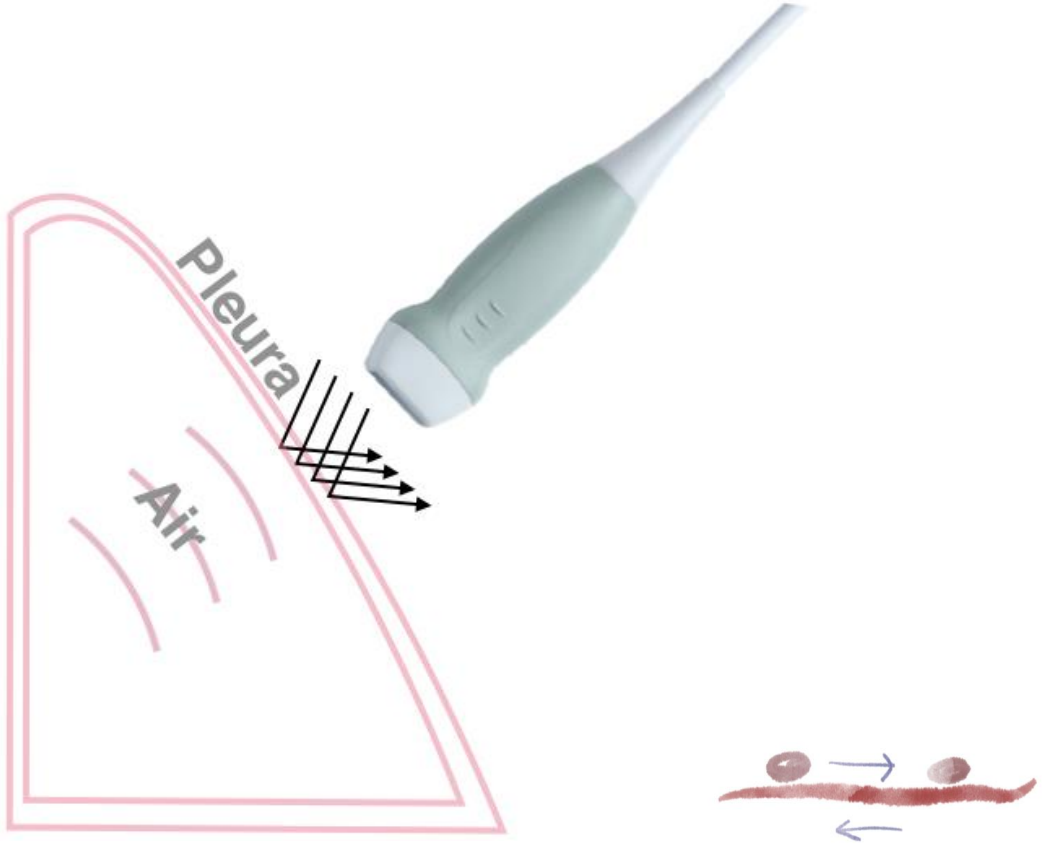
Lung sliding

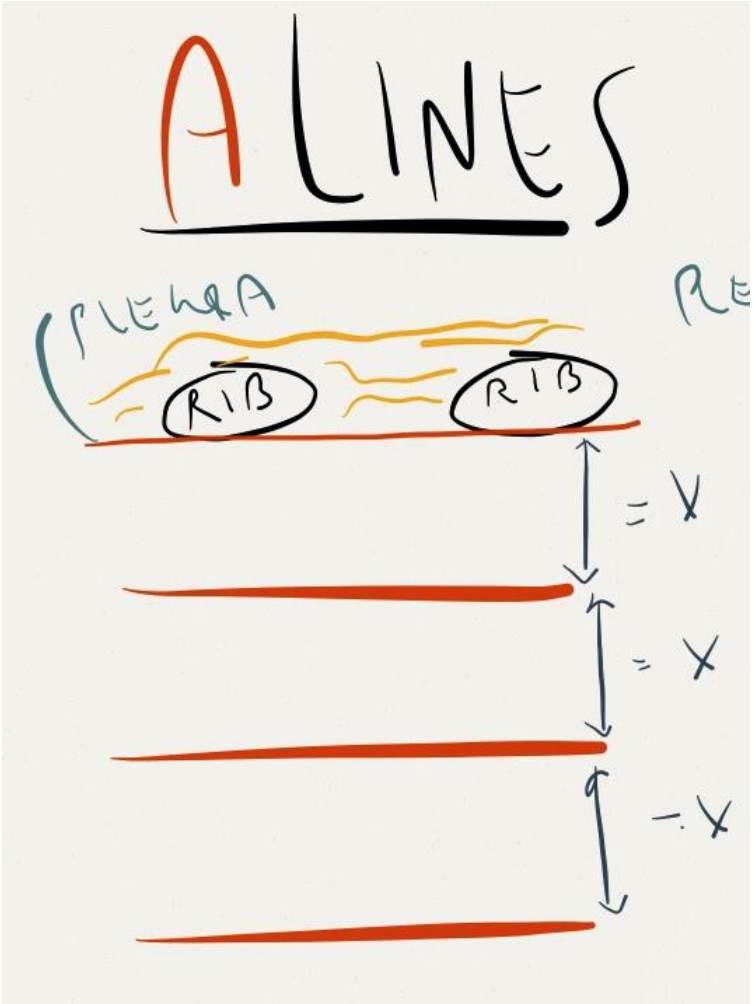
Slide courtesy Dr L Cattarossi

Normal lung : M-mode



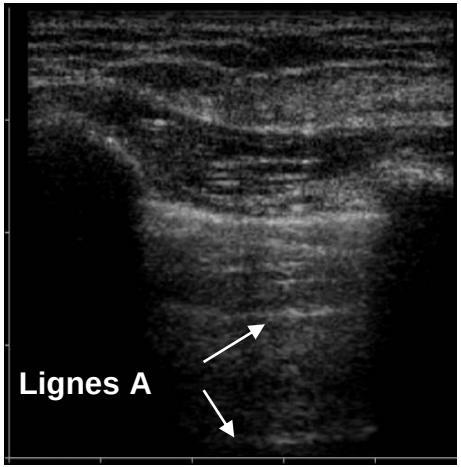
Rebel EM

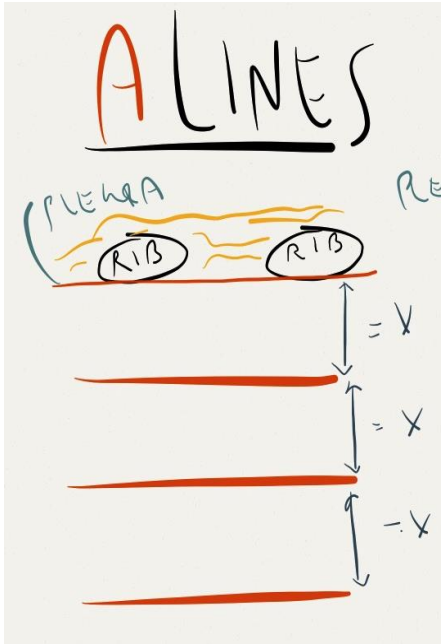



A LINES
PLEURA
RIB
RIB
= X
= X
= X

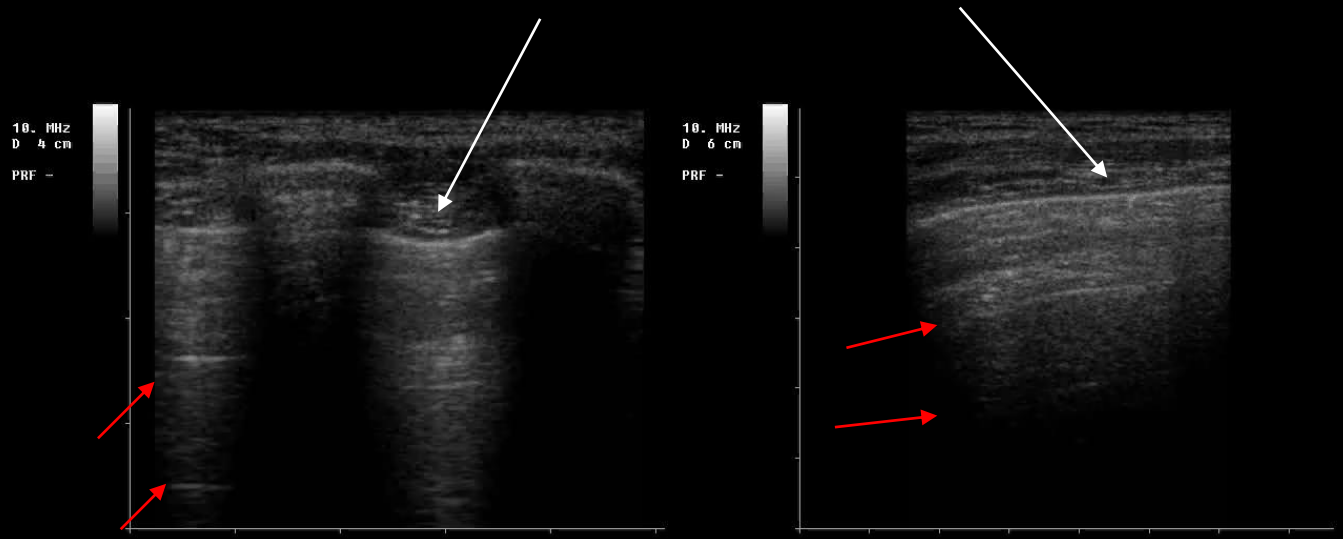
A lines

- A = air (physiological ou pathological)
- Static horizontal lines
- Artifacts of repetition





Normal lung



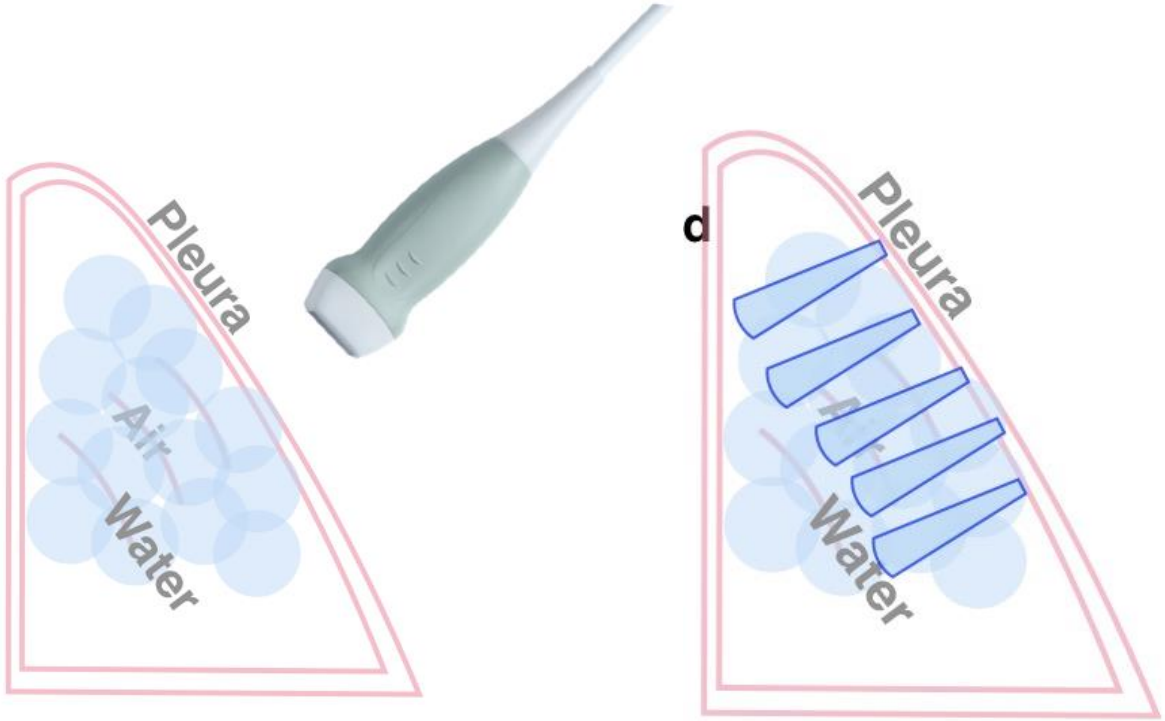
A LINES

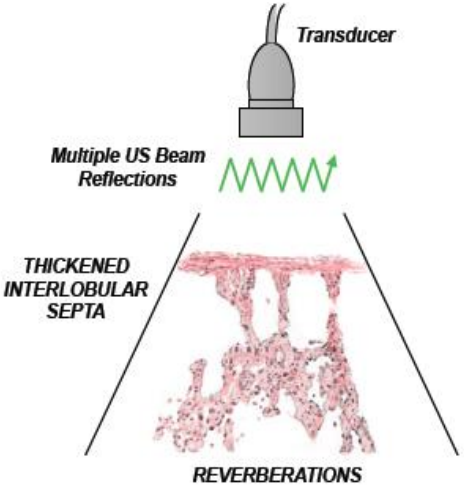
A regular pleural line

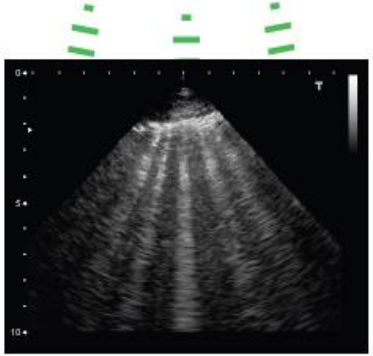
Lung sliding

Slide courtesy Dr L Cattarossi

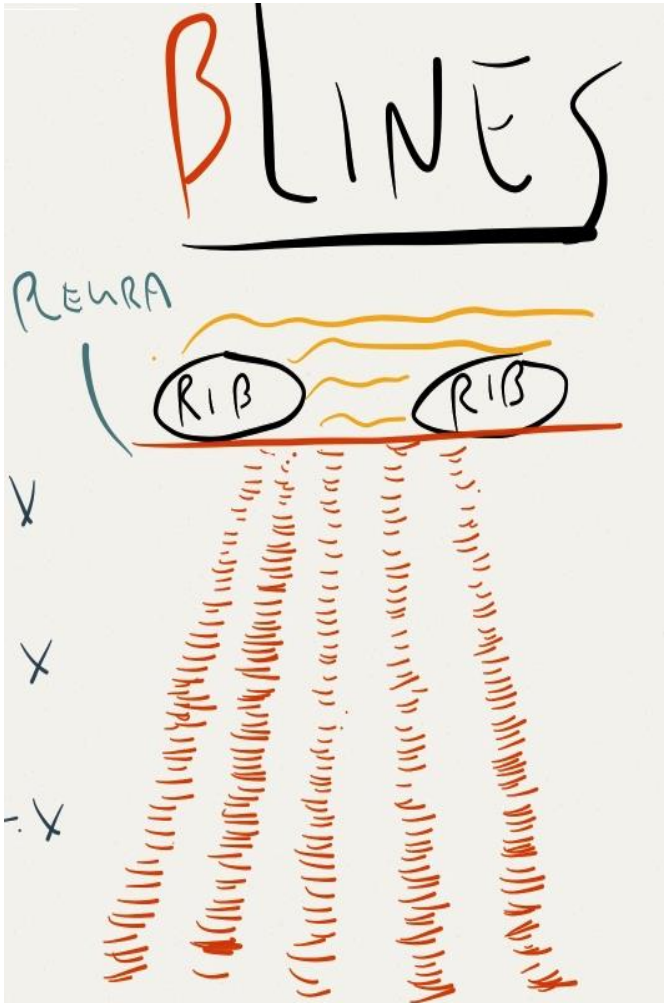
B for fluid







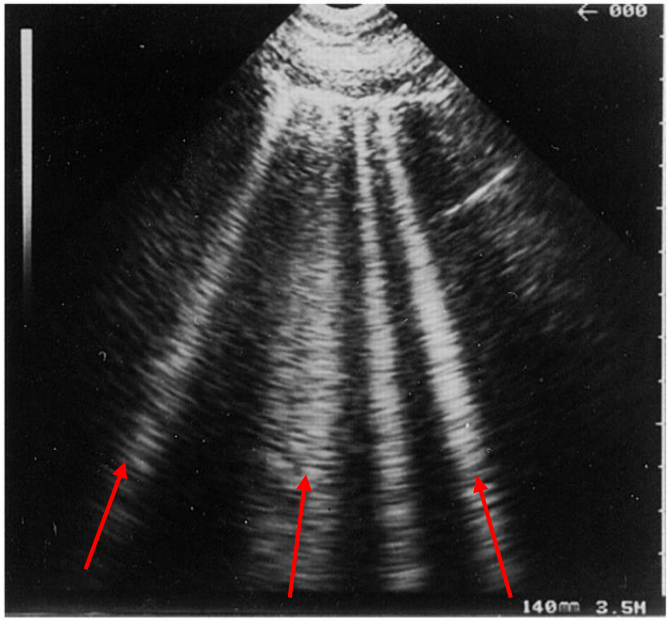
COMET TAILS (B lines)



B lines

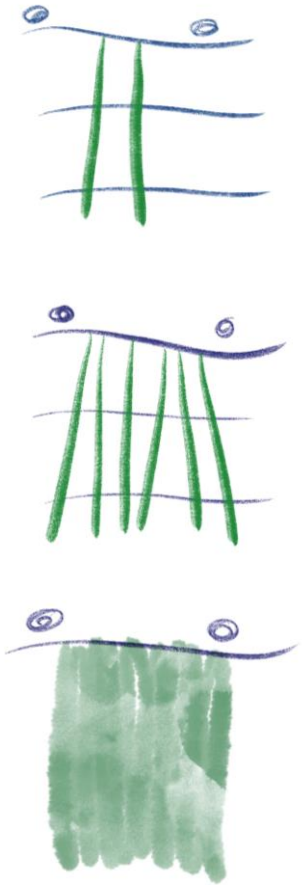
« Comet tails »

- Air/fluid interaction
- Dynamic
- Arise at the pleural line

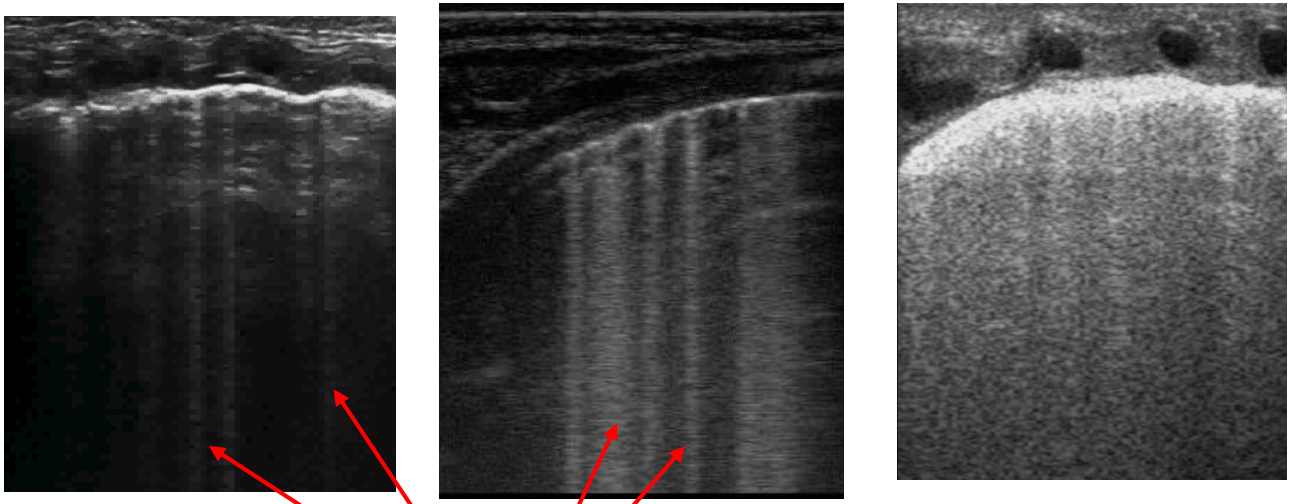


Lichtenstein D. et al. The comet-tail artifact. An ultrasound sign of alveolar-interstitial syndrome. Am JRespir Crit Care Med. 1997 Nov;156(5):1640-6.

B for fluid



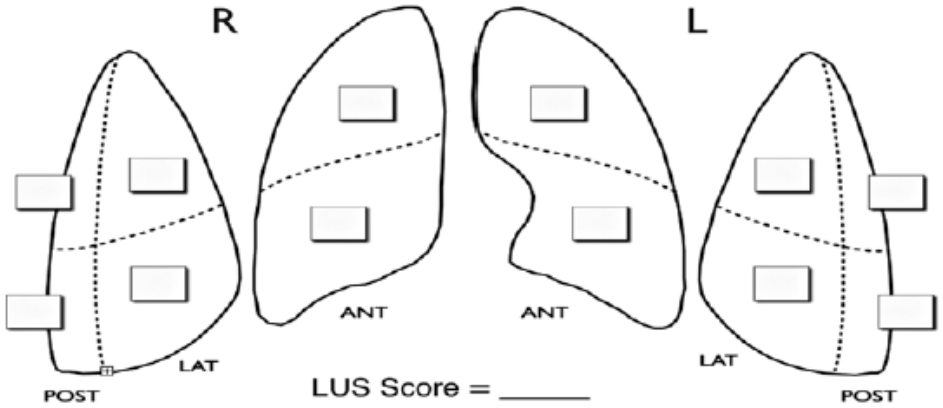
B-lines

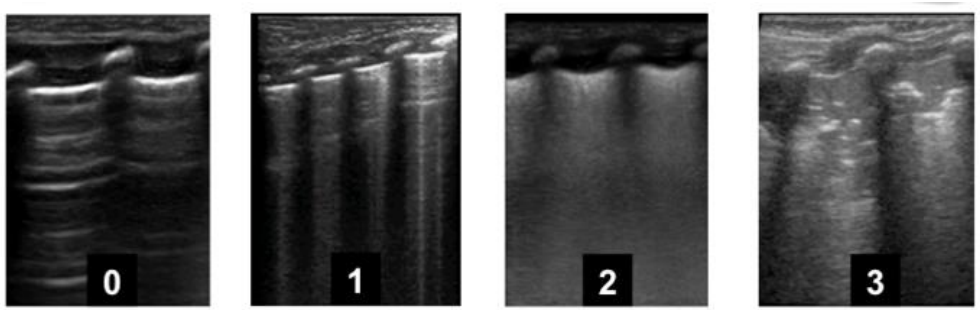


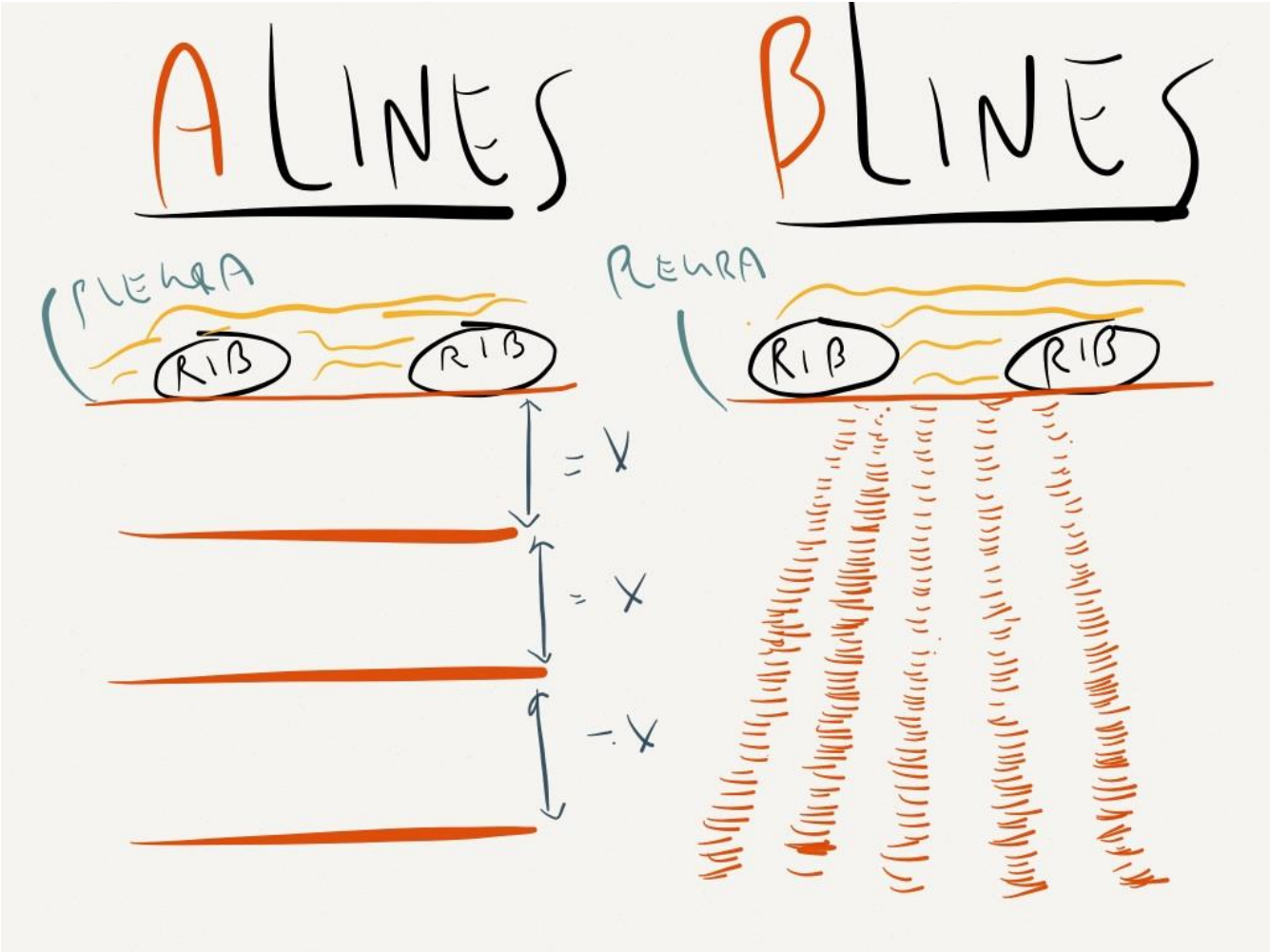
B LINES

B-lines/“comet tails”

TO B OR NOT TO B….



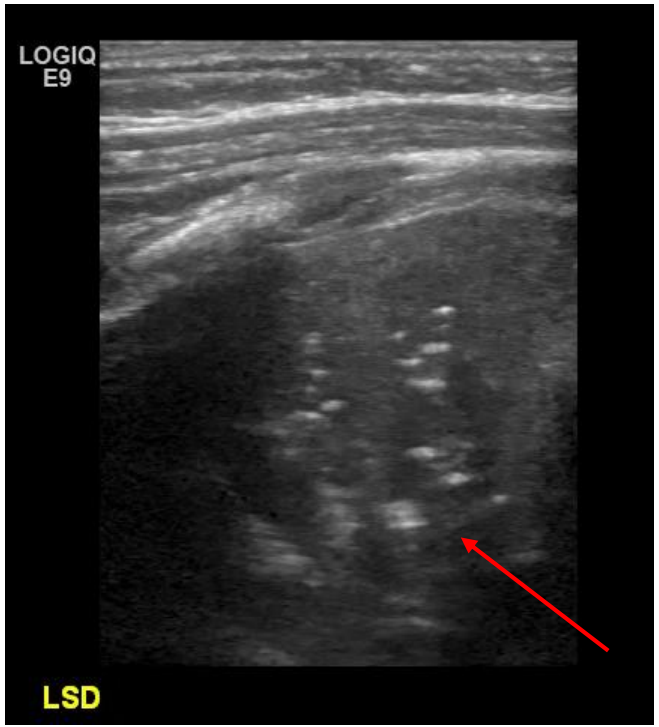


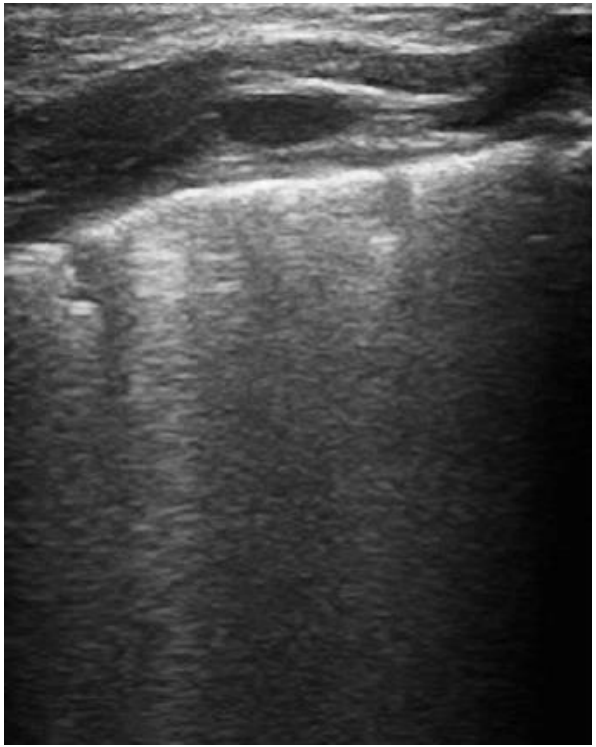

A LINES
B LINES
PLEURA
RIB
RIB
PLEURA
RIB
RIB

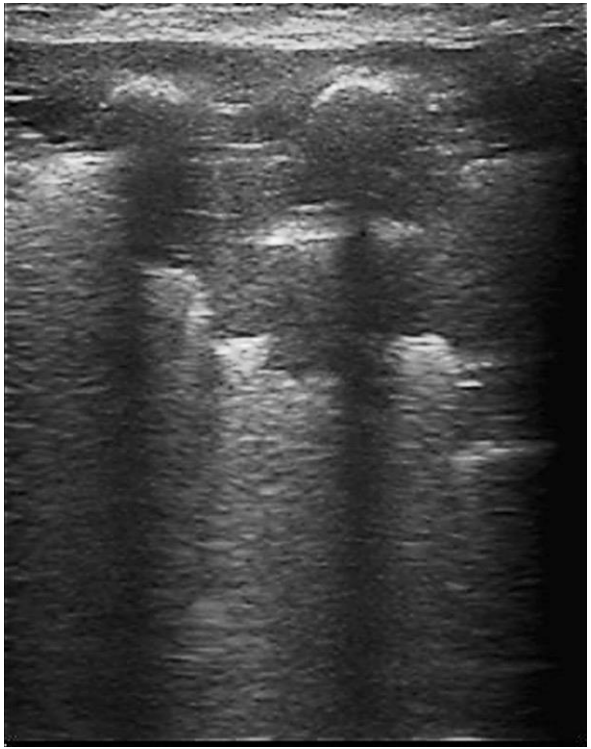
C = consolidation

- Non aerated lung
- Tissue/solid organ appearance

  « Tissue-like sign »
- Bronchograms



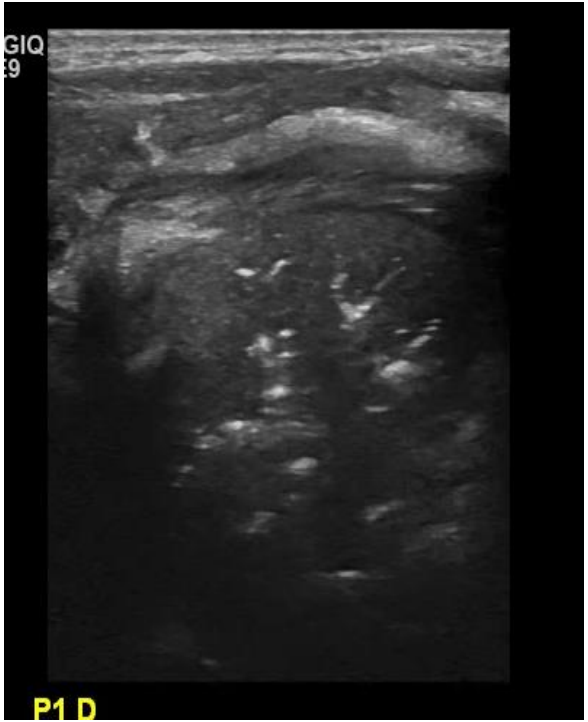




The shred sign = irregular and ill-defined borders

Dynamic bronchogram : pneumonia?

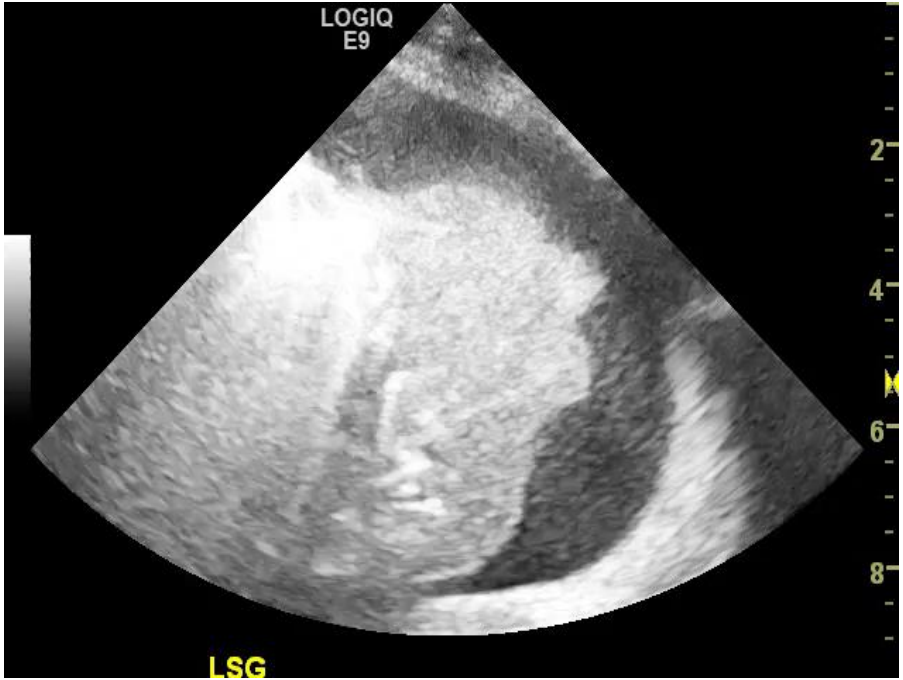
Static bronchogram : atelectasis ?



Pleural effusion

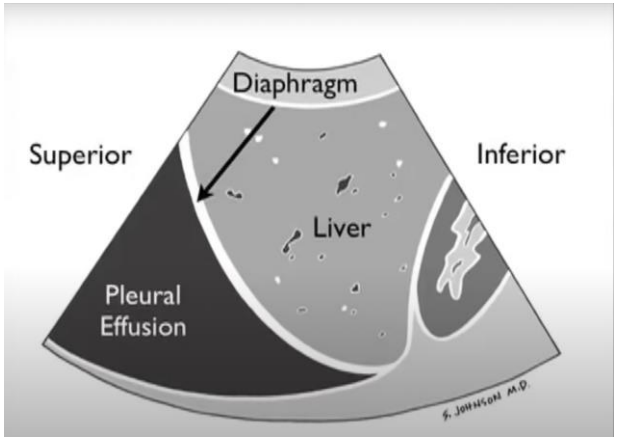
Often black but not always

- A hypoechoic space
- Anatomical structures defined
- Dynamic

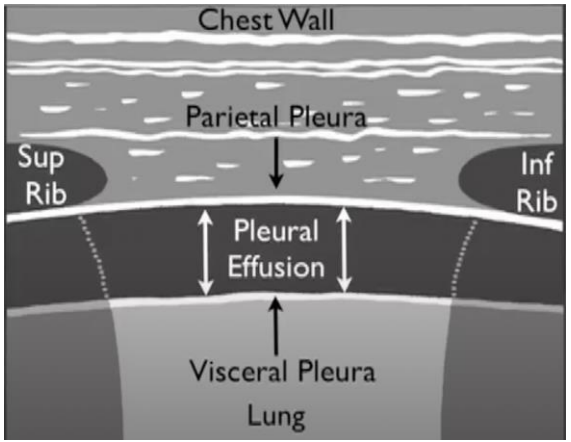


Pleural effusion

Lower frequency probe (3-5Mz)
Transverse view

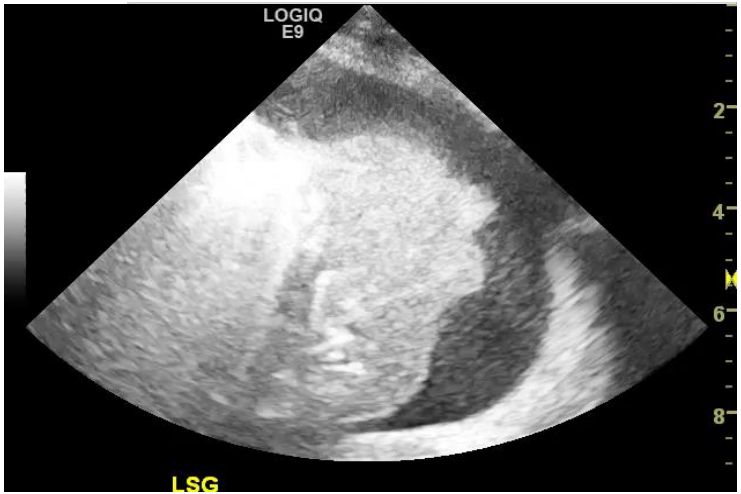


Higher frequency probe (> 10MHz)
Transverse view

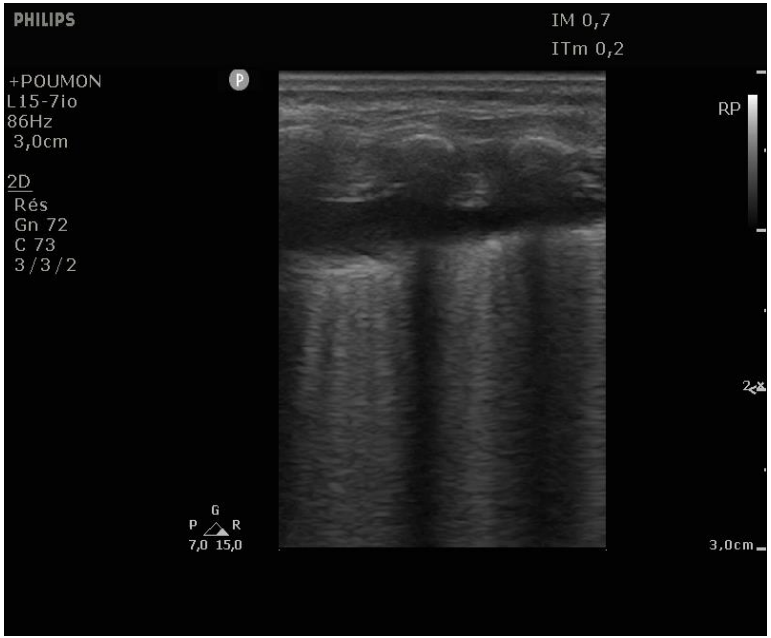


Pleural effusion

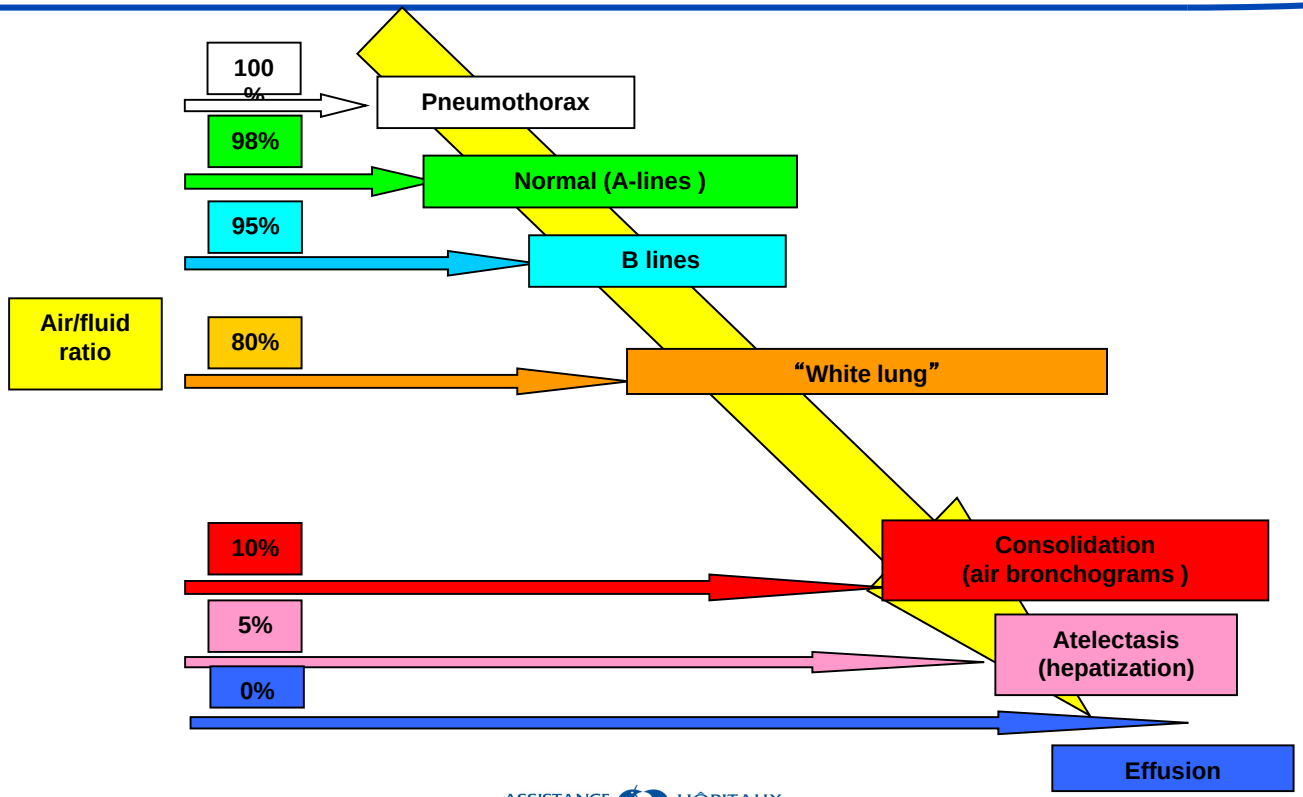
Lower frequency probe (micro/convex) Transverse view



High frequency linear probe Transverse view



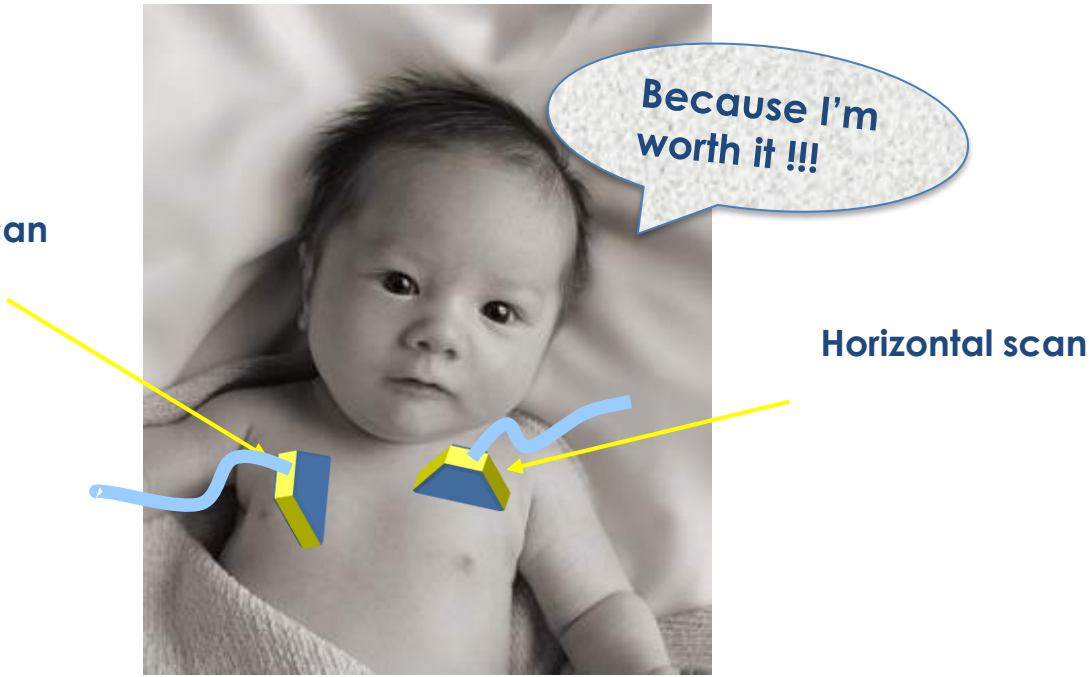
Lung aeration : artifacts and « real » images

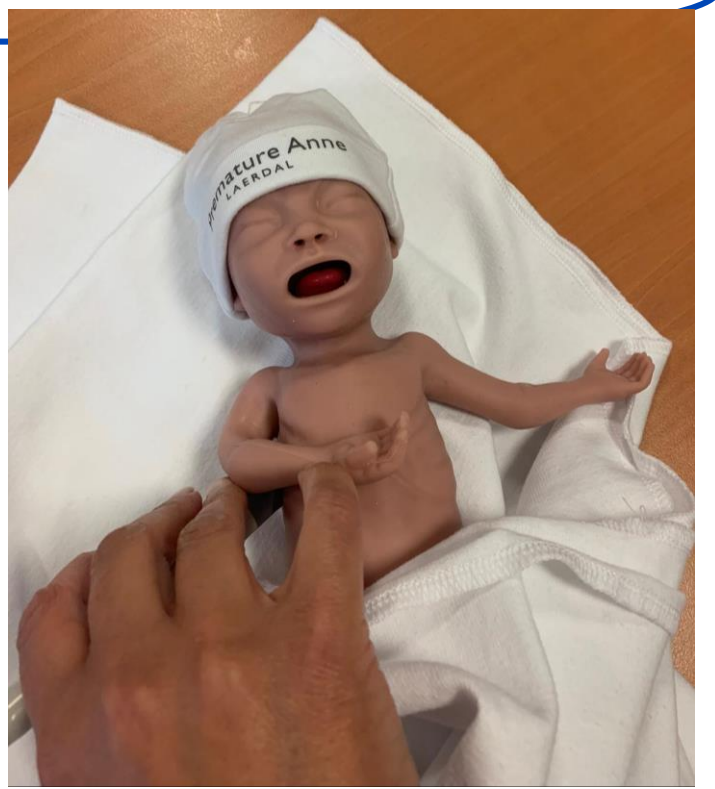


Adapted from L. Cattarossi with permission

The newborn baby

- All ultrasound signs are found in the newborn
- Fluid-rich lung at birth





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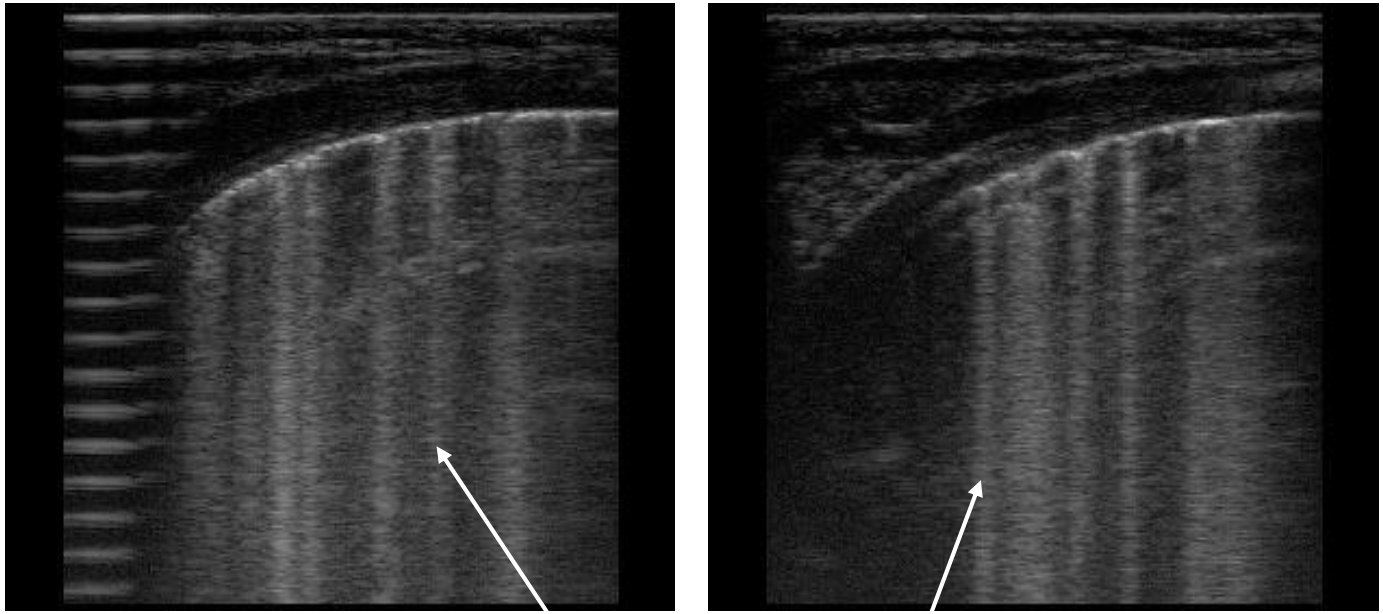
The transitional period



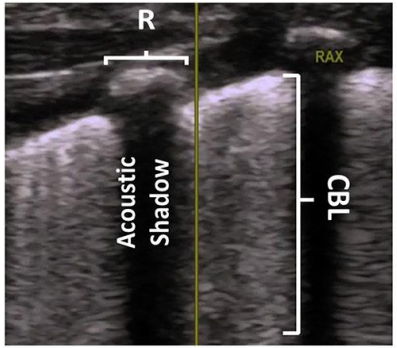
Many B-lines

Lung ultrasound immediately after birth to describe normal neonatal transition: an observational study

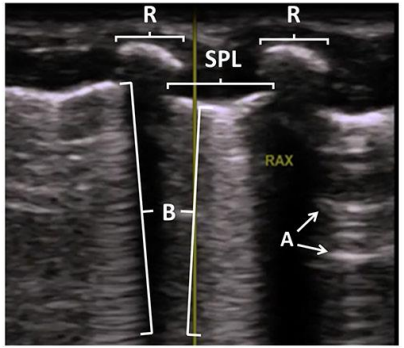
Douglas A Blank,[1,2] C Omar Farouk Kamlin,[1] Sheryle R Rogerson,[1] Lisa M Fox,[1] Laila Lorenz,[1,3] Stefan Charles Kane,[4,5] Graeme R Polglase,[2] Stuart B Hooper,[2] Peter G Davis[1]

- In a population of healthy newborns, all infants achieved lung aeration and partial airway liquid clearance within the first 20 min after birth.
- Serial lung ultrasound can be used to monitor changes in lung aeration and airway liquid clearance after birth.
- Complete airway liquid clearance is typically achieved within the first 4 hours after birth.

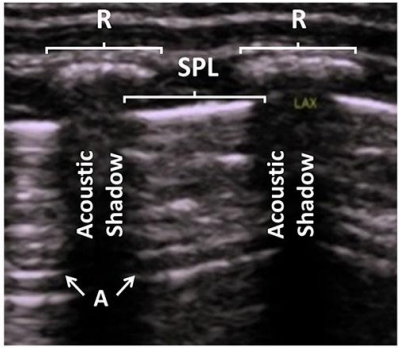
Lung Ultrasound Grading



Type 1: Fluid retention, pleural line blunt, "white-out" appearance from coalescence of B-lines (CBL)



Type 2: Establishment of a clear, sharp pleural line (SPL) and partial fluid clearance, vertical B-lines (B) obscuring horizontal A-lines (A) are seen



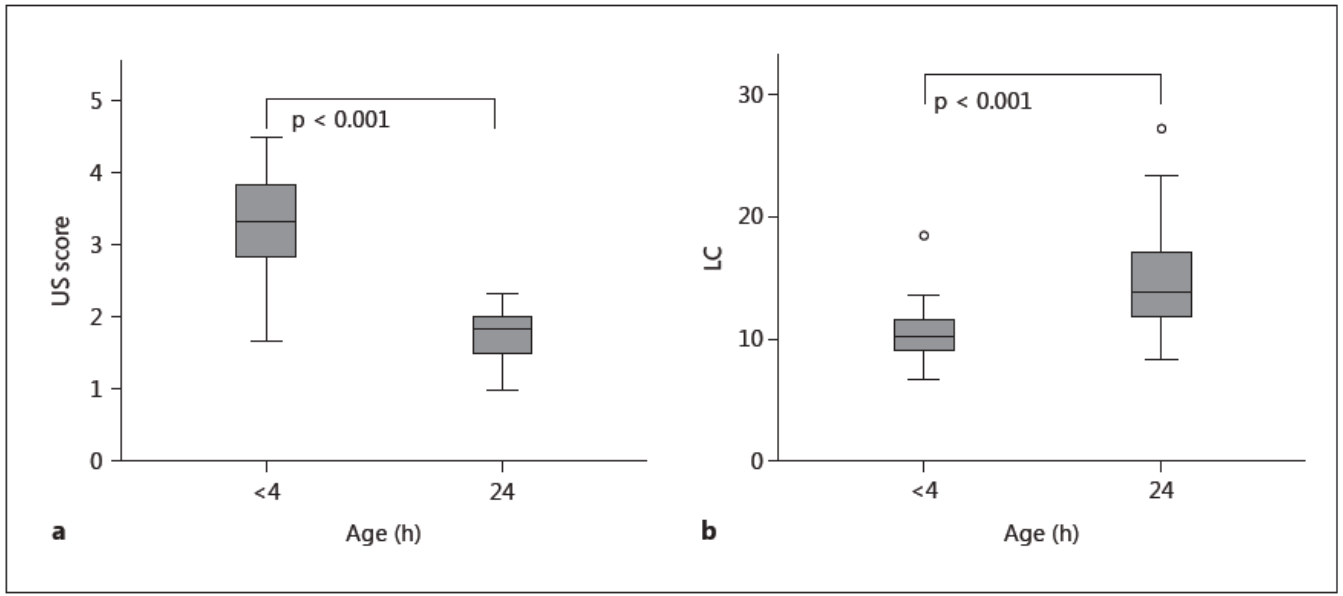
Type 3: Full aeration and fluid absorption, sharp pleural line (SPL), only horizontal A-lines seen

More aeration and fluid clearance

Lung Ultrasound and Static Lung Compliance during Postnatal Adaptation in Healthy Term Infants

Neonatology 2015;108:287–292

Laura Martelius[a] Liina Süvari[b] Cecilia Janér[b] Otto Helve[b] Anu Kaskinen[b]
Turkka Kirjavainen[b] Olli Pitkänen[b, c] Sture Andersson[b]



Neonatology

Original Paper

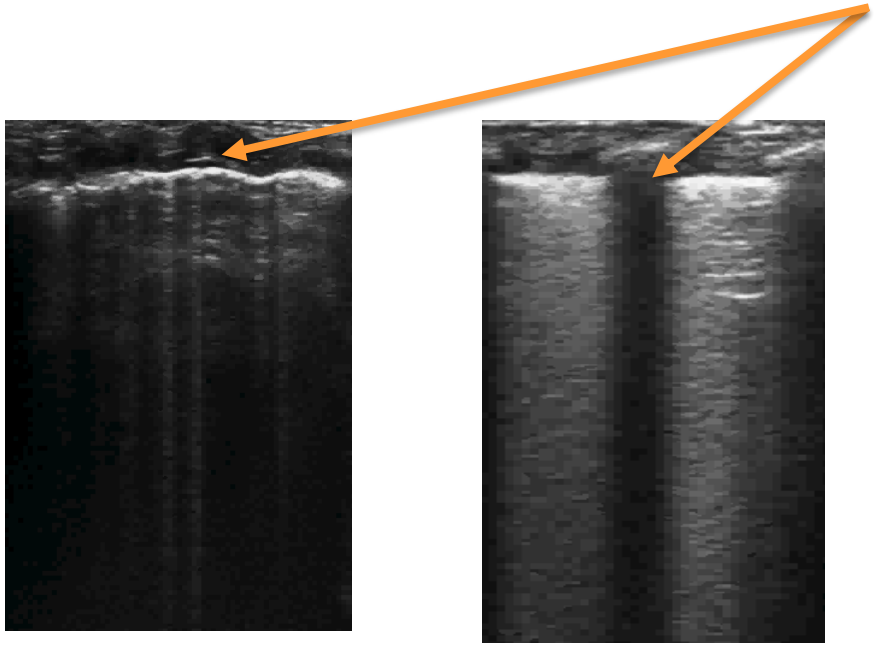
Neonatology 2007;91:203–209
DOI: 10.1159/000097454

Received: February 27, 2006
Accepted after revision: September 12, 2006
Published online: December 6, 2006

The 'Double Lung Point': An Ultrasound Sign Diagnostic of Transient Tachypnea of the Newborn

Roberto Copetti[a] Luigi Cattarossi[b]

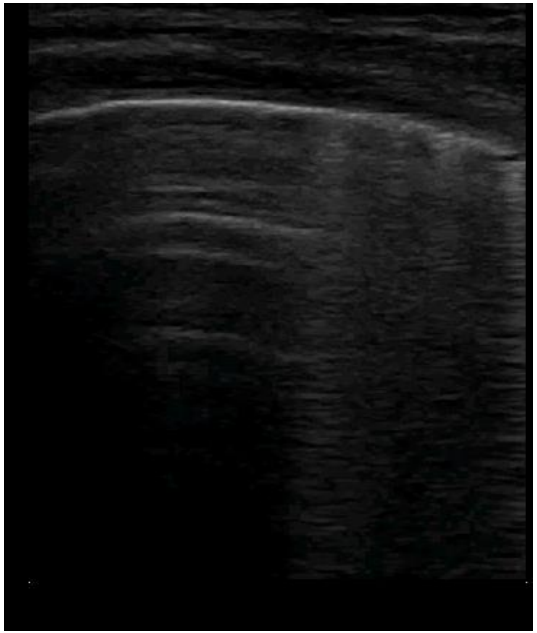
TTN



APEX

BASE

The « double lung point »



Original Paper

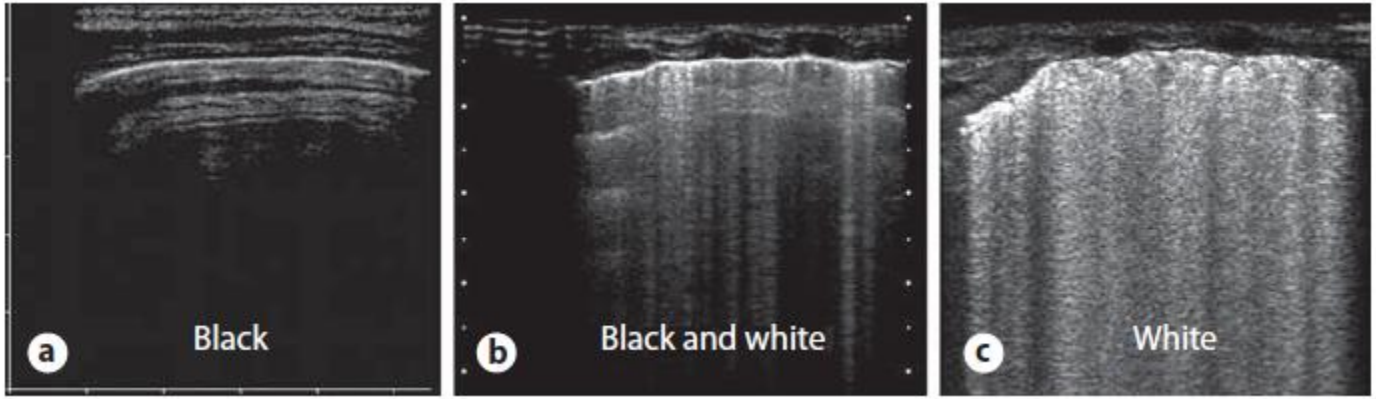
Neonatology
formerly Biology of the Neonate

Neonatology 2008;94:52–59
DOI: 10.1159/000113059

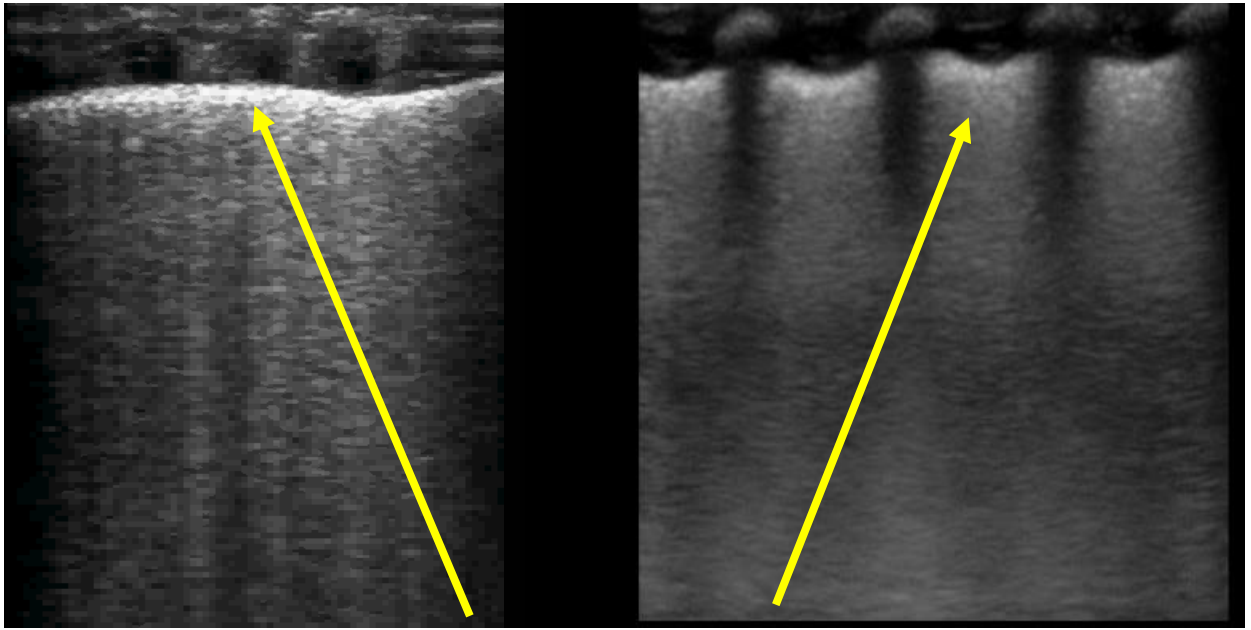
Received: July 5, 2007
Accepted after revision: November 8, 2007
Published online: January 15, 2008

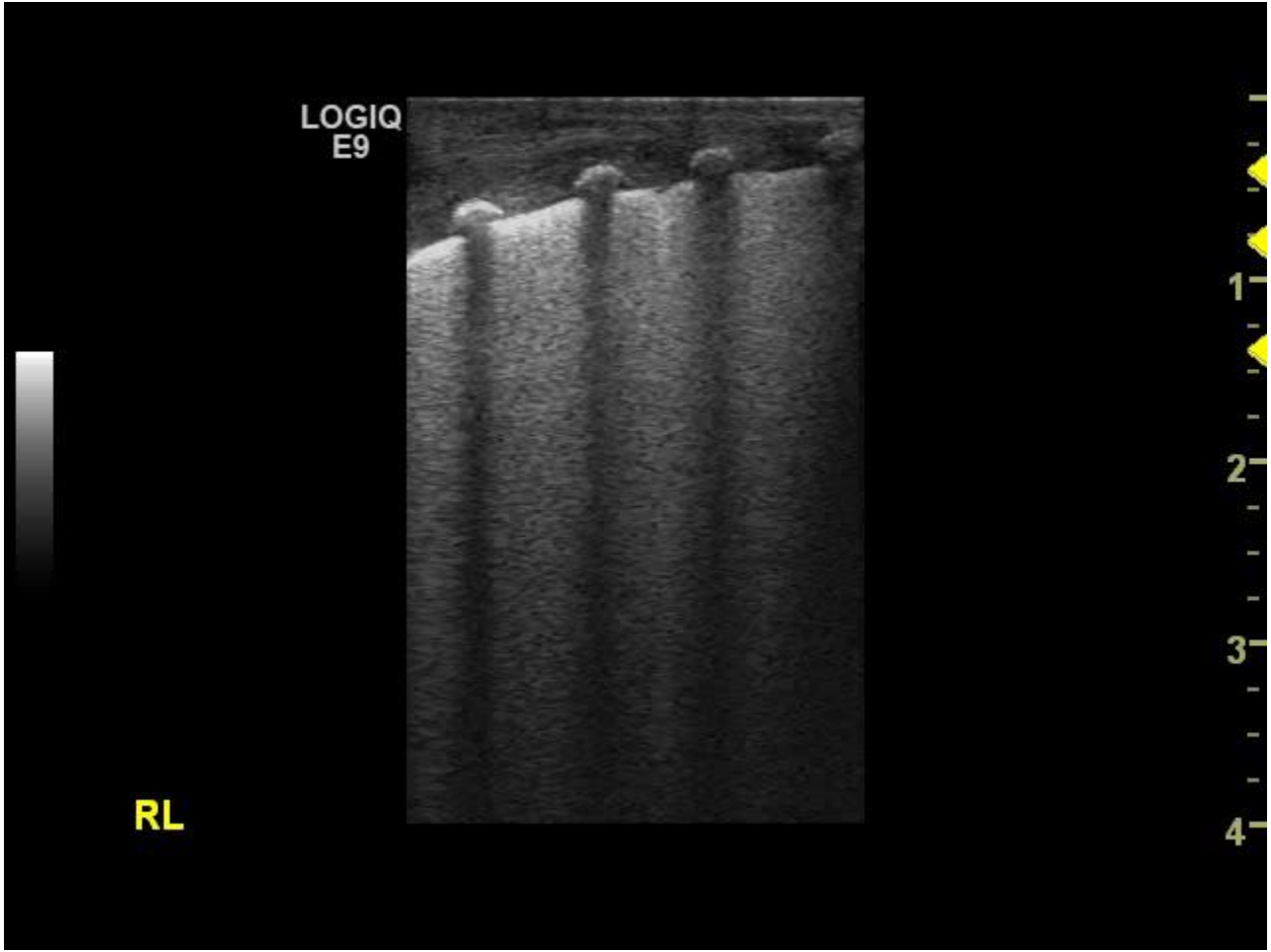
Lung Ultrasound in Respiratory Distress Syndrome: A Useful Tool for Early Diagnosis

Roberto Copetti[a] Luigi Cattarossi[a] Franco Macagno[b] Marco Violino[b]
Riccardo Furlan[b]



RDS




LOGIQ
E9
RL
1
2
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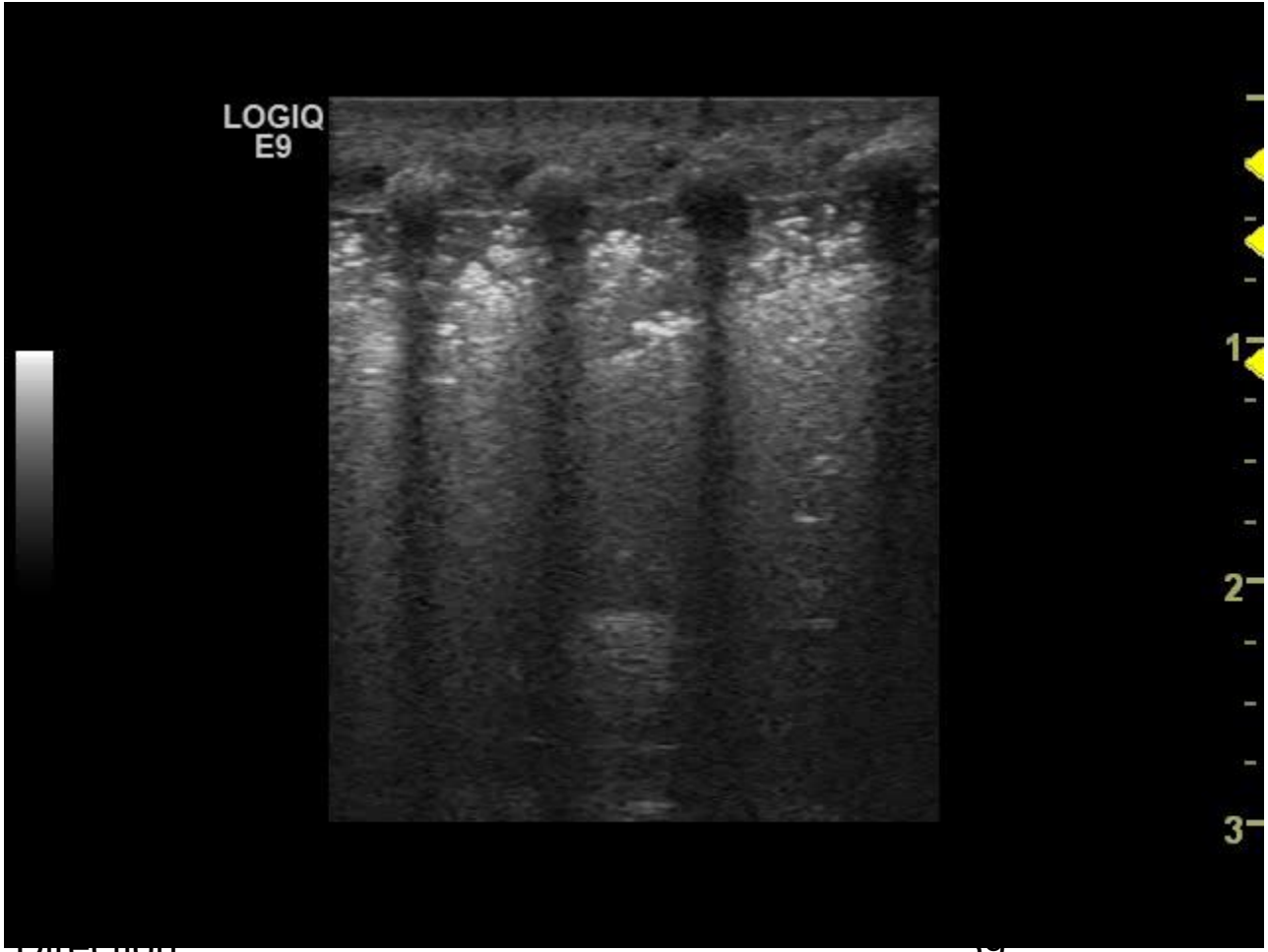
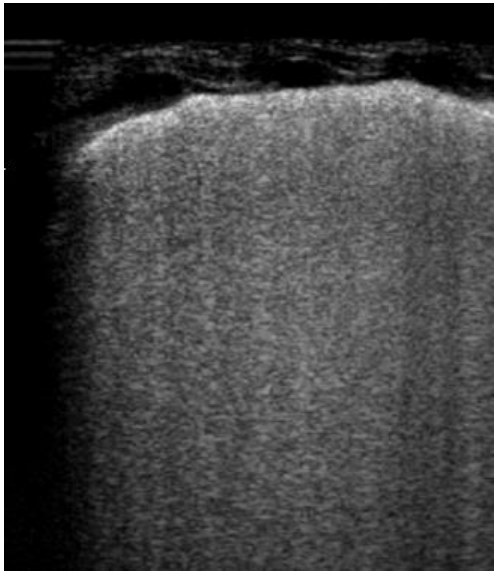

LOGIQ
E9
1
2
3

RDS vs TTN



Look for the A-lines!

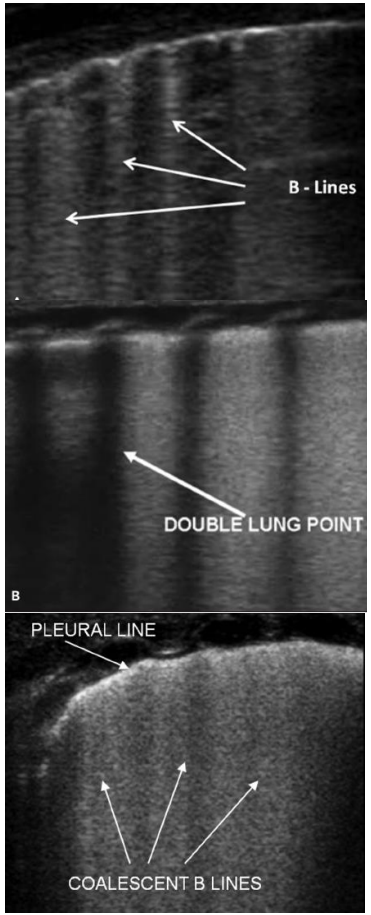
Neonatal Lung Sonography

Interobserver Agreement Between Physician Interpreters With Varying Levels of Experience

Giacomo Brusa, MD, Marilena Savoia, MD, Michela Vergine, MD, Andrea Bon, MD, Roberto Copetti, MD, Luigi Cattarossi, MD

Table 2. Interobserver Agreement Between Main and Expert, Intermediate, and Beginner Control Interpreters

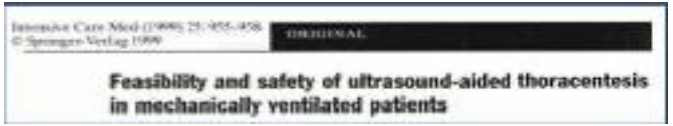
Interobserver Agreement	κ1 (95% CI)	κ2 (95% CI)	κ3 (95% CI)
General	0.94 (0.88–1.00)	0.72 (0.61–0.83)	0.81 (0.71–0.90)
RDS specific	0.94 (0.87–1.00)	0.90 (0.81–0.99)	0.87 (0.78–0.97)
TTN specific	0.95 (0.89–1.00)	0.76 (0.64–0.88)	0.81 (0.70–0.91)

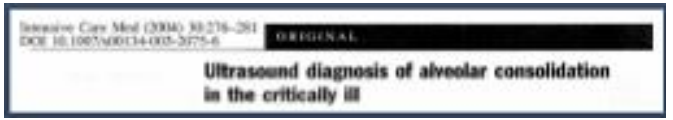


J Ultrasound Med 2015; 34:1549–1554

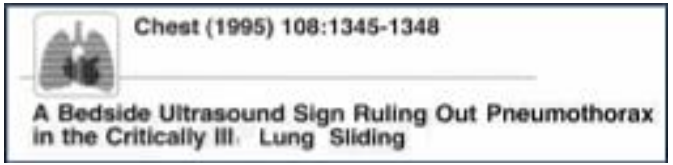
Lung ultrasound vs CT scans

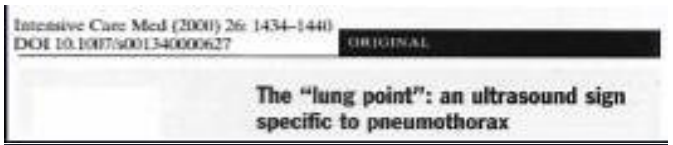
	Sensitivity - Specificity
Pleural effusion	97 - 94%
Consolidation	90 - 98%
Interstitial syndrome	100 - 100%
Pneumothorax	100 - 91%
« Occult » Pneumothorax	79 – 100%

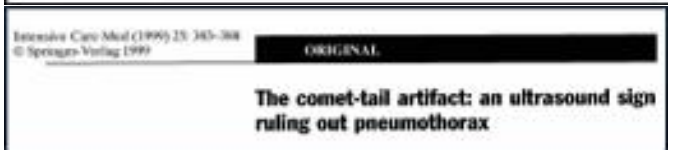

Feasibility and safety of ultrasound-aided thoracentesis in mechanically ventilated patients

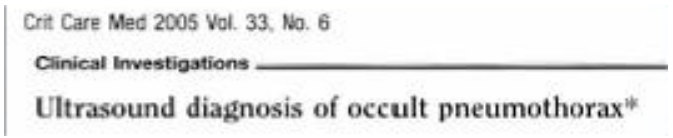

Ultrasound diagnosis of alveolar consolidation in the critically ill


The Comet-Tail Artifact
An Ultrasound Sign of Alveolar-Interstitial Syndrome

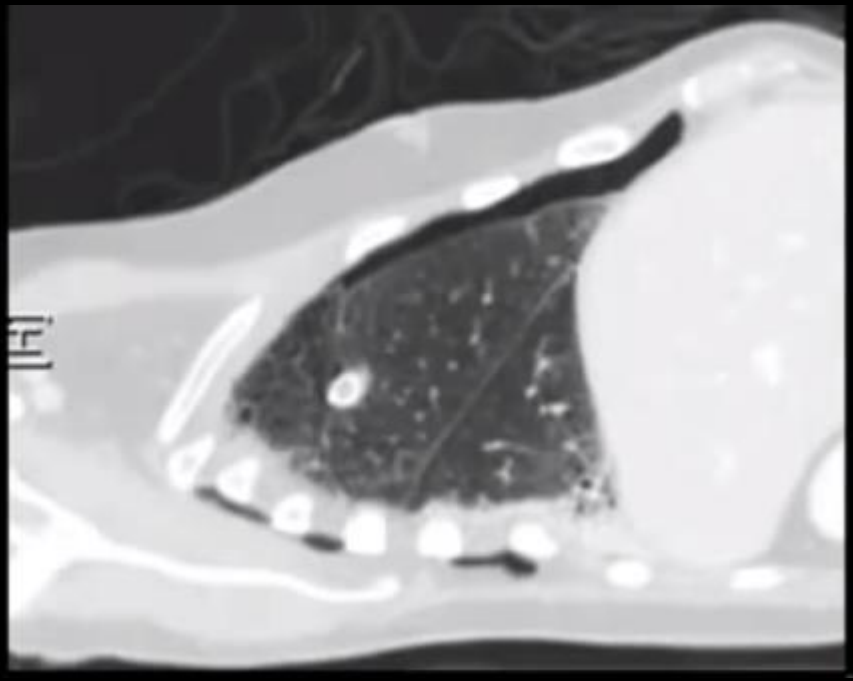

Chest (1995) 108:1345-1348
A Bedside Ultrasound Sign Ruling Out Pneumothorax in the Critically Ill. Lung Sliding


The "lung point": an ultrasound sign specific to pneumothorax

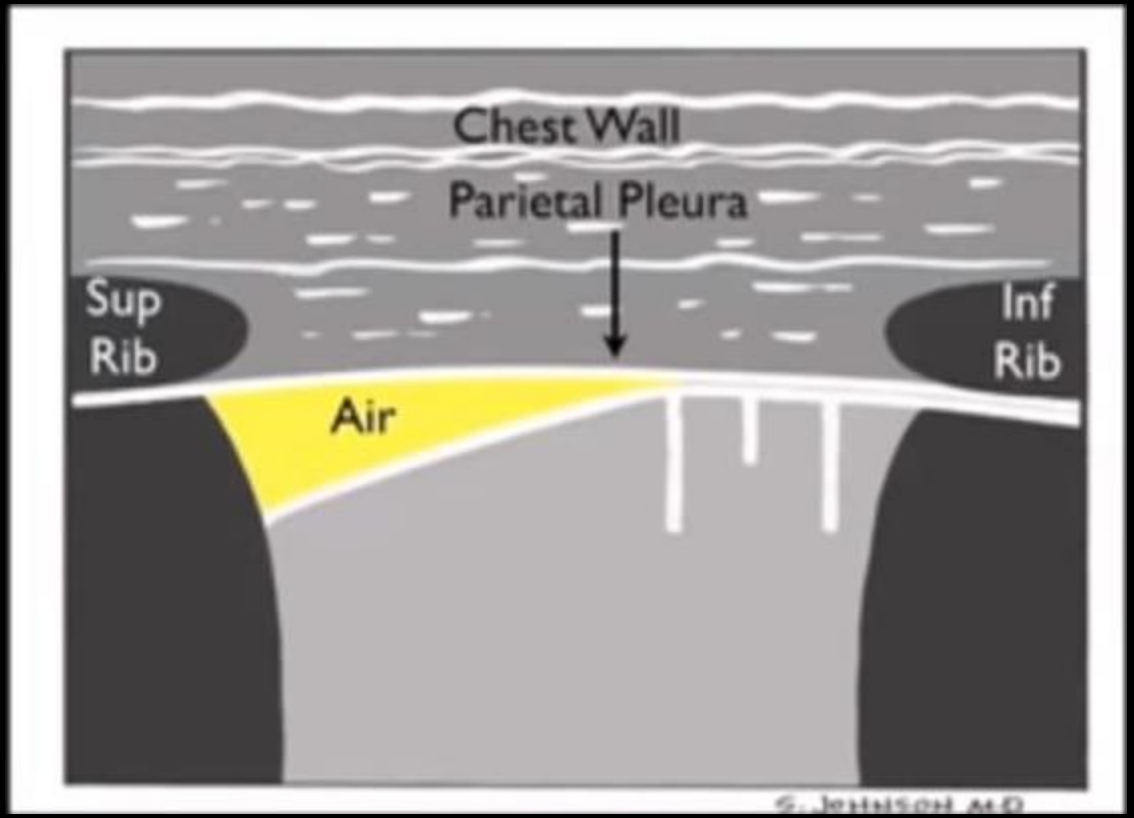

The comet-tail artifact: an ultrasound sign ruling out pneumothorax


Crit Care Med 2005 Vol. 33, No. 6
Clinical Investigations
Ultrasound diagnosis of occult pneumothorax*

Pneumothorax



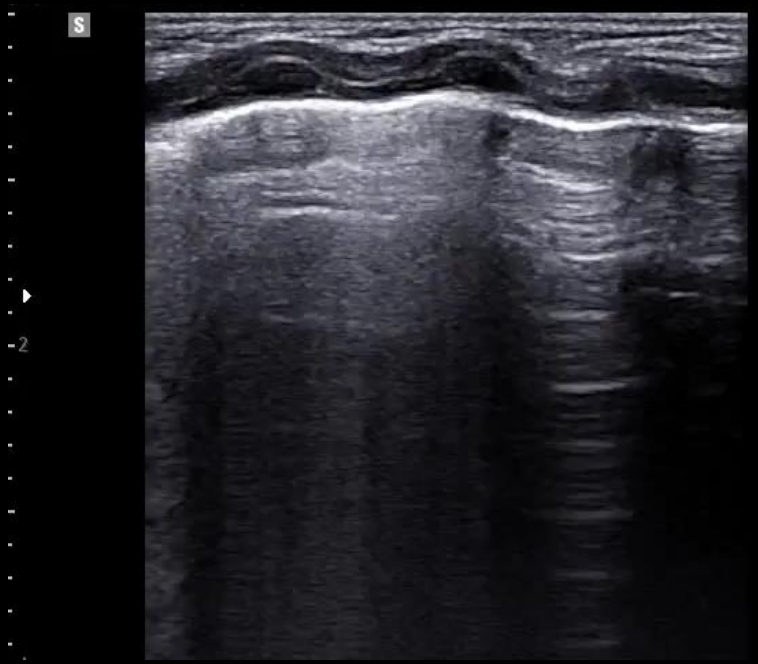
Western Sono : Lung Ultrasound – Interpreting the lung and pleural «signatures »

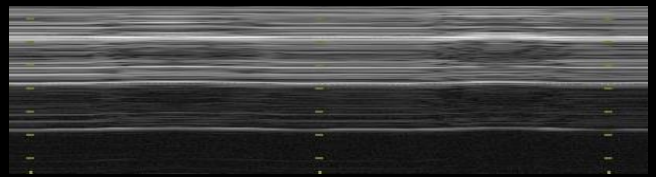


Western Sono : Lung Ultrasound – Interpreting the lung and pleural «signatures »

Pneumothorax

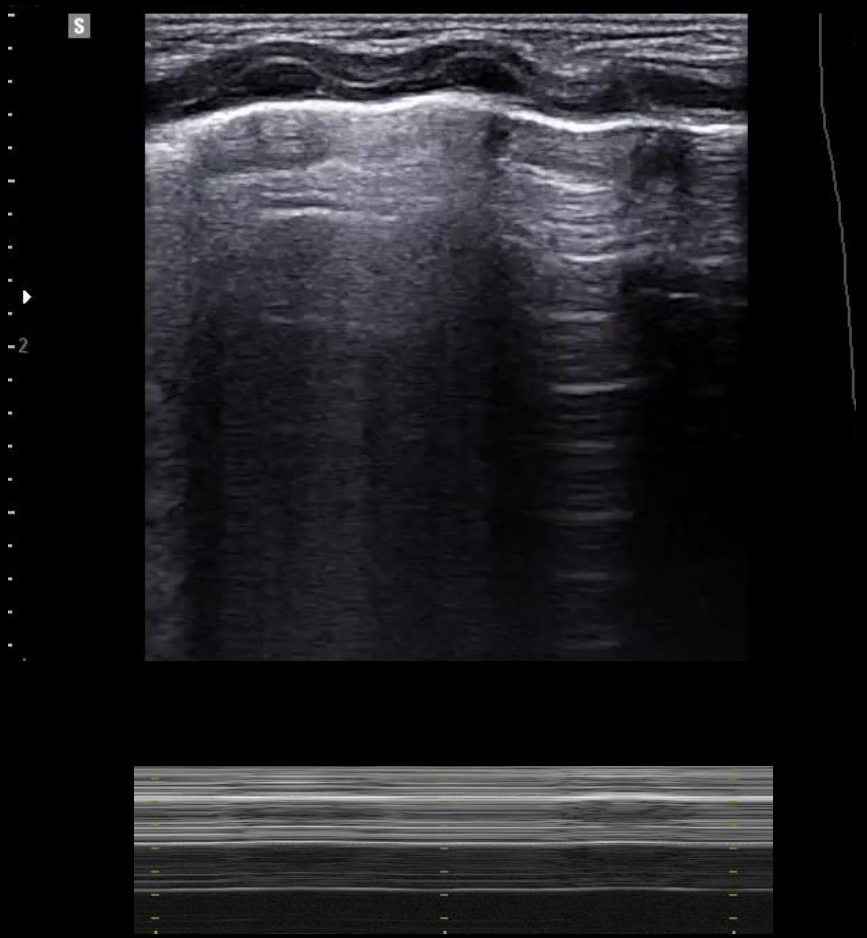
1. Absence of lung sliding





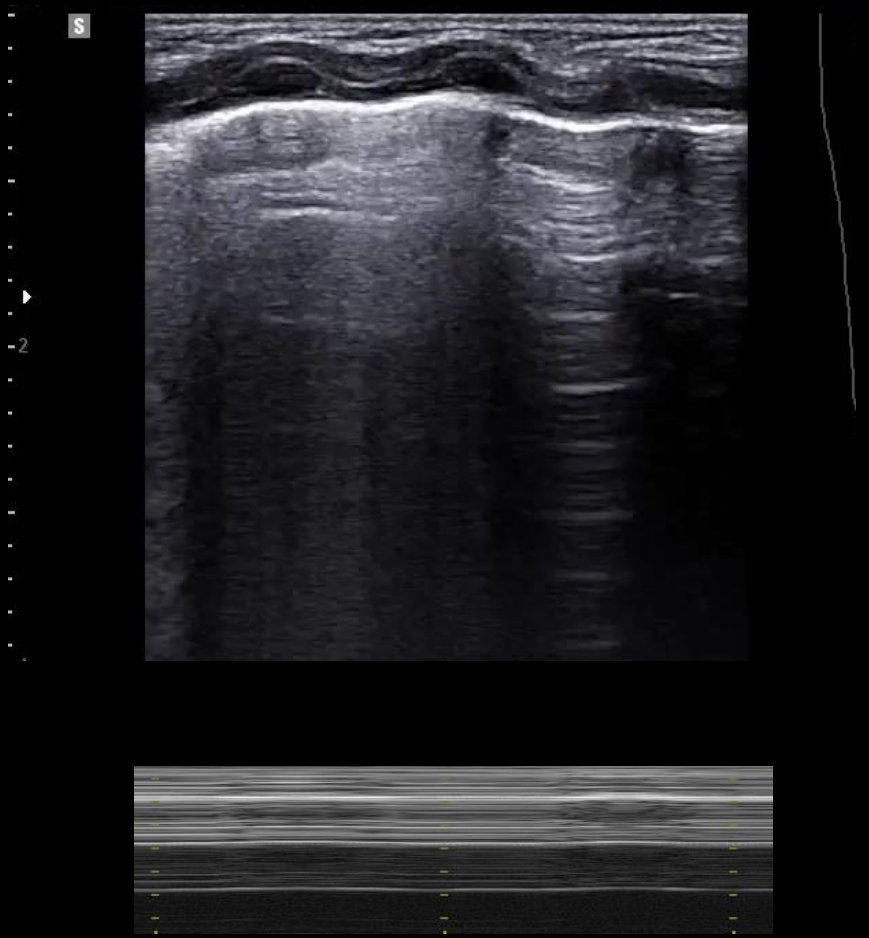
Pneumothorax

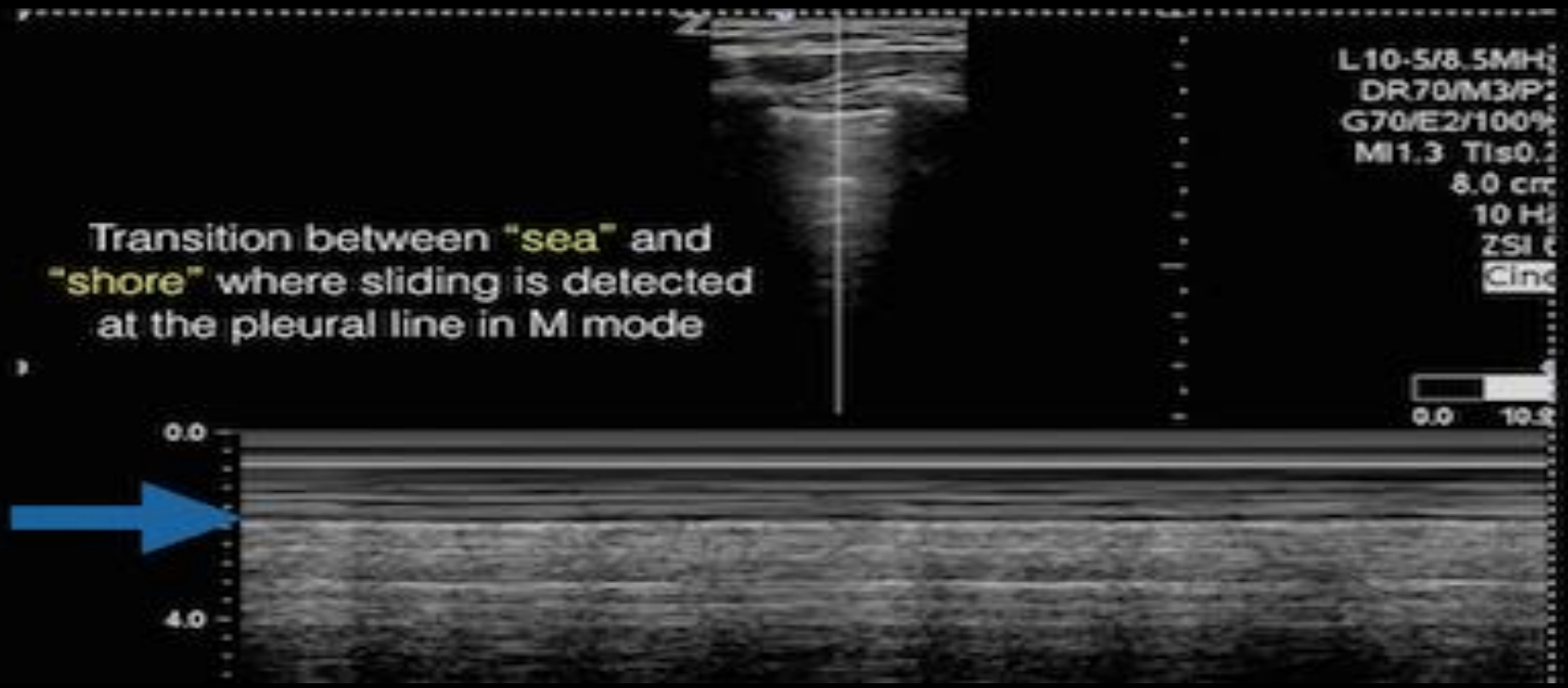
1. Absence of lung sliding
2. No B-lines (only A-lines)

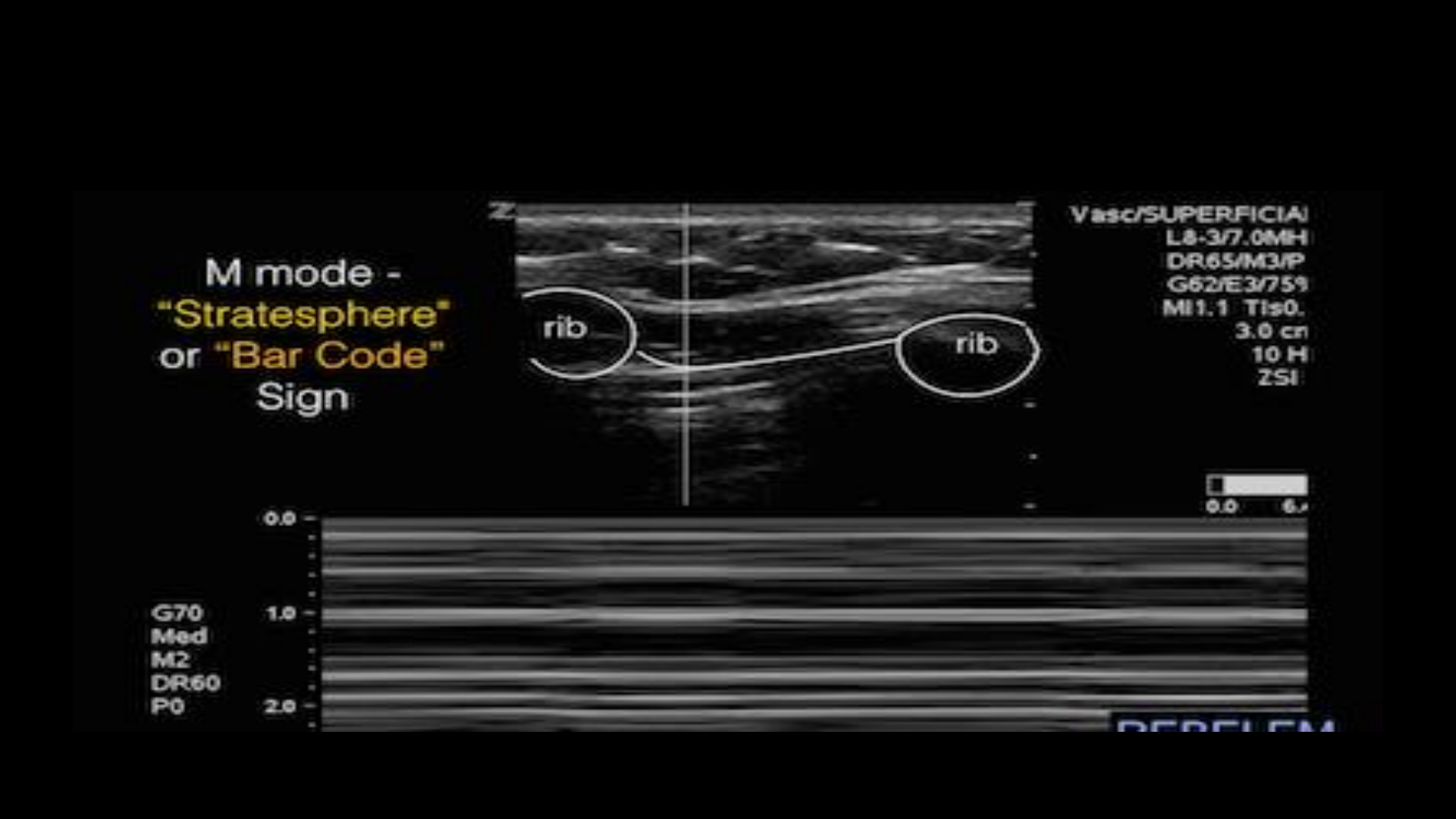


Pneumothorax

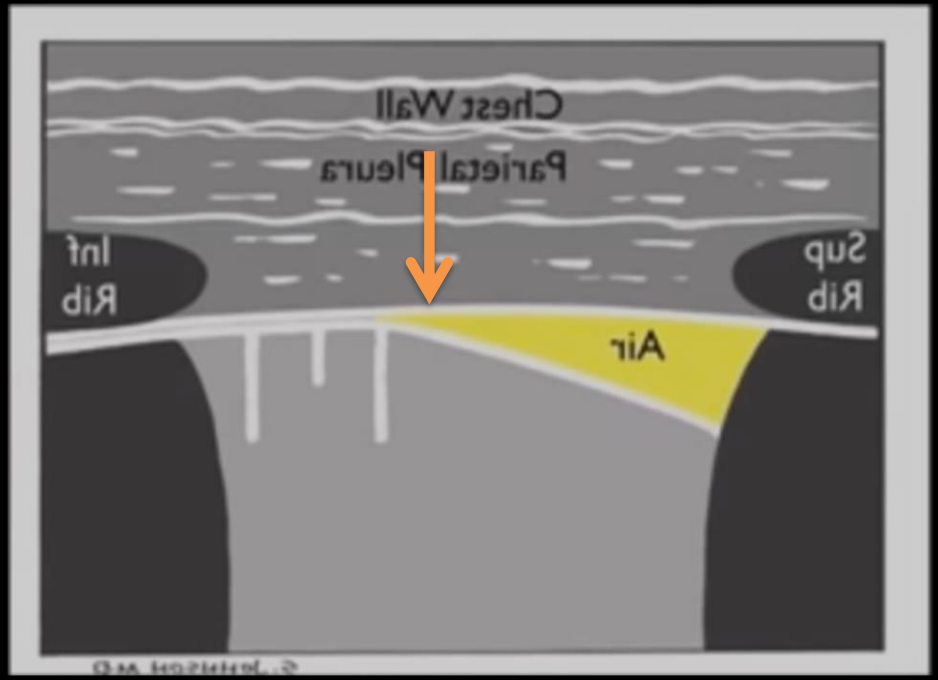
1. Absence of lung sliding
2. No B-lines (only A-lines)
3. Stratosphere sign in M-mode

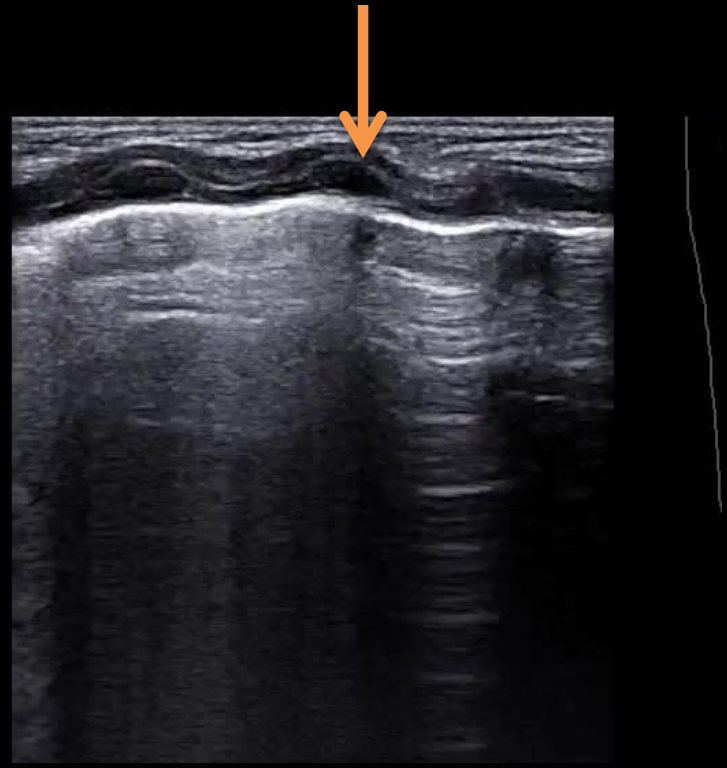



Transition between "sea" and "shore" where sliding is detected at the pleural line in M mode
L10-5/8.5MH
DR70/M3/P
G70/E2/100%
MI1.3 TIs0.
8.0 cm
10 H
ZSI
Cine
0.0
0.0
4.0


M mode -
"Stratesphere"
or "Bar Code"
Sign
rib
rib
Vasc/SUPERFICIAl
L8-3/7.0MH
DR65/M3/P
G62/E3/75
MI1.1 TIs0.
3.0 cn
10 H
ZSI
0.0
1.0
2.0
G70
Med
M2
DR60
P0

Pneumothorax



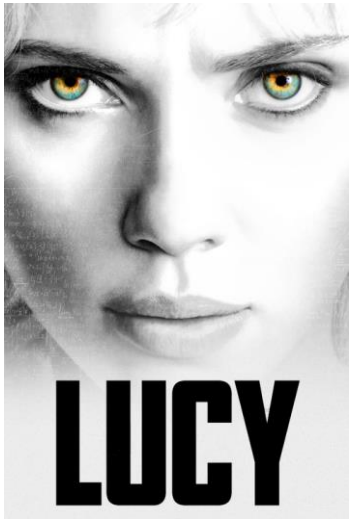


The lung point confirms diagnosis

Pneumothorax

Lung ultrasound in the crashing infant

- International multicenter trial
- "Crashing neonates"
- Rule in/out pneumothorax
- 26/42 pneumothorax
- Echo = 5.3 min vs RxT = 19 min
- Excellent sensitivity and specificity

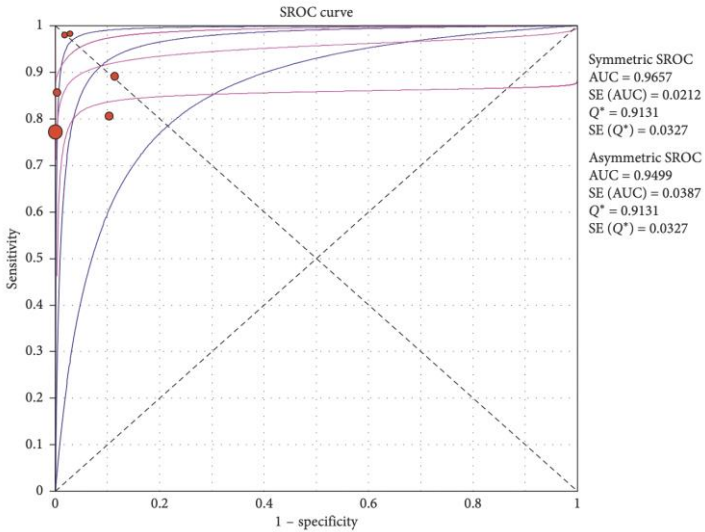


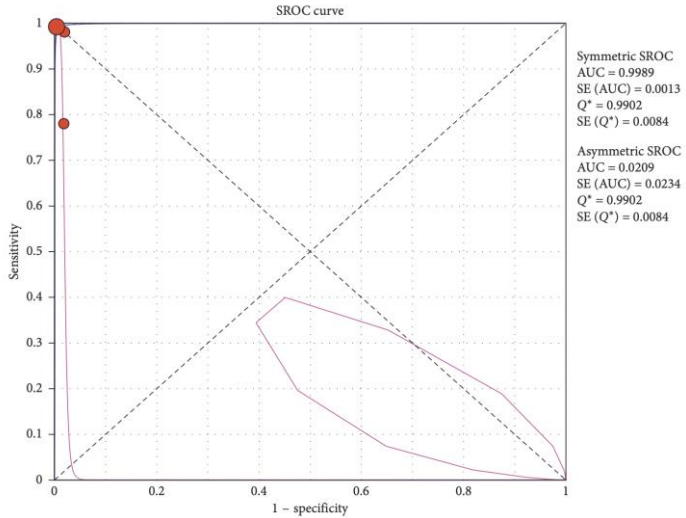
Raimondi F et al. J Pediatrics. *2016*

Accuracy of Ultrasound in Diagnosis of Pneumothorax: A Comparison between Neonates and Adults—A Systematic Review and Meta-Analysis

Hamid Dahmarde,[1] Fateme Parooie,[2] and Morteza Salarzaei[2]

Canadian Respiratory Journal
Volume 2019, Article ID 5271982, 16 pages
https://doi.org/10.1155/2019/5271982





Accuracy of Ultrasound in Diagnosis of Pneumothorax: A Comparison between Neonates and Adults—A Systematic Review and Meta-Analysis

- General population

Sensitivity = 98.6% (97.7%–99.2%),
Specificity = 85.1% (88.18%–88.5%),
Odds ratio = 387.72% (76.204–1972.7)

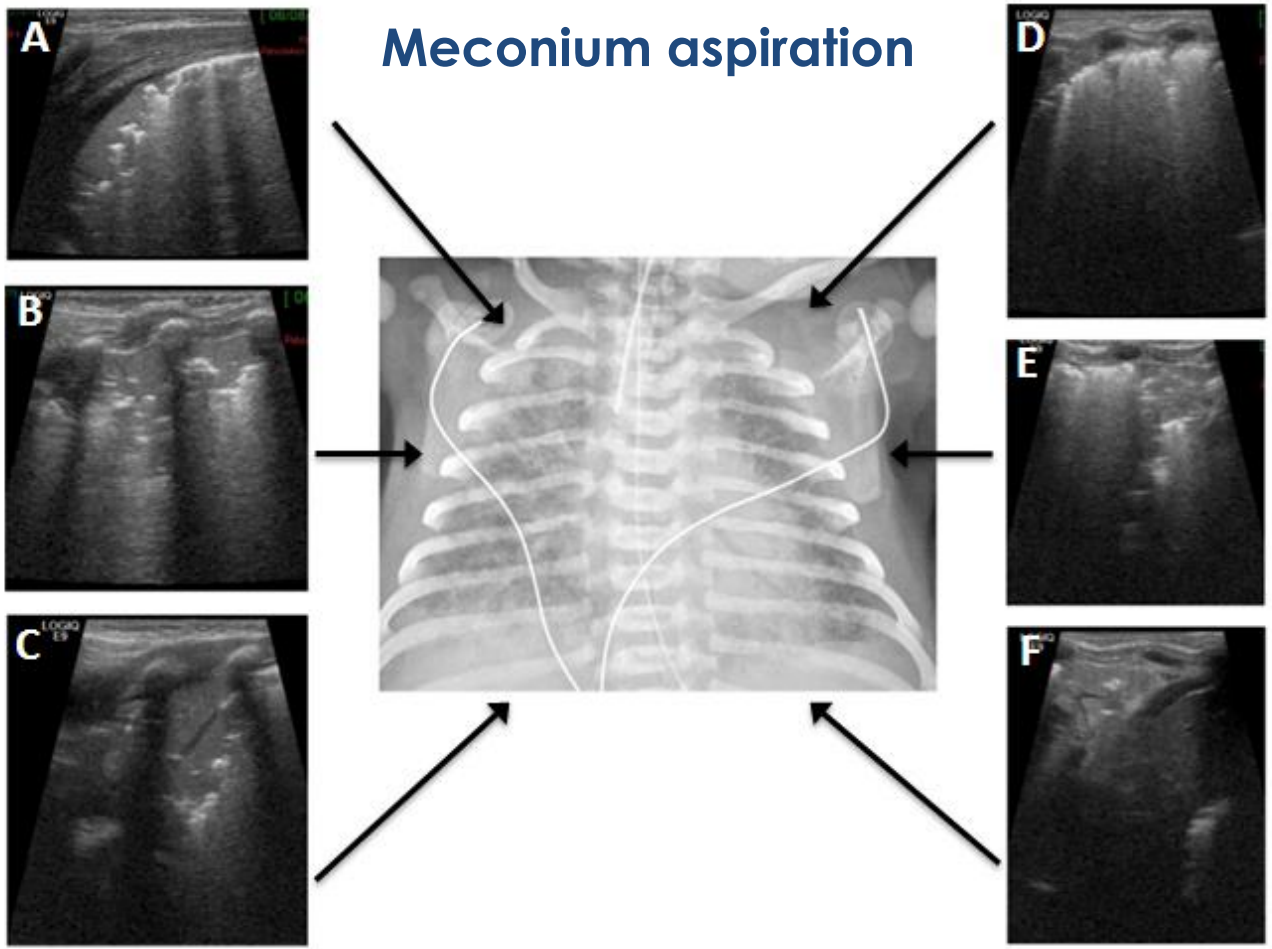
- Neonates

Sensitivity = 96.7% (88.3%–99.6%)
Specificity = 100% (97.7%–100%),
Odds ratio = 1343.1% (167.20–10788.9)

- Adults

Sensitivity = 82.9% (78.3–86.9%
Specificity = 98.2% (97.0%–99.0%)
Odds ratio = 423.13% (45.222–3959.1),

Meconium aspiration

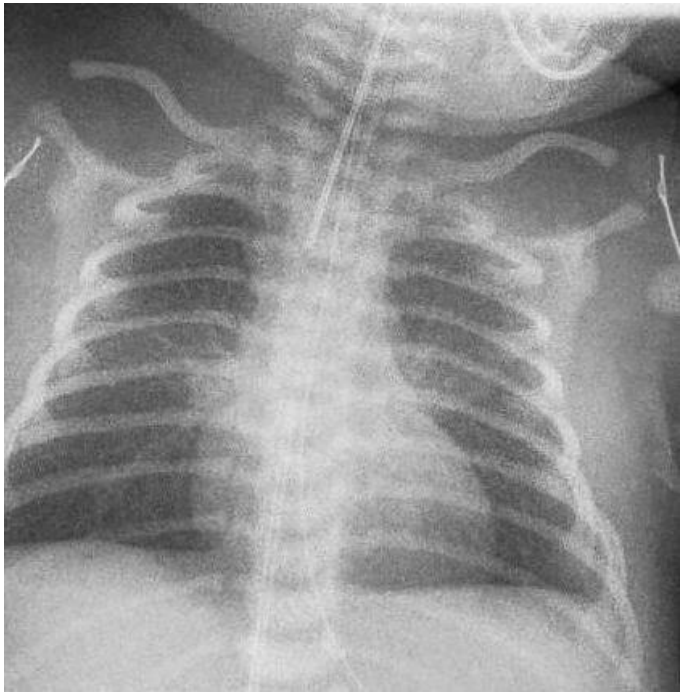


Marco Piastra et al. *Early Human Development*. 2014

Clinical case

- Term baby, pregnancy OK
- No history for infection
- Severe and progressive respiratory distress

- Tainted amniotic fluid, but nothing on intubation
- Hypoxic on FiO2 100%
- HFOV, iNO by transport team



Corresponding chest X-ray

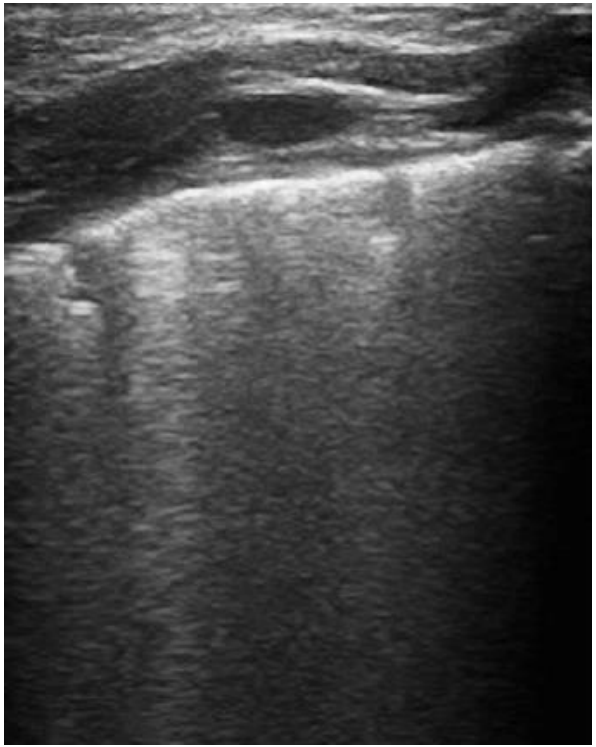
Clinical case

- HFOV, iNO by transport team
- Curare

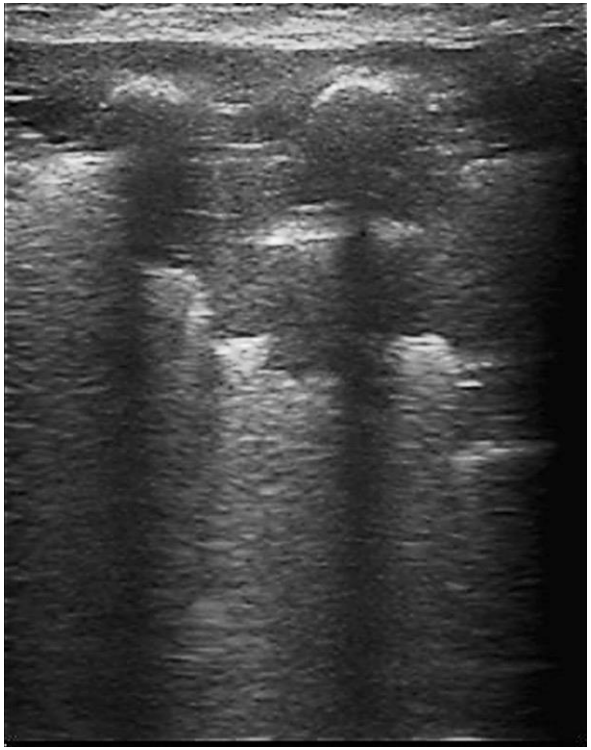
- Sat 90% on FiO2 100%

- Suspected congenital heart disease

- SOS cardiology
- Admitted to NICU for stabilization



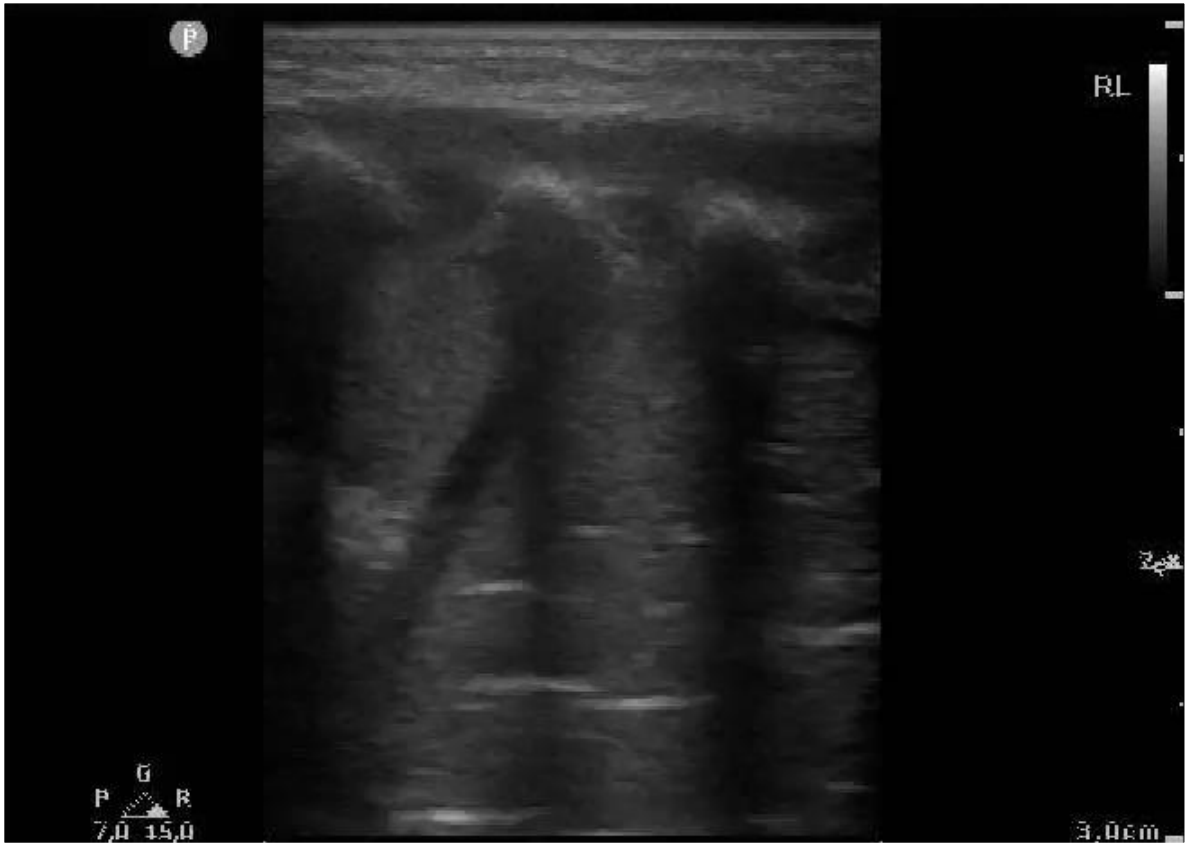
Anterior scan
Irregular pleural line and B-lines

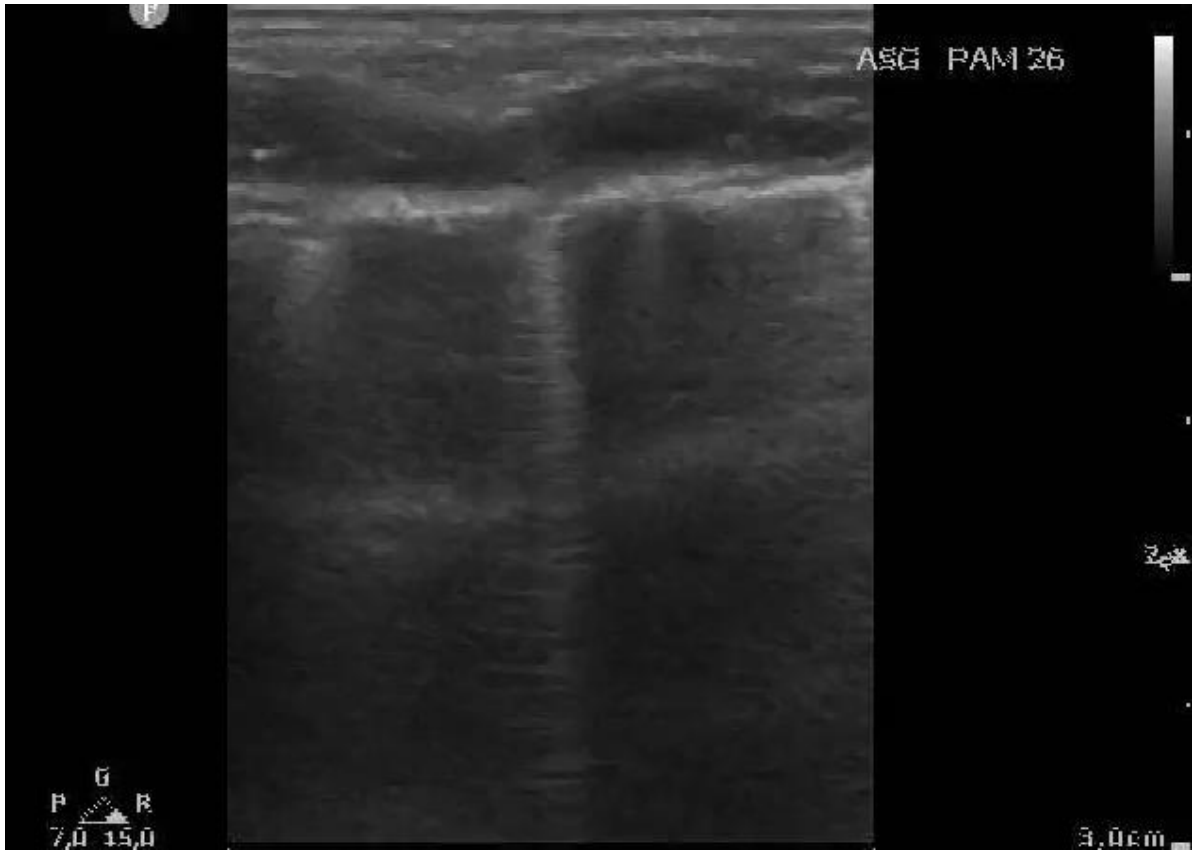


Lateral vertical scan
Consolidation and B-lines

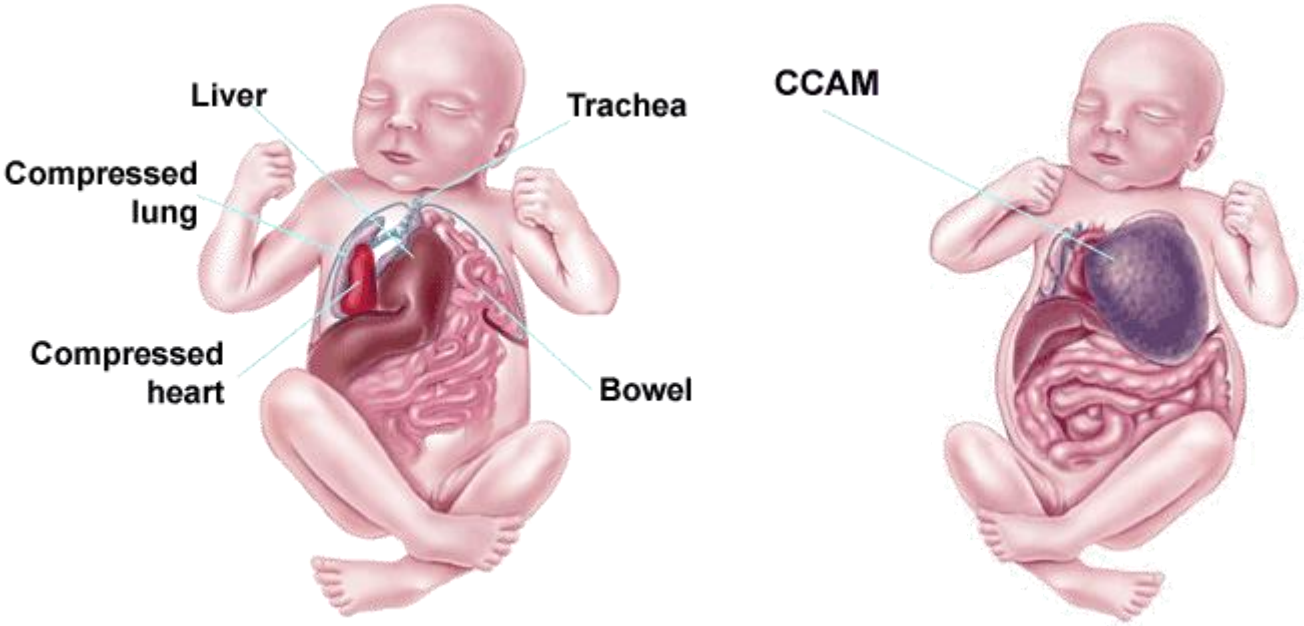
Lateral vertical scan
Atelectasis

Horizontal scan - posterolateral
Atelectasis with pleural effusion


P
RL
G
P
R
7.0 15.0
3.0cm


ASG PAM 26
G
P R
7,0 15,0
3,0cm

Congenital lung malformations

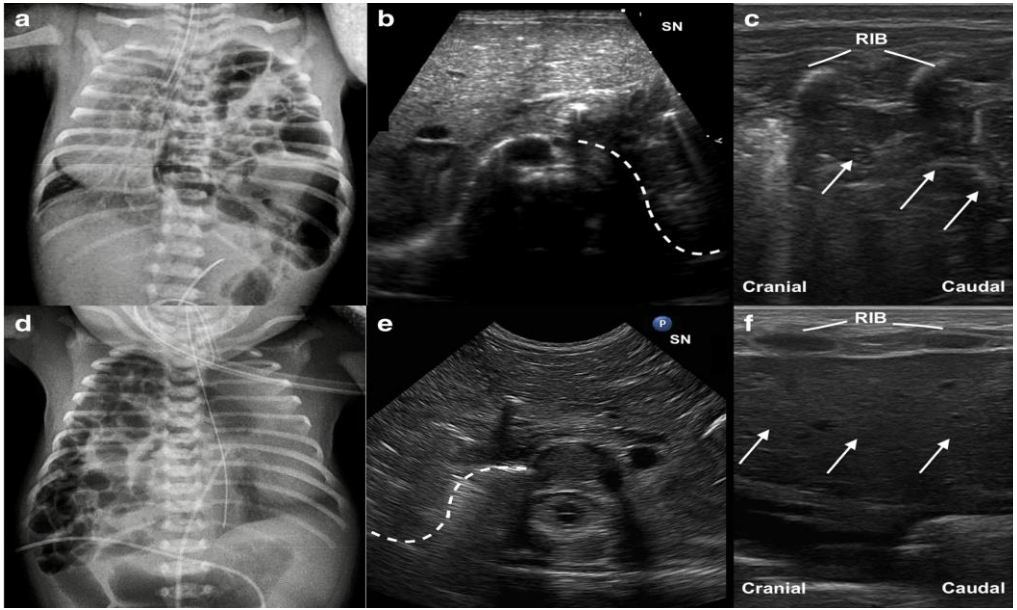


European Journal of Pediatrics
https//doi.org/10.1007/s00431-019-03321-y

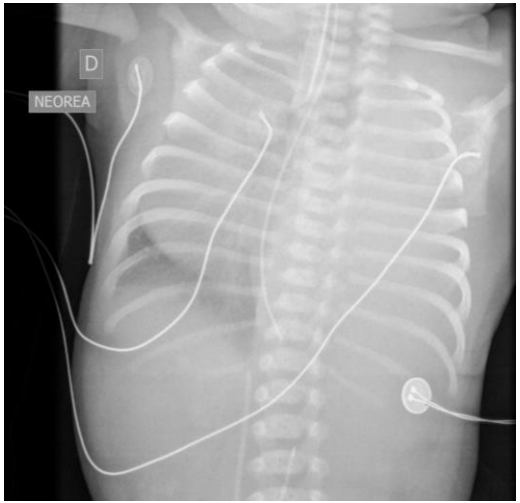
ORIGINAL ARTICLE

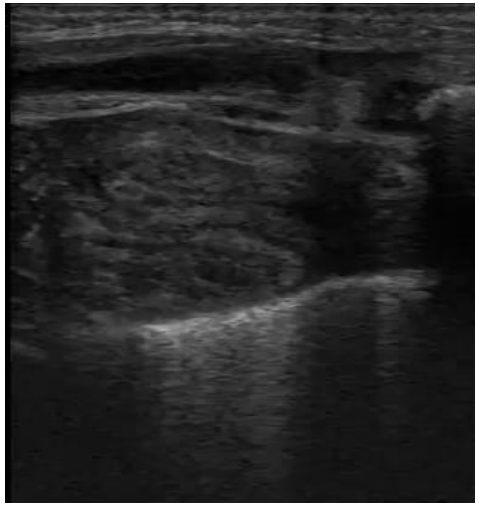
Lung ultrasound findings in congenital diaphragmatic hernia

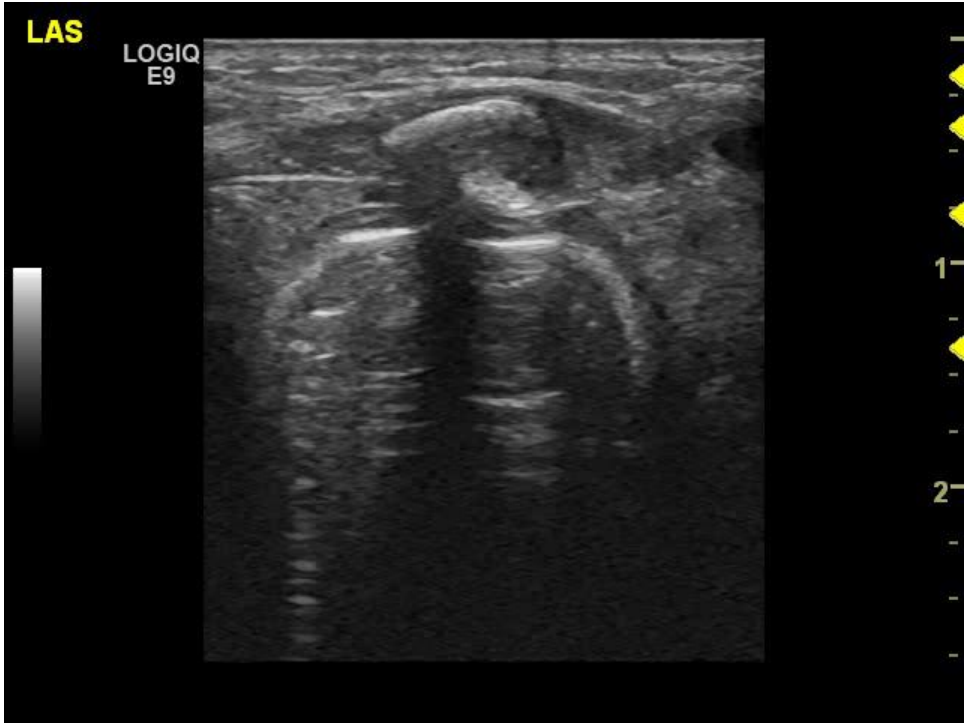
Iuri Corsini[1] &Niccolò Parri[2] &Caterina Coviello[1] &Valentina Leonardi[1] &Carlo Dani[1,3]



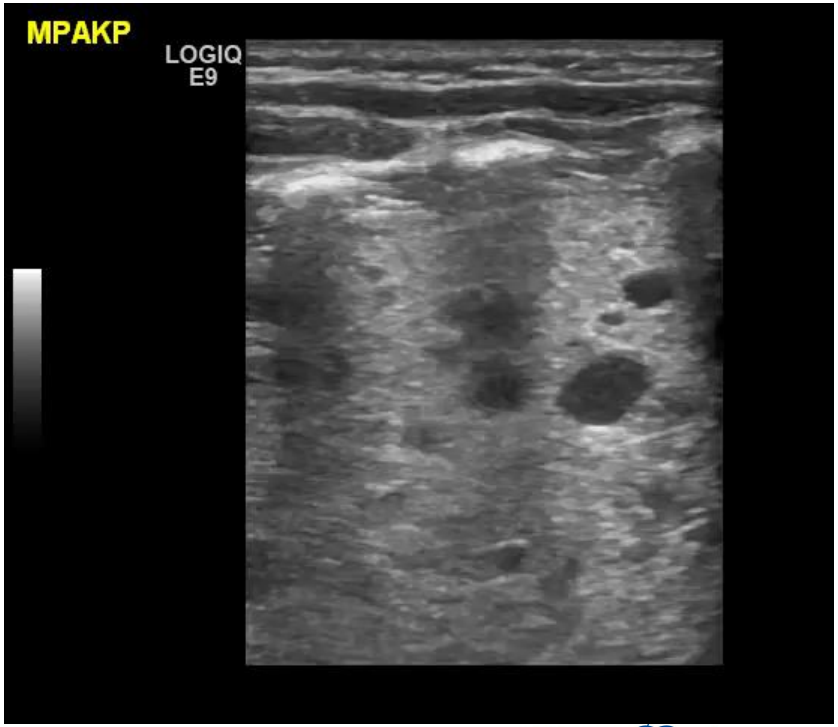
Congenital diaphragmatic hernia

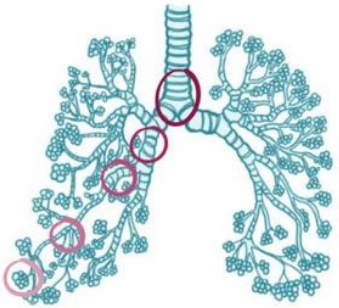





LAS
LOGIQ
E9
1
2

CPAM

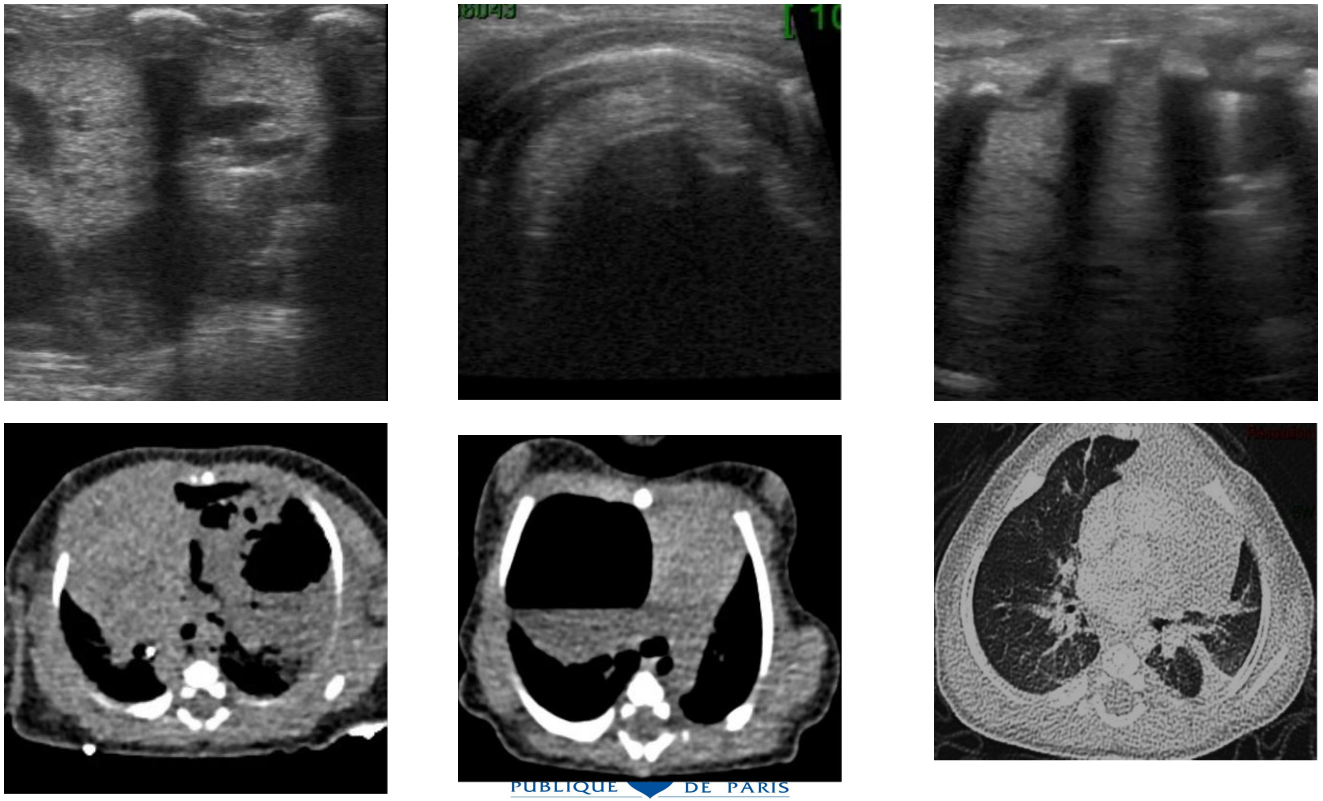




Lung Ultrasound Findings in Congenital Pulmonary Airway Malformation

Nadya Yousef, MD[1,2] Mostafa Mokhtari, MD[2] Philippe Durand, MD[2] Francesco Raimondi, MD, PhD[3]
Fiorella Migliaro, MD[3] Alexandra Letourneau, MD[4] Pierre Tissières, MD, PhD[2]
Daniele De Luca, MD, PhD[1,5]

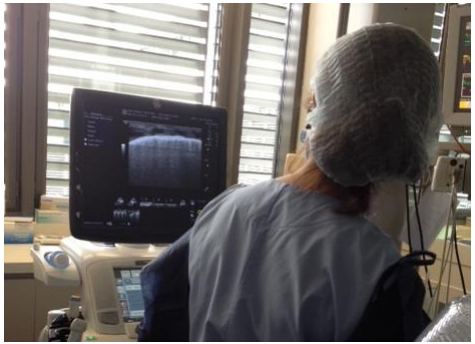
Hôpitaux universitaires Paris-Sud
Antoine-Béclère Bicêtre Paul-Brousse



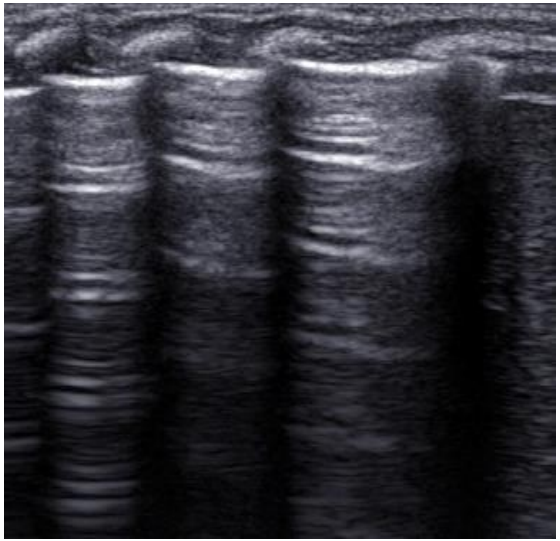
PUBLIQUE DE PARIS

Yousef et al, 2018

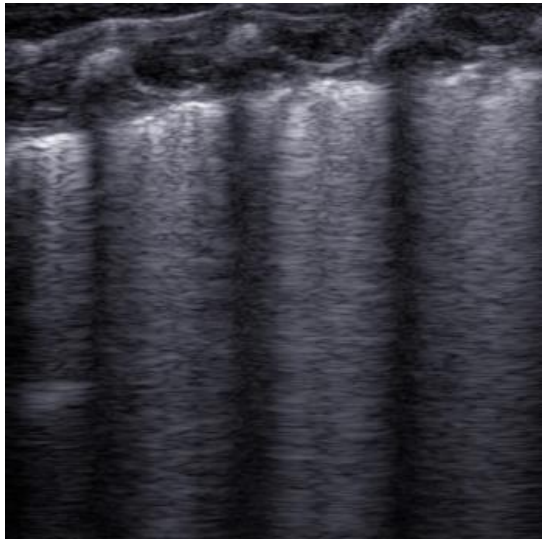
THE QUEST FOR « FONCTIONNAL » LUNG ULTRASOUND



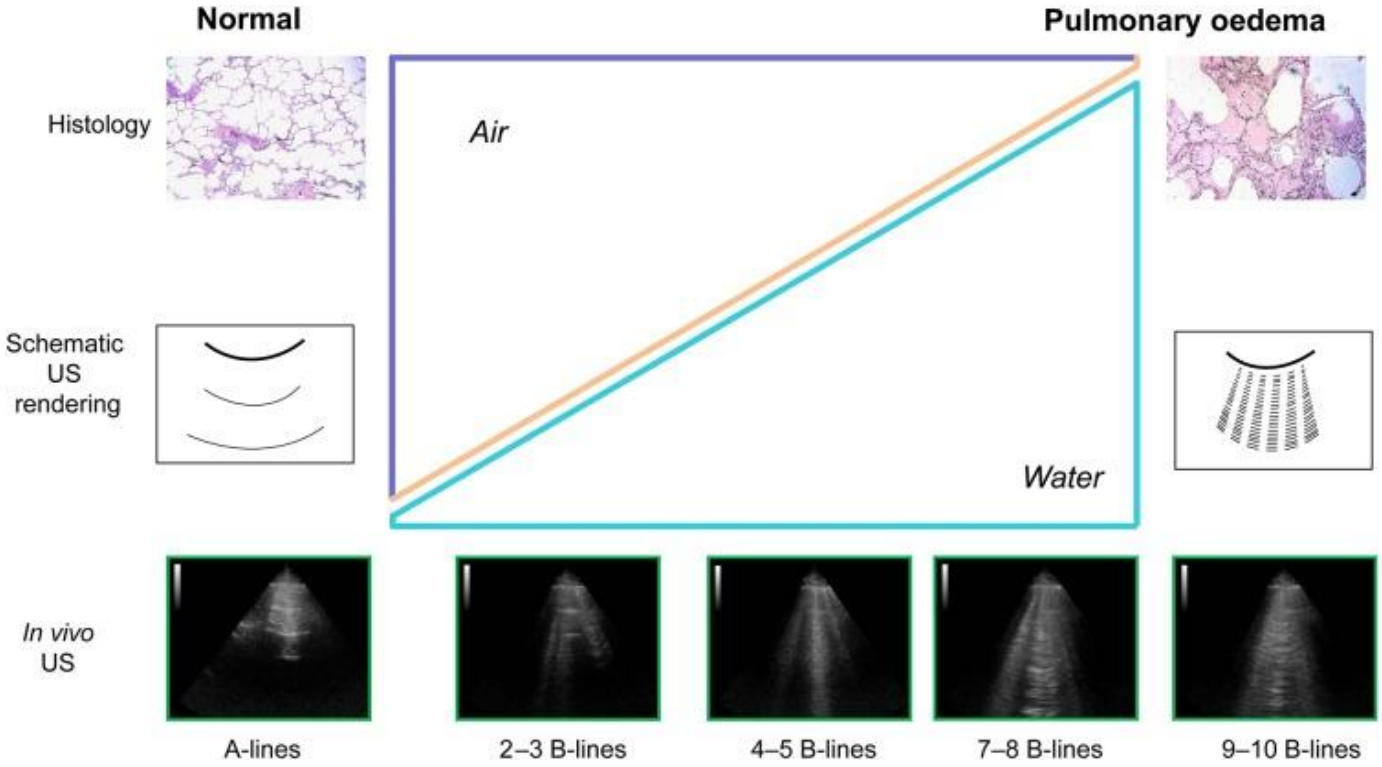
Lung ultrasound evaluates loss of lung aeration



Normal lung

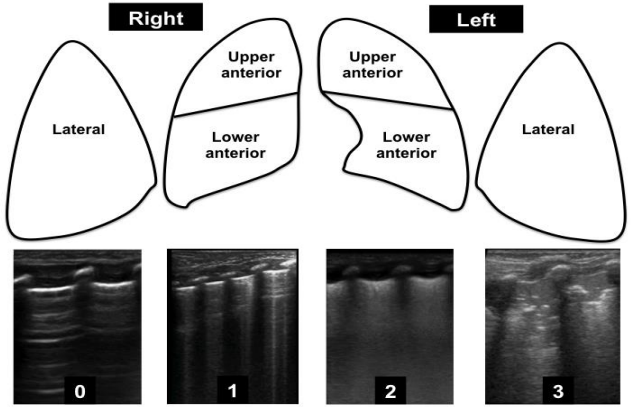


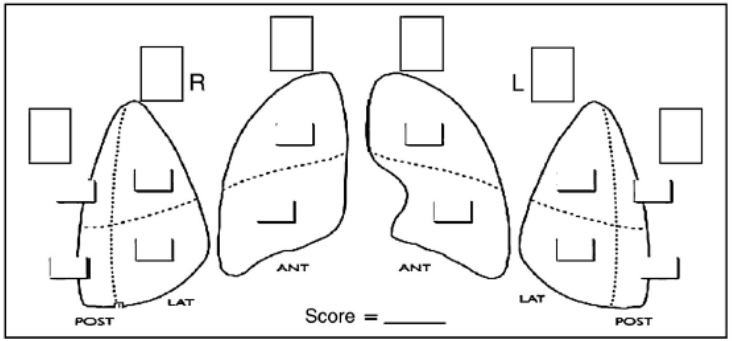
"White" lung as in RDS
Loss of aeration


Normal
Pulmonary oedema
Histology
Air
Water
Schematic US rendering
In vivo US
A-lines
2–3 B-lines
4–5 B-lines
7–8 B-lines
9–10 B-lines

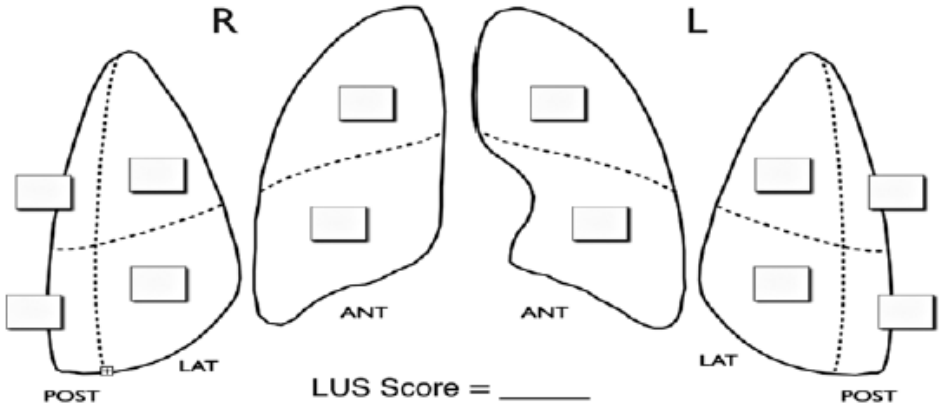
Multiple lung ultrasound scores available

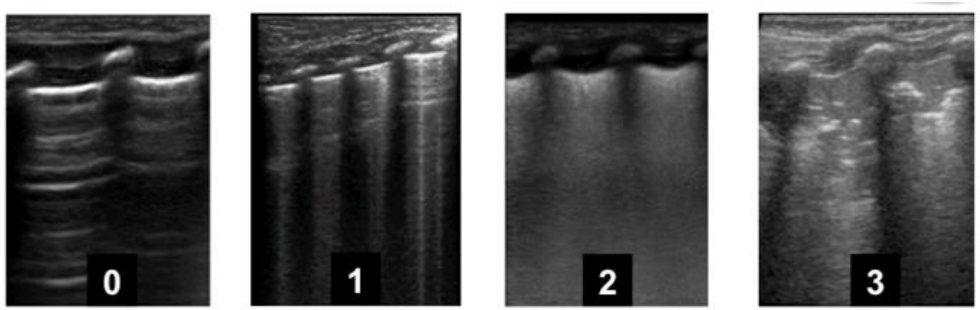
- Guide respiratory management
- Evaluate for EVLW
- Response to treatment
- Progression towards CLD
- Adapted neonatal scores
  - Surfactant
  - Progression towards CLD





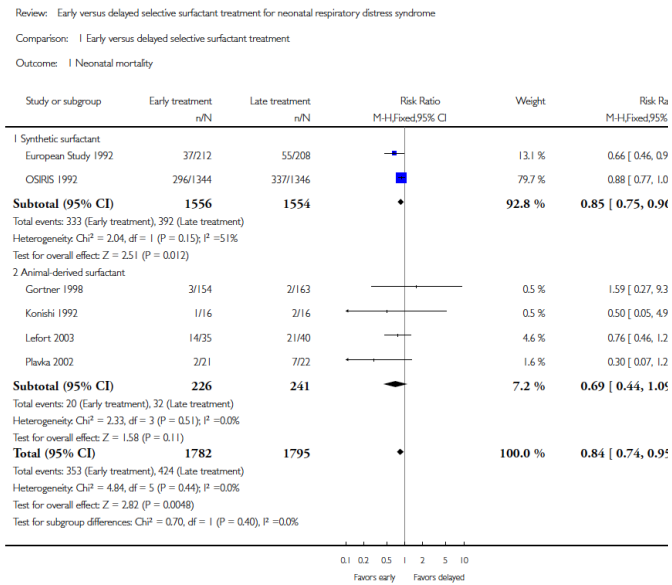
TO B OR NOT TO B….

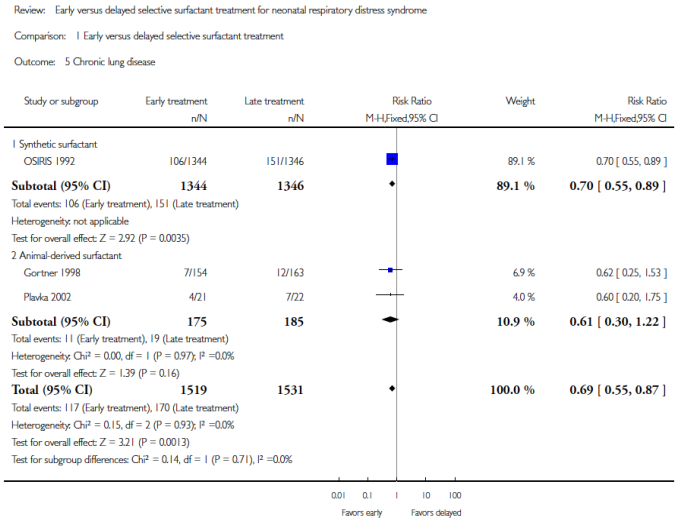




Surfactant elective administration now recommended

- Early surfactant (3 hrs) reduces mortality and BPD
- No easy bedside tools to estimate lung volumes





Bahadue FL et al, Cochrane Databse Syst Rev 2012

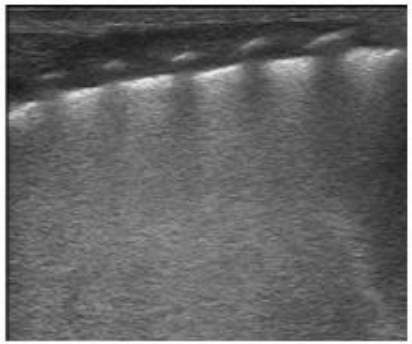
Raimondi et al. Critical Care 2012, 16:R220
http://ccforum.com/content/16/6/R220

CRITICAL CARE

RESEARCH Open Access

Can neonatal lung ultrasound monitor fluid clearance and predict the need of respiratory support?

Francesco Raimondi[1*], Fiorella Migliaro[1], Angela Sodano[1], Angela Umbaldo[1], Antonia Romano[1], Gianfranco Vallone[2] and Letizia Capasso[1]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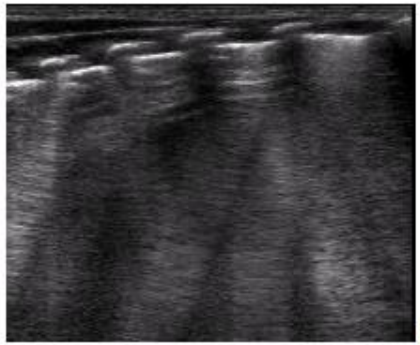
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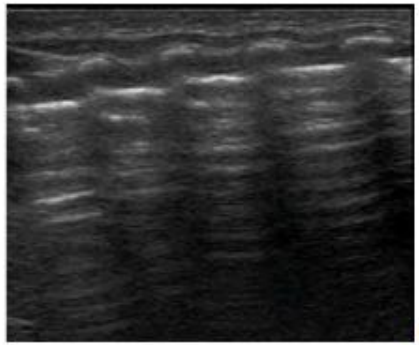

C

A semi-quantitative score can predict surfactant need

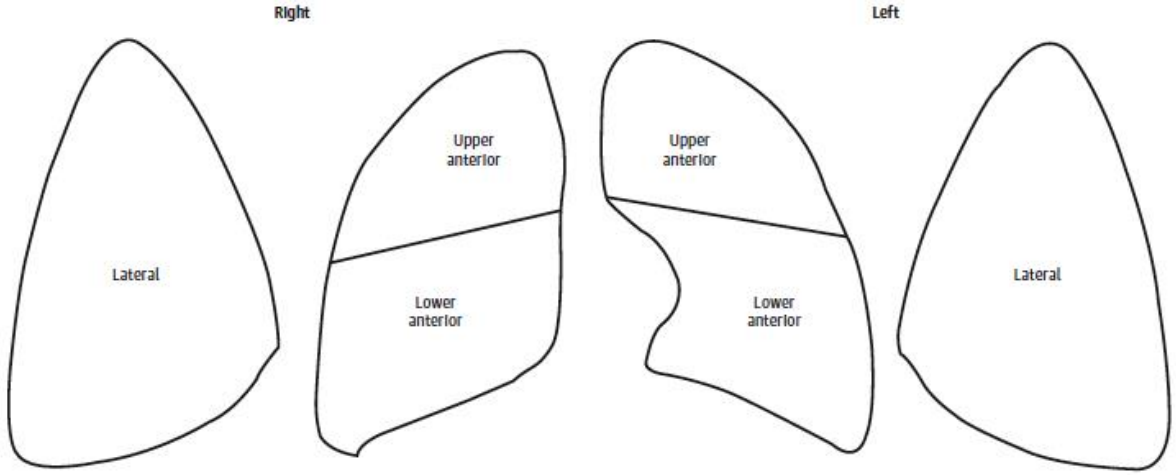
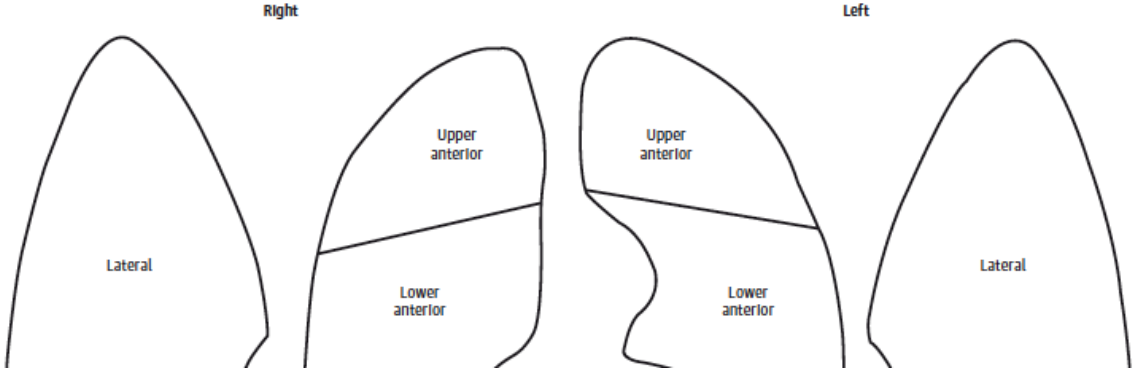


Figure 1. Description of the Lung Ultrasonography Score

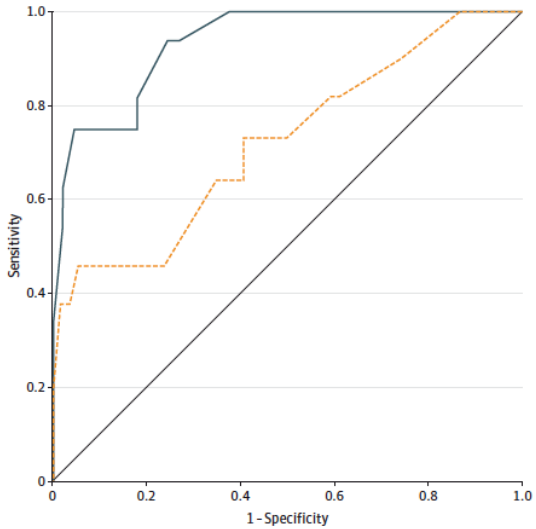


Lung Ultrasonography Score to Evaluate Oxygenation and Surfactant Need in Neonates Treated With Continuous Positive Airway Pressure

Roselyne Brat, MD; Nadya Yousef, MD; Roman Klifa, MD; Stephanie Reynaud, MD; Shivani Shankar Aguilera, MD; Daniele De Luca, MD, PhD

JAMA Pediatr. 2015;169(8):e151797. doi:10.1001/jamapediatrics.2015.1797

Figure 3. Receiver Operating Characteristic Analysis for the Prediction of Surfactant Administration



Dark blue line indicates lung ultrasonography score for babies with a gestational age less than 34 weeks; yellow line, lung ultrasonography score for babies with a gestational age of 34 weeks or greater. Area under the 2 curves is significantly different (P = .02).

Brat R et al. **JAMA Pediatr 2015**

PEDIATRICS®
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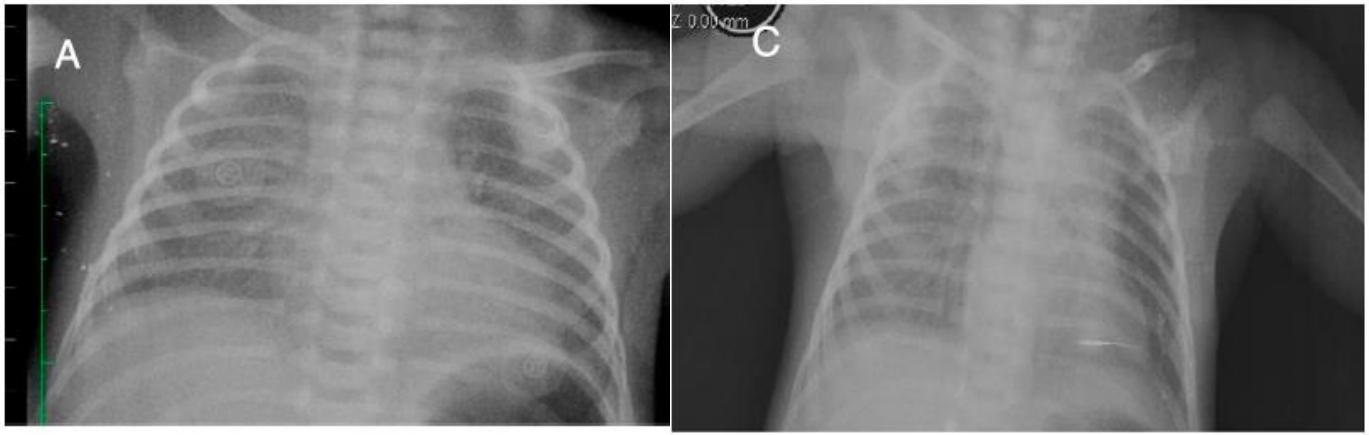
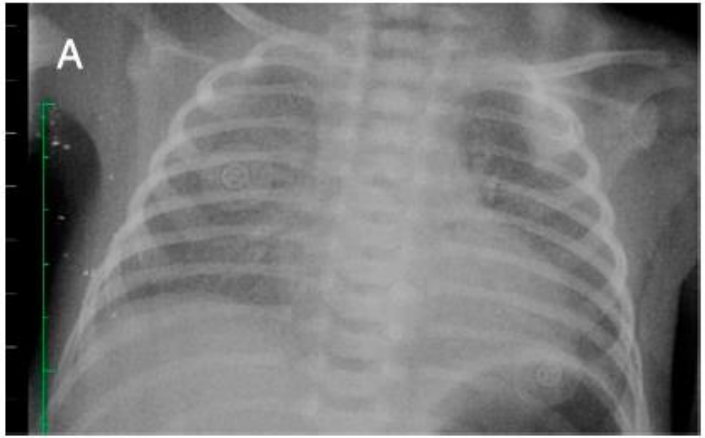
Use of Neonatal Chest Ultrasound to Predict Noninvasive Ventilation Failure

Francesco Raimondi, Fiorella Migliaro, Angela Sodano, Teresa Ferrara, Silvia Lama, Gianfranco Vallone and Letizia Capasso

TABLE 2 Concordance of Ultrasound and Radiographic Results

Ultrasound Result	Radiographic Result			
	Grade 4	Grade 3	Grade 2	Grade 1
Type 1	0	0	7	9
Type 2	0	0	6	6
Type 3	0	0	2	22
Type 1/2	0	0	0	2


A
C


A


C


TERAPIA INTENSIVA NEONATALE

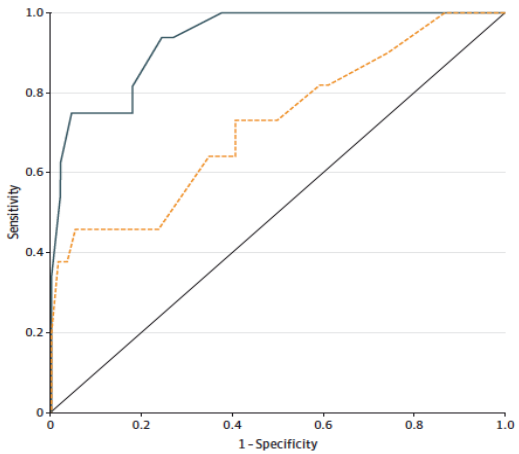

TERAPIA INTENSIVA NEONATALE

Original Investigation | CARING FOR THE CRITICALLY ILL PATIENT

Lung Ultrasonography Score to Evaluate Oxygenation and Surfactant Need in Neonates Treated With Continuous Positive Airway Pressure

Roselyne Brat, MD; Nadya Yousef, MD; Roman Klifa, MD; Stephanie Reynaud, MD; Shivani Shankar Aguilera, MD; Daniele De Luca, MD, PhD

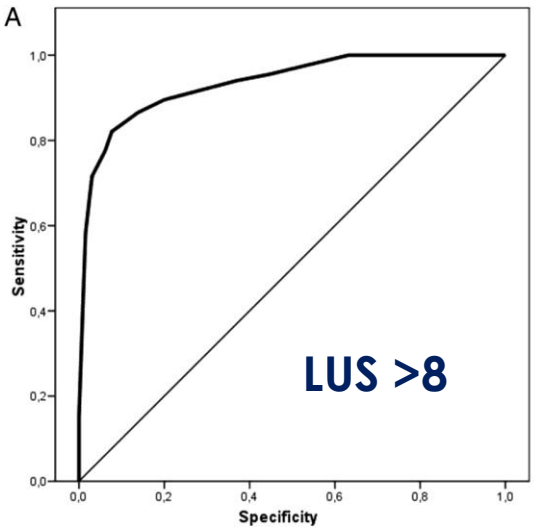
Figure 3. Receiver Operating Characteristic Analysis for the Prediction of Surfactant Administration



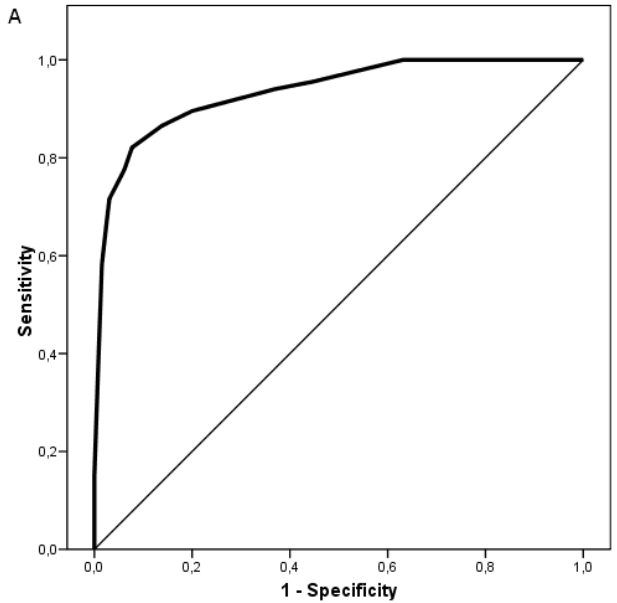
Lung Ultrasound Score Predicts Surfactant Need in Extremely Preterm Neonates

Lucia De Martino, MD,[a,b] Nadya Yousef, MD,[a] Rafik Ben-Ammar, MD,[a] Francesco Raimondi, MD, PhD,[b] Shivani Shankar-Aguilera, MD,[a] Daniele De Luca, MD, PhD[a,c]

PEDIATRICS Volume 142, number 3, September 2018:e20180463

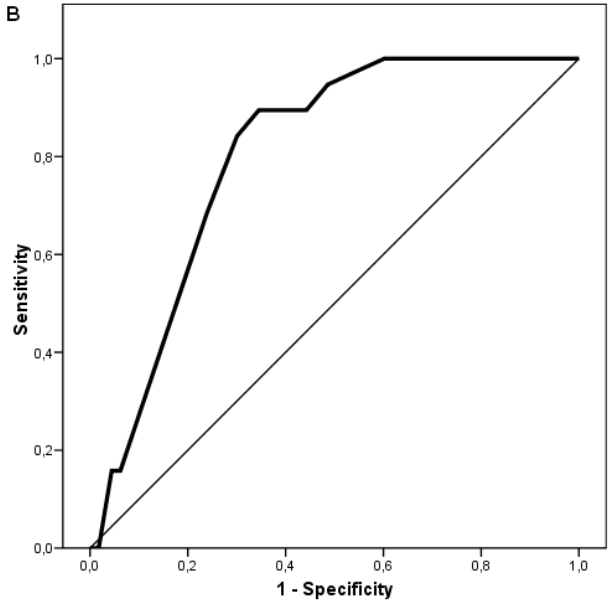


Surfactant treatment

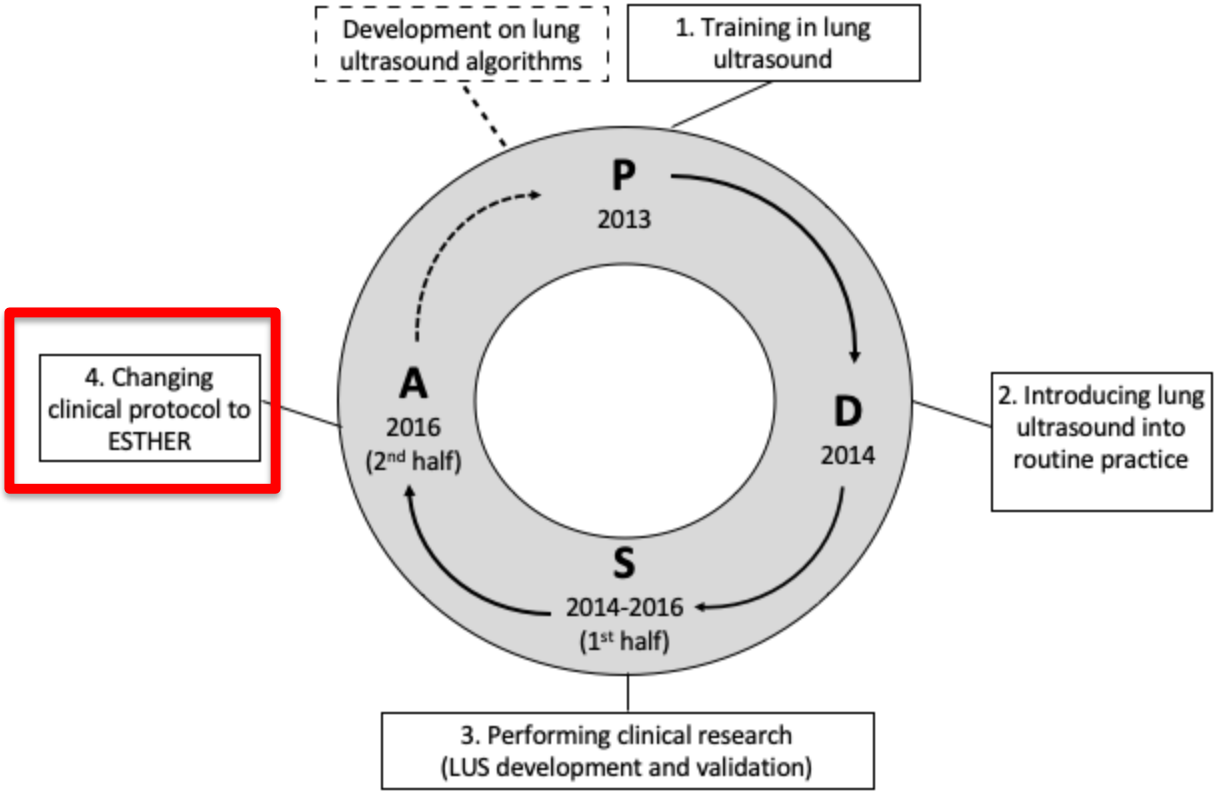


AUC 0.94 (95%CI: 0.90-0.98;p<0.0001)
Global accuracy 89%

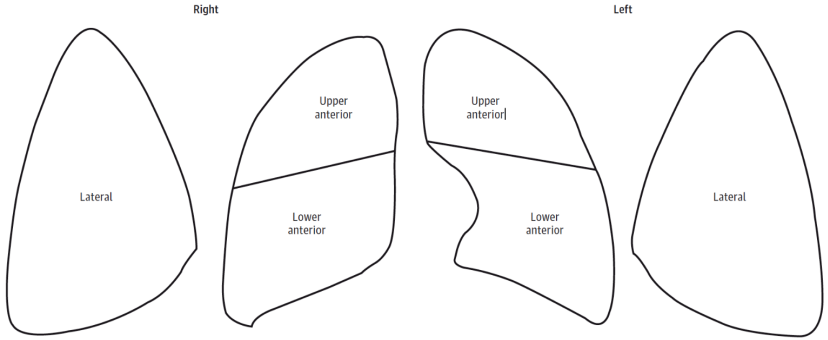
Surfactant re-treatment

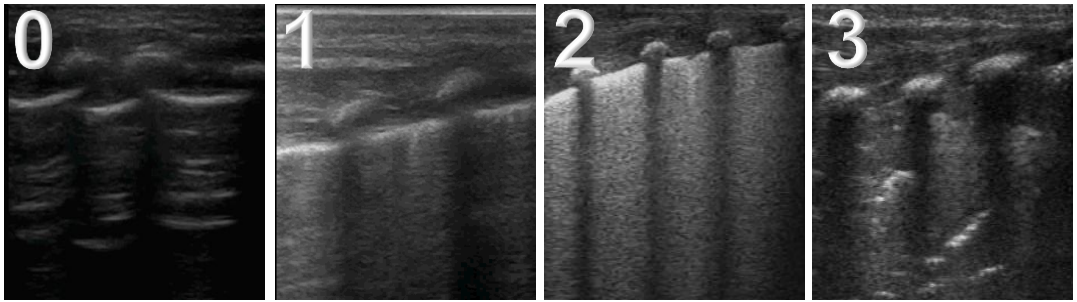


AUC 0.803 (95%CI: 0.72-0.89;p<0.0001)
Global accuracy 73%


Development on lung ultrasound algorithms
1. Training in lung ultrasound
P
2013
D
2014
S
2014-2016
(1st half)
A
2016
(2nd half)
4. Changing clinical protocol to ESTHER
2. Introducing lung ultrasound into routine practice
3. Performing clinical research
(LUS development and validation)

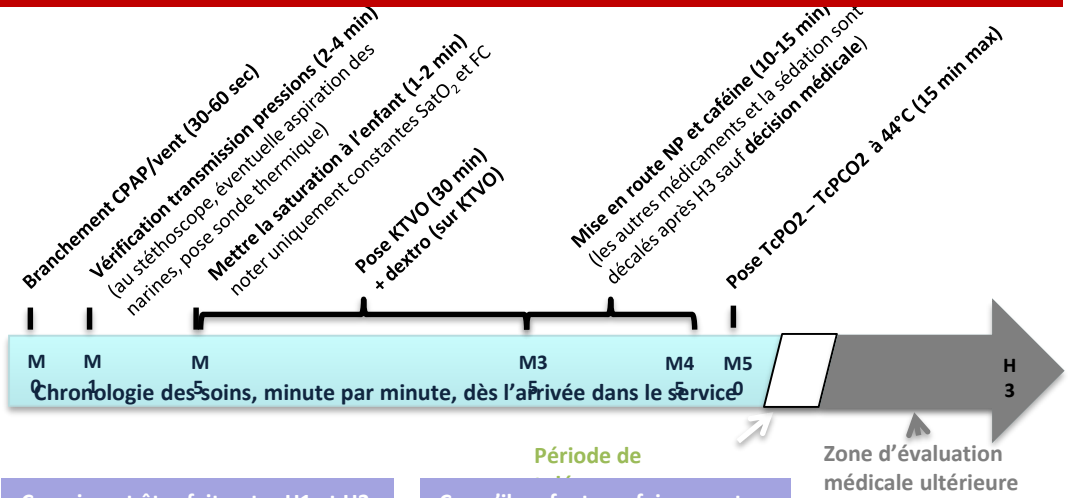
ESTHER
"Echography"-guided Surfactant THERapy





Raschetti R, Yousef N
J Pediatr. 2019

La première heure en RNN pour les enfants ≤ 28 semaines – *"golden hour"*

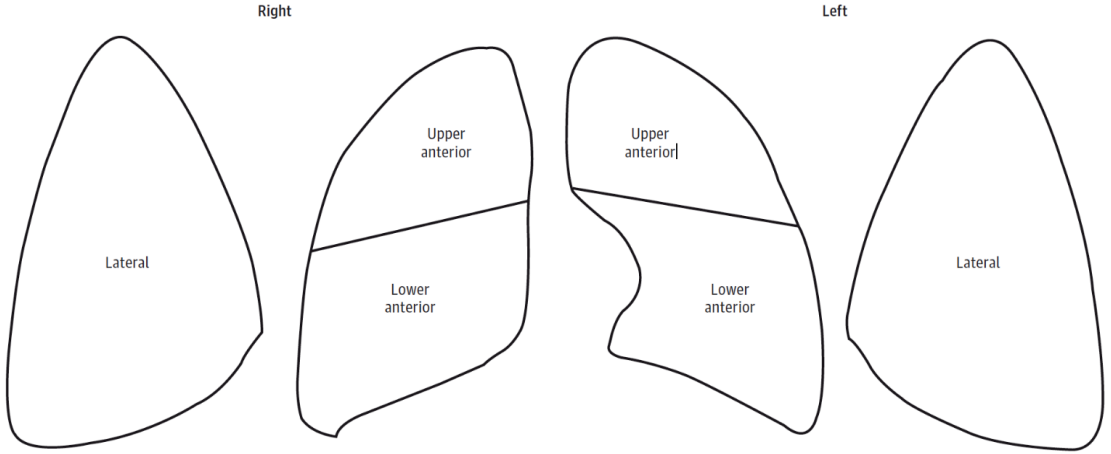


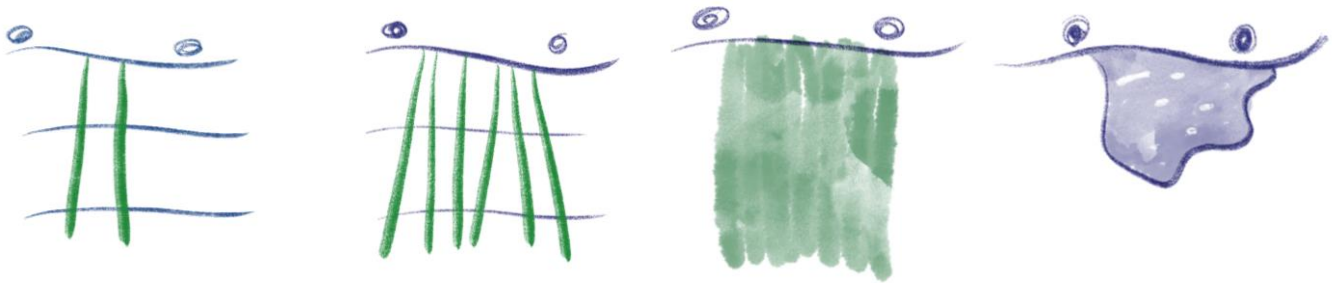
Ce qui peut être fait entre H1 et H3 (sur demande médicale)

- Pose d'un KTA
- Administration des antibiotiques

Ce qu'il ne faut pas faire avant H3

- Administration de la sédation
- Prise de tension au brassard
- Mesurer la température, la taille, le PC
- Prélèvements bactériologiques
- Prélèvements sanguins autres que glycémie capillaire au KTVO
- Vérifier le repère de la sonde endo-trachéale
- Mettre des électrodes sur le thorax





SCORE 0 SCORE 1 SCORE 2 SCORE 3

ESTHER: Echo-guided Surfactant THERapy

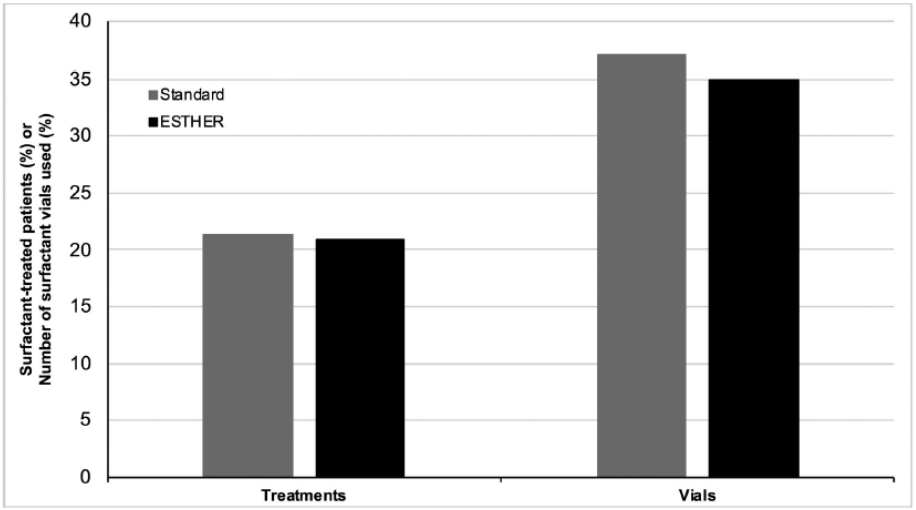


Fig. 1 Use of surfactant before and after the introduction of the ultrasound-guided administration policy. Data are expressed as (1) proportion of preterm (gestational age $\leq 32^{6/7}$ weeks) neonates with respiratory distress syndrome receiving at least one surfactant dose; and (2) proportion of vials used in preterm (gestational age $\leq 32^{6/7}$ weeks) neonates. In the first case, the denominator is represented by the total number of preterm (gestational age $\leq 32^{6/7}$ weeks) neonates admitted to the NICU; in the second case, the denominator is represented by the total number of vials used in the NICU for neonates of any gestational age. Gray and black represent the "standard" and "echography-guided surfactant therapy" periods, respectively. Raw data are in the text. ESTHER, echography-guided surfactant therapy; NICU, neonatal intensive care unit.

Raschetti R. ***J Pediatr 2019***
De Luca D. ***Am J Perinatol 2020***

The ULTRASURF Trial

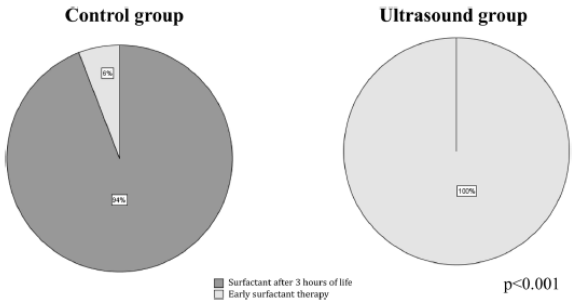


Fig. 4 Pie graph representing the proportion of patients who received early surfactant therapy (within the first 3 h of life) in each group

	Ultrasound group ($n = 29$)	Control group ($n = 27$)	p
FiO_2 after surfactant (%)	28 (25–30)	35 (31–40)	< 0.001
SpO_2 after surfactant (%)	93.5 (92–95)	90 (90-90.8)	0.001
S/F after surfactant	345 (290–381)	285 (241–300)	0.012
MV	5 (17.2%)	10 (37.0%)	0.095
Duration of MV (days)	2 (1–4.5)	2 (1.8–4.3)	0.523
Ventilator-free days	28 (28–28)	28 (26–28)	0.082
NIV	29 (100%)	27 (100%)	1.000
Duration of NIV (days)	3 (2–17)	4 (3–22)	0.428
Duration of oxygen (days)	6 (2–23.5)	5.5 (3–22.8)	0.926
Length of stay in the NICU (days)	47 (34–69)	52 (38–68)	0.780
BPD	3 (10.3%)	3 (11.1%)	1.000

Data are expressed as mean (standard deviation) or median (25^{th}–75^{th} percentile) and number (%) as appropriate. *BPD* bronchopulmonary dysplasia, *MV* invasive mechanical ventilation, *NICU* neonatal intensive care unit, *NIV* non-invasive mechanical ventilation, and *S/F* SpO_2/FiO_2 ratio

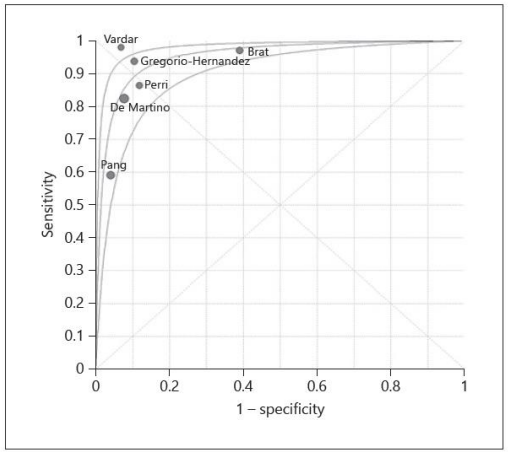
Rodriguez-Fanjul J. **Eur J Pediatr 2020**

4 DTA studies

Table 3 Pooled analysis of diagnostic accuracy parameters of studies using lung ultrasonography score >5–6 for evaluating the need for surfactant therapy or mechanical ventilation

Parameter	Pooled analysis
Pooled sensitivity	0.88; 95% CI 0.80 to 0.93; two studies; 189 participants
Pooled specificity	0.82; 95% CI 0.74 to 0.89; two studies; 189 participants
Pooled false positive rate	0.17; 95% CI 0.11 to 0.25; two studies; 189 participants
Pooled diagnostic OR	38.58; 95% CI 6.18 to 70.98; two studies; 189 participants
Pooled likelihood ratio +ve	5.17; 95% CI 2.90 to 7.44; two studies; 189 participants
Pooled likelihood ratio –ve	0.13; 95% CI 0.05 to 0.21; two studies; 189 participants

6 DTA studies

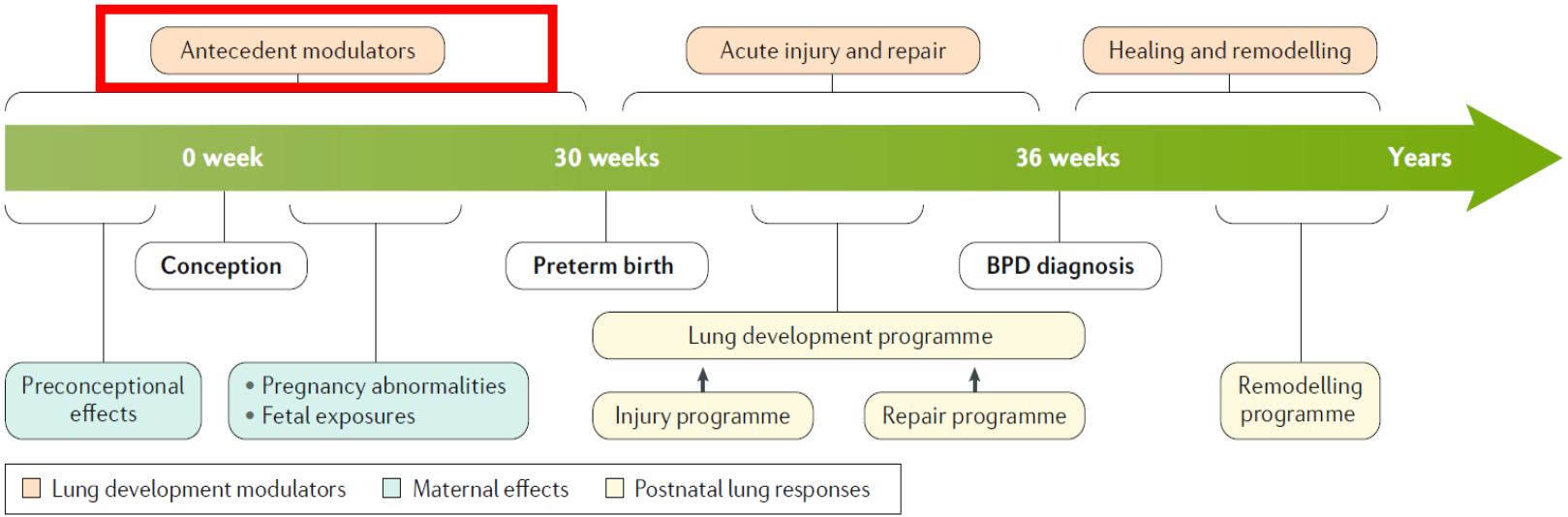


Razak A. *Arch Dis Child Fetal Neonatal Ed 2019*

De Luca D. Neonatology 2021

Can LU predict BPD?

- BPD a multifactorial and complex diseases
- No new treatment options
- Transabdominal approach used previously. Limited view
- Growing evidence using the transthoracic approach


Antecedent modulators
Acute injury and repair
Healing and remodelling
0 week
30 weeks
36 weeks
Years
Conception
Preterm birth
BPD diagnosis
Lung development programme
Preconceptional effects
• Pregnancy abnormalities
• Fetal exposures
Injury programme
Repair programme
Remodelling programme
Lung development modulators
Maternal effects
Postnatal lung responses

And then …. what ??

American Journal of Respiratory and Critical Care Medicine

Lung Ultrasound to Monitor Extremely Preterm Infants and Predict BPD: Multicenter Longitudinal Cohort Study

Barbara Loi , Giulia Vigo , Eugenio Baraldi , Francesco Raimondi , Virgilio P Carnielli , Fabio Mosca , Daniele De Luca , and , On behalf of the LUSTRE (Lung UltraSound To pReterm nEonates) study group

Multicenter, international, prospective, longitudinal, cohort, diagnostic accuracy study consecutively enrolling inborn neonates with gestational age ≤30+6 weeks.

Lung ultrasound (D1, D7, D14, D28) + blood gases + WOB score.

BPD severity and GA-adjusted LUS significantly correlated at 7 and 14 days (p <0.0001).

American Journal of Respiratory and Critical Care Medicine

Lung Ultrasound to Monitor Extremely Preterm Infants and Predict BPD: Multicenter Longitudinal Cohort Study

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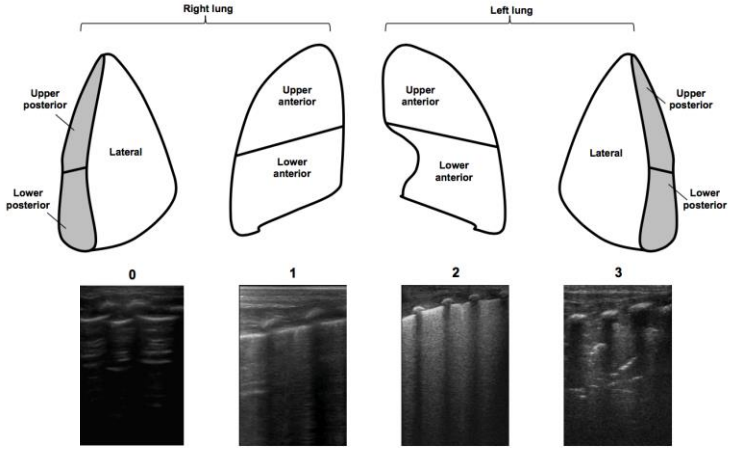
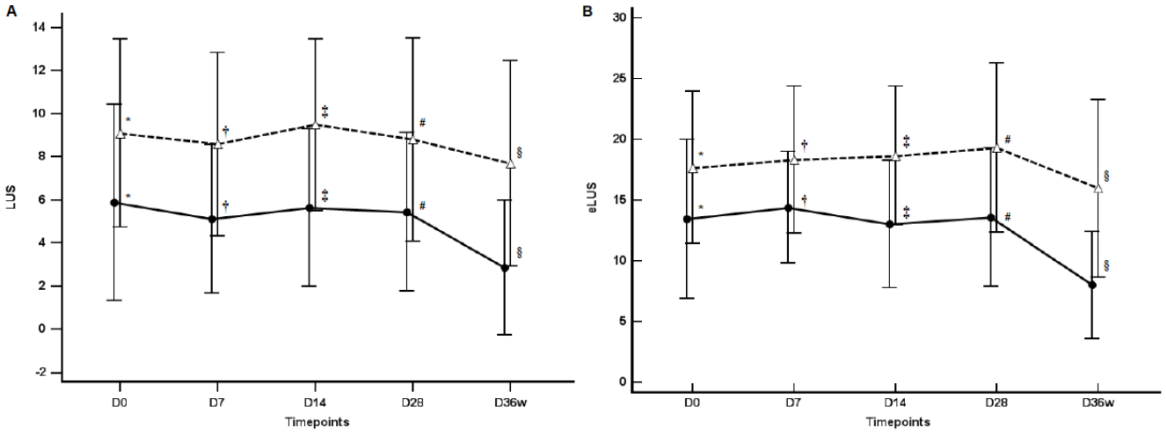




Meta-Analysis of Lung Ultrasound Scores for Early Prediction of Bronchopulmonary Dysplasia

Lucilla Pezza[1], Almudena Alonso-Ojembarrena[2], Yasser Elsayed[3], Nadya Yousef[1], Luca Vedovelli[4], Francesco Raimondi[5], and Daniele De Luca[1,6]

[1]Division of Paediatrics and Neonatal Critical Care, "A. Béclère" Medical Centre, Paris Saclay University Hospitals, APHP, Paris, France; [2]Neonatal Intensive Care Unit, Biomedical Research and Innovation Institute of Cádiz, Puerta del Mar University Hospital, Cádiz, Spain; [3]Department of Pediatrics and Child Health, University of Manitoba, Winnipeg, Manitoba, Canada; [4]Unit of Biostatistics, Epidemiology, and Public Health, Department of Cardiac, Thoracic, Vascular Sciences and Public Health, University of Padova, Padova, Italy; [5]Division of Paediatrics, Department of Translational Medical Sciences, Federico II University, Naples, Italy; and [6]Physiopathology and Therapeutic Innovation Unit-INSERM U999, Paris Saclay University, Paris, France

Table 1. Characteristics of articles included in the meta-analysis and their population details

Author/Country [Year]	Neonates	Males	Prenatal Steroids	GA (*wk*)	IMV (*d*)	BPD	Probe	Frequency (*MHz*)
Mohamed (Canada) 2021 (32)	152	67 (44)	110 (56)	26.5 ± 1.2	10 ± 23	87 (57)	Linear	20
Liu (China) 2021 (33)	130	62 (48)	70 (54)	29.2 ± 1.8	N/A	50 (39)	Linear	9
Alonso-Ojembarrena (Spain) 2021 (34)	298	174 (58)	273 (92)	28.3 ± 2.3	8.2 ± 17.4	155 (52)	Linear or microlinear	8–15
Raimondi (Italy) 2021 (35)	172	81 (47)	167 (97)	28.4 ± 2	N/A	23 (13)	Linear or microlinear	10–15
Loi (France and Italy) 2020 (36)	147	77 (52)	123 (84)	27.3 ± 1.9	7.2 ± 12.8	72 (49)	Linear or microlinear	10–15
Oulego-Erroz (Spain) 2020 (37)	42	29 (69)	29 (69)	29.1 ± 2.4	4.3 ± 10.9	21 (50)	Linear	6
Abdelmawla (Canada) 2019 (38)*	27	15 (55)	15 (56)	27.3 ± 1.5	21 ± 4.2	14 (52)	Microlinear	14
Alonso-Ojembarrena (Spain) 2019 (39)	59	34 (58)	46 (78)	28.7 ± 3.1	5.9 ± 4.7	21 (36)	Microlinear	15

Definition of abbreviations: BPD = bronchopulmonary dysplasia; GA = gestational age; IMV = invasive mechanical ventilation; N/A = not available. Proportions are reported as *n* (%) and continuous variables are described as mean ± standard deviation. Data exclusively refer to neonates of gestational age ⩽32 weeks enrolled in each study. Prenatal steroid prophylaxis was considered if a complete course was given. Invasive ventilation was considered as total duration of ventilation during the neonatal intensive care unit stay.
*This study was the only one with a retrospective design (38).

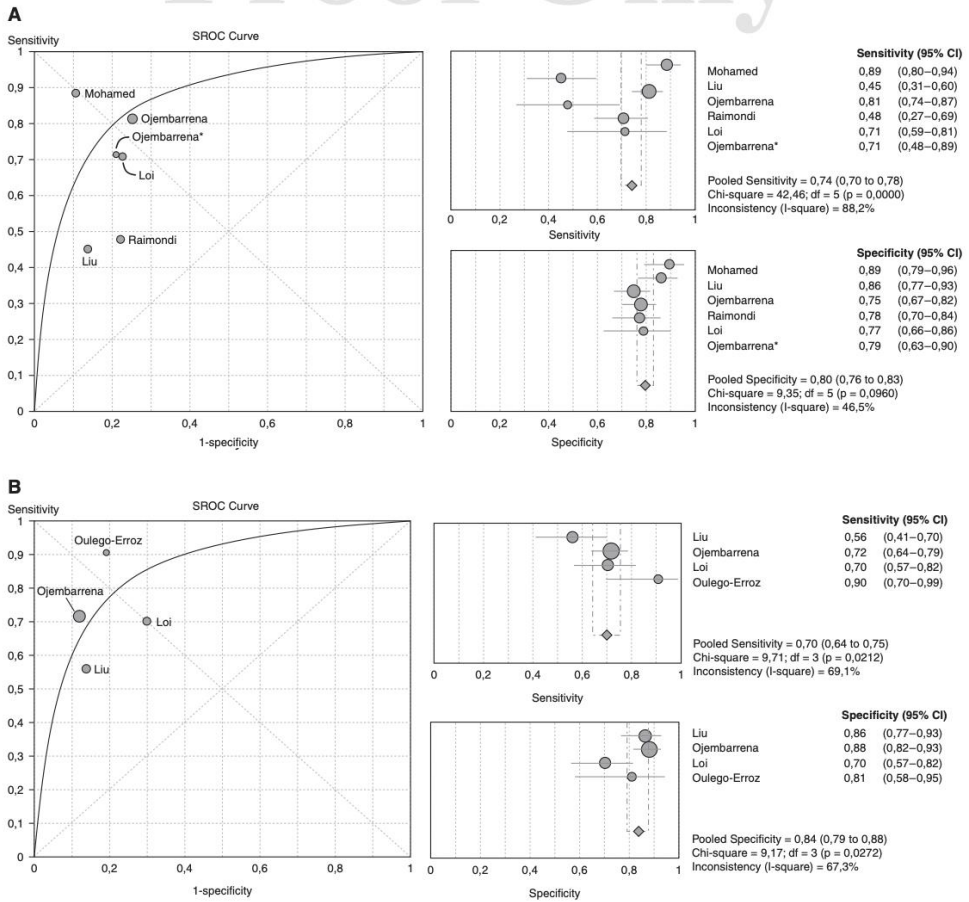


Figure 2. Prediction of bronchopulmonary dysplasia at 7 days of life. (*A* and *B*) The results of SROC analysis for lung ultrasound score (LUS) and extended lung ultrasound score (eLUS), respectively; *N* = 958 (*A*) and *N* = 584 (*B*). Both *A* and *B* show the SROC curve, and each study is represented by a gray circle whose diameter is proportional to study weight. Diamonds and horizontal lines represent the pooled sensitivity or specificity and their 95% confidence interval, respectively. Studies are identified with their first author's name; *indicates the first study performed by Alonso-Ojembarrena and colleagues (39). Thresholds associated with best sensitivity and specificity ranged between 4 and 10 for LUS and between 10 and 13 for eLUS (with the exception of Oulego-Erroz and colleagues (37) reporting a threshold of 5). CI = confidence interval; SROC = summary receiver operator characteristics.

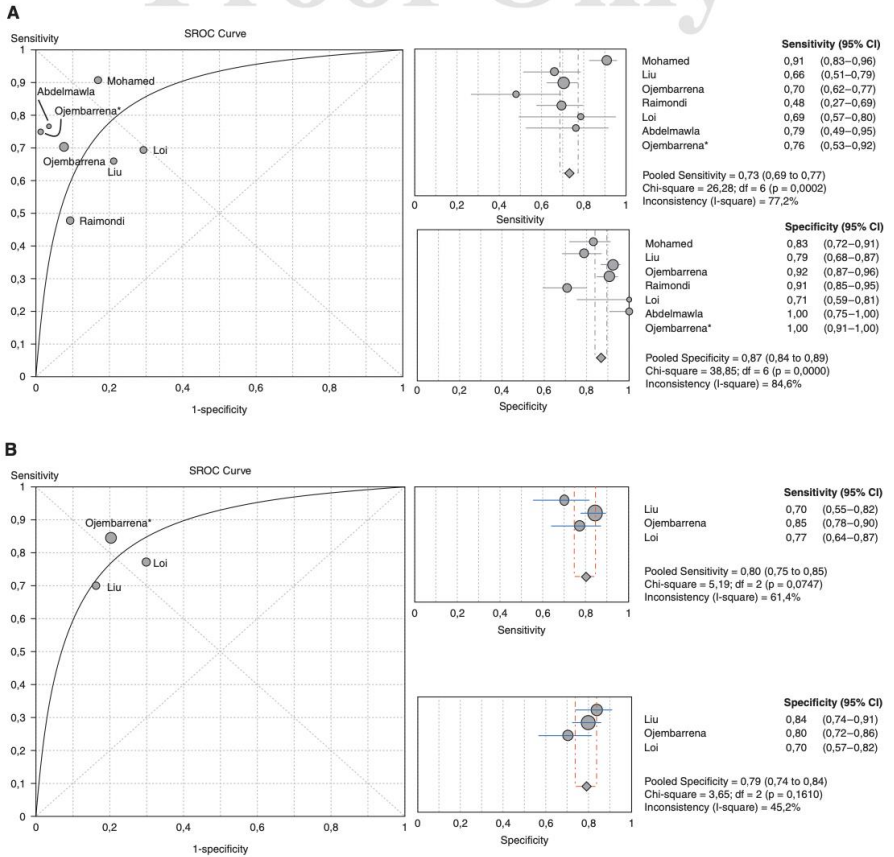
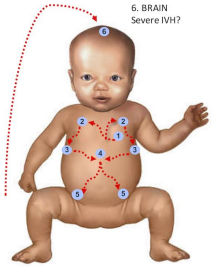


Figure 3. Prediction of bronchopulmonary dysplasia at 14 days of life. (*A* and *B*) The results of SROC analysis for lung ultrasound score (LUS) and extended lung ultrasound score (eLUS), respectively; *N* = 985 (*A*) and *N* = 542 (*B*). Both *A* and *B* show the SROC curve, and each study is represented by a gray circle whose diameter is proportional to study weight. Diamonds and horizontal lines represent the pooled sensitivity or specificity and their 95% confidence interval, respectively. Studies are identified with their first author's name; *indicates the first study performed by Alonso-Ojembarrena and colleagues (39). Thresholds associated with best sensitivity and specificity ranged between 5 and 11 for LUS (with the exception of Liu and colleagues (33) reporting a threshold of 1) and was 6, 8, and 13 for eLUS in Alonso-Ojembarrena and colleagues (34), Liu and colleagues (33), and Loi and colleagues (36), respectively. CI = confidence interval; SROC = summary receiver operator characteristics.

SAFE-R



START

Targeted Echocardiography

Myocardial dysfunction?

Echocardiogram

Expert opinion needed
Rule out CHD

Anterior chest wall
Substernal or left parasternal axis

Tamponade?

YES

Tamponade CONFIRMED

Needle aspirate

NO

Anterior chest wall
Vertical scan.

Lung Sliding?

NO

YES

Pneumothorax NOT ruled out

Inferior postero-lateral chest wall
Vertical scan

Pneumothorax RULED OUT

Only A lines?
No B lines?

NO

Effusion?

YES

Effusion CONFIRMED

Needle aspirate

Move probe laterally
Vertical scan.

YES

Pneumothorax RULED OUT

NO

Lung point?

YES

NO

Pneumothorax CONFIRMED

Needle aspirate

Pneumothorax HIGHLY PROBABLE

Need for other diagnostic modalities

Other cause

Expert opinion needed
Rule out CHD

Pulsatile Abdominal Aorta?

Subcostal view
Vertical scan

NO

URGENT Expert opinion needed

Acute/critical aortic occlusion RULED OUT

YES

Suspect Critical coarctation or thrombosis of aorta

Abundant free abdominal fluid?

Abdominal ultrasound
Iliac fossae

YES

NO

Critical acute abdomen IMPROBABLE

Suspect Intestinal perforation PN extravasation Hemoperitoneum

Targeted Workup/ Management

Brain ultrasound
Coronal/sagittal view

Severe IVH?

NO

YES

Severe cerebral bleeding RULED OUT

Other cause

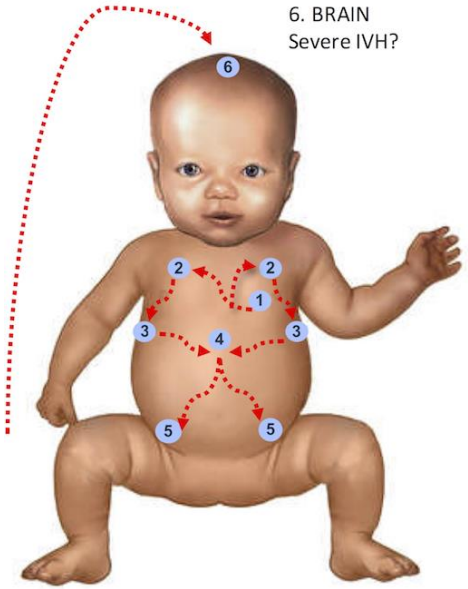
Further workup needed
Rule out sepsis

Expert opinion needed
Rule out CHD

Supportive Management

Yousef et al, EJPE 2021

SAFE-R



6. BRAIN
Severe IVH?

1. HEART
Tamponade?

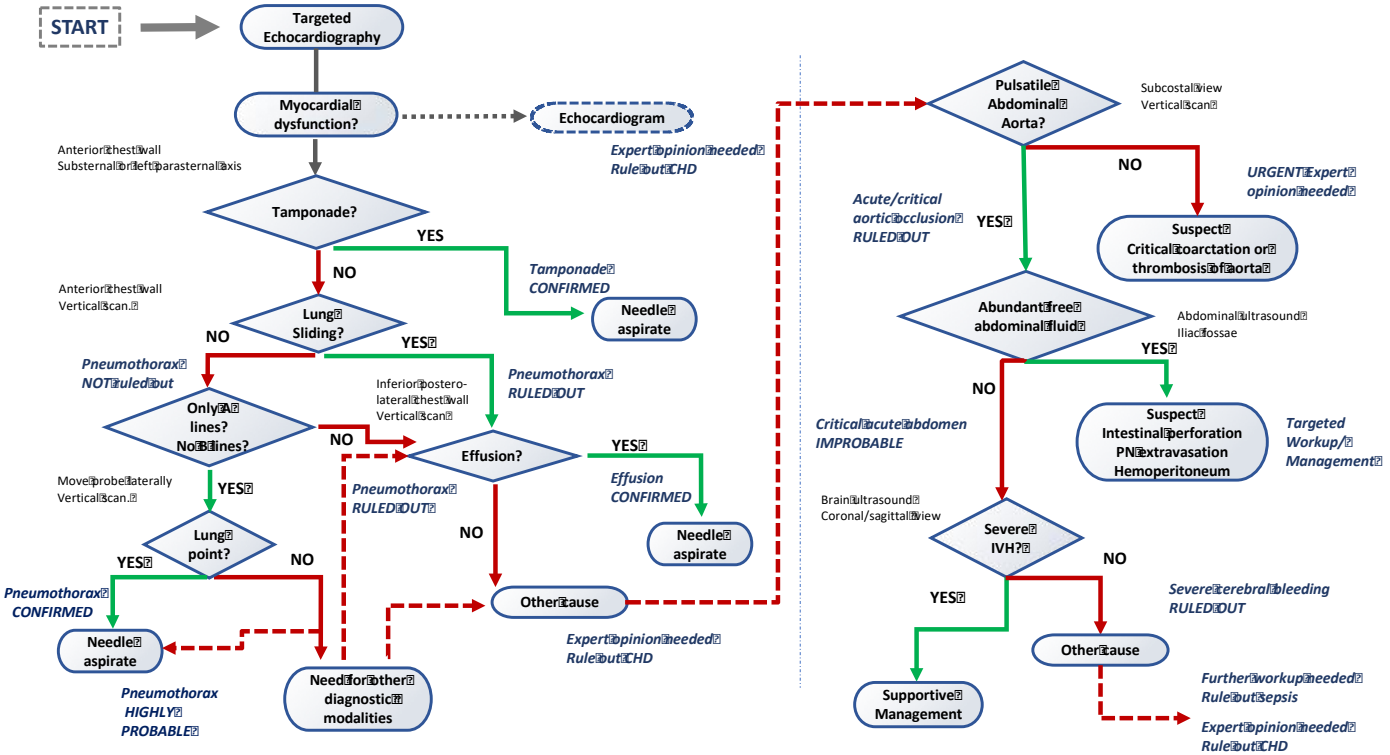
2. LUNG
Tension pneumothorax?

3. LUNG
Massive pleural effusion?

4. AORTA
Critical aortic occlusion?

5. ABDOMEN
Free abdominal fluid?

Yousef et al, EJPE 2021



Yousef et al, EJPE 2021

Lung ultrasound

Hôpitaux universitaires Paris-Sud
Antoine-Béclère Bicêtre Paul-Brousse

Quick

Accessible

No radiation

Bedside

Real time

Cost

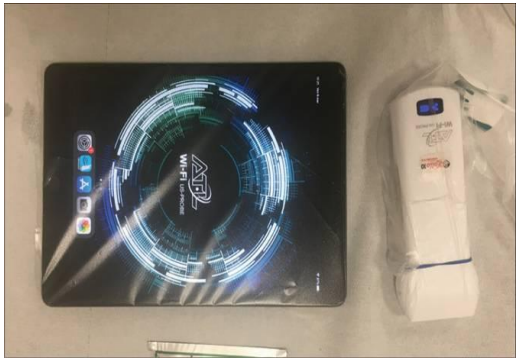
Steep learning curve

ASSISTANCE PUBLIQUE HÔPITAUX DE PARIS

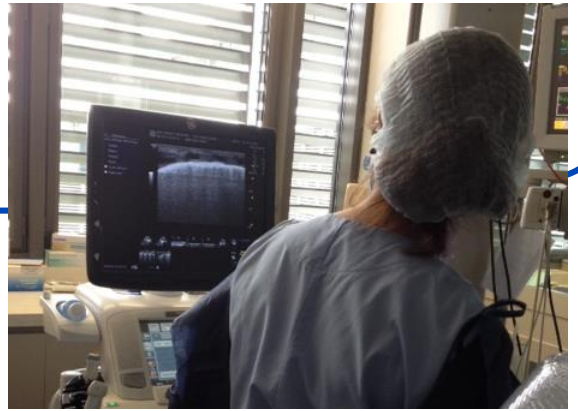
Neonatal Lung ultrasound today

Many barriers remain

- "Resistance" to change = multifactorial
- Significant variation in clinical practice
- Poor governance structure
- Poor training structure
- Medico-legal concerns?



Neonatal Lung ultrasound today



- Specific pediatric guidelines published
- Educational guidelines/Training (Urgent!)
- Certification/Governance (Urgent!)
- Functional LU/Integration into POCUS protocols: The future?

Thank you!

And a big thank you to the teams at
A Beclere, APHP- Paris Saclay
And to collaborators, to the patients and their families

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