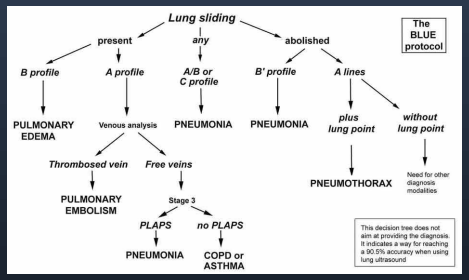
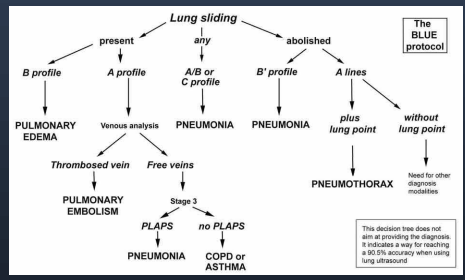
Lung Ultrasound in the Critically Ill

Ten signs: the alphabet for performing the BLUE-protocol



Daniel Lichtenstein
Service de Réanimation Médicale
Hôpital Ambroise-Paré
Boulogne (Paris-West)
France



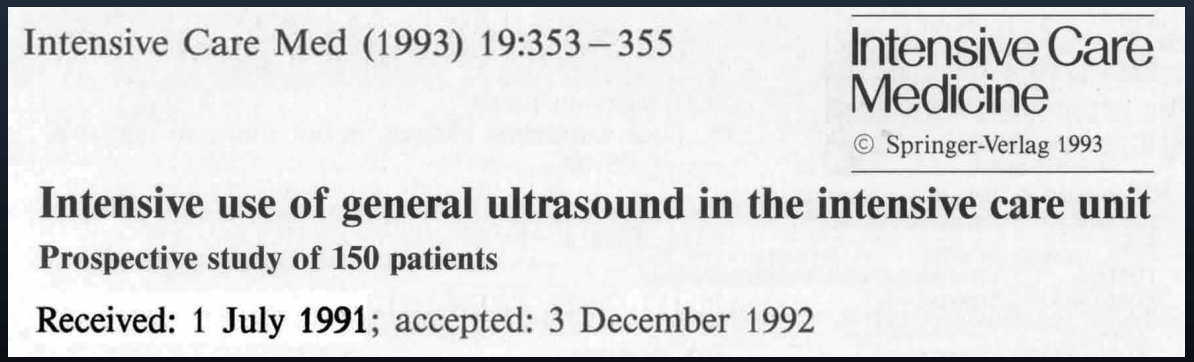
CEURF
CERCLE DES ECHOGRAPHISTES D'URGENCE ET DE REANIMATION FRANCOPHONES

The lung, not suitable for ultrasound?

"The lungs are a major hindrance for the use of ultrasound at the thoracic level".

In Harrison PR. Principles of Internal Medicine. 1992:1043

Simply wrong



Intensive Care Med (1993) 19:353–355

Intensive Care Medicine

Intensive use of general ultrasound in the intensive care unit

Prospective study of 150 patients

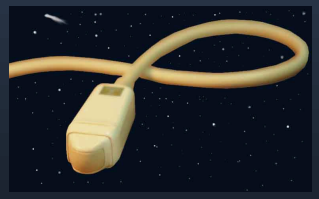
Received: 1 **July 1991**; accepted: 3 December 1992

Announced in the body of this article, sent in 1991 to the Journal

The ideal equipment*

Slides regarding these issues have been withdrawn in the document specifically designed for the First World Congress of Ultrasound in Education (Prof. Richard Hoppmann).

Shortly: we use since 1992 a simple unit (no Doppler, one single, universal probe) for lung ultrasound in the critically ill, in a holistic approach including a whole body assessment. This unit starts on in 7 seconds, has a flat, easy-to-clean keyboard and analogic image quality. Height, 27 cm. Width: 33 cm with cart.

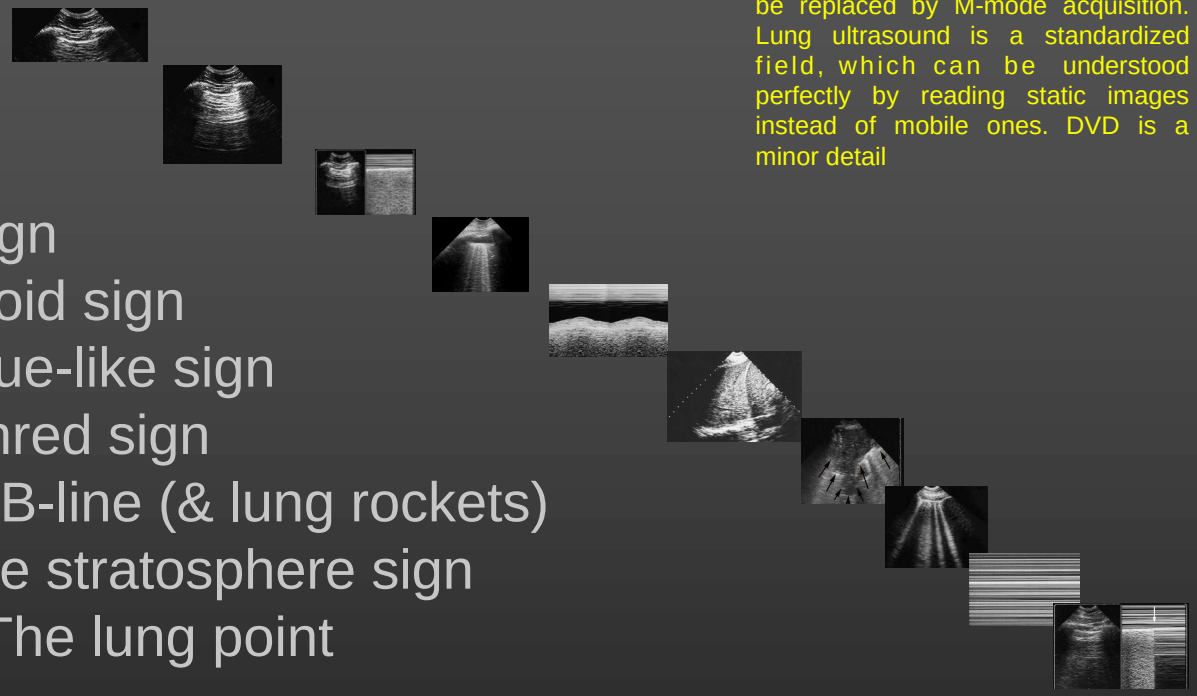


For those who have modern equipments, but want to make an idea, we suggest abdominal probes and the by-pass of all filters.

* To withdraw in suitable presentations

The ten basic signs

The bat sign
The A-line
Lung sliding
The quad sign
The sinusoid sign
The tissue-like sign
The shred sign
The B-line (& lung rockets)
The stratosphere sign
The lung point

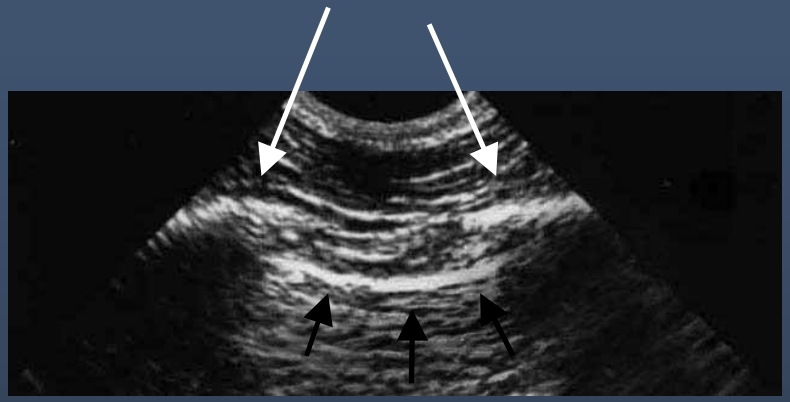


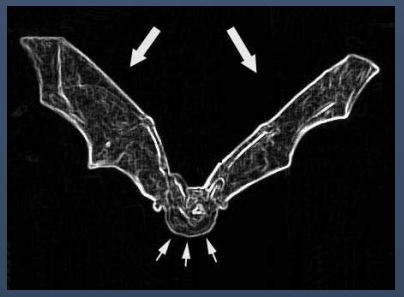
Important note

There is no DVD (in progress). Note meanwhile that dynamic images can be replaced by M-mode acquisition. Lung ultrasound is a standardized field, which can be understood perfectly by reading static images instead of mobile ones. DVD is a minor detail

The mastery of these signs allows control of multiple settings: acute respiratory failure, ARDS management, hemodynamic therapy in shocked patient, neonate assessment, traumatized patient. It works in up-to-date ICUs as well as austere areas or spaceships.

1) The bat sign



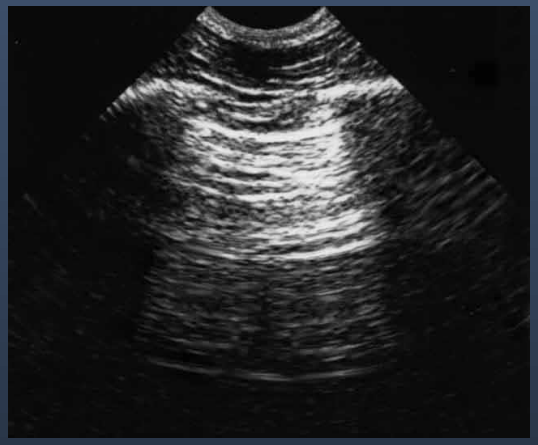


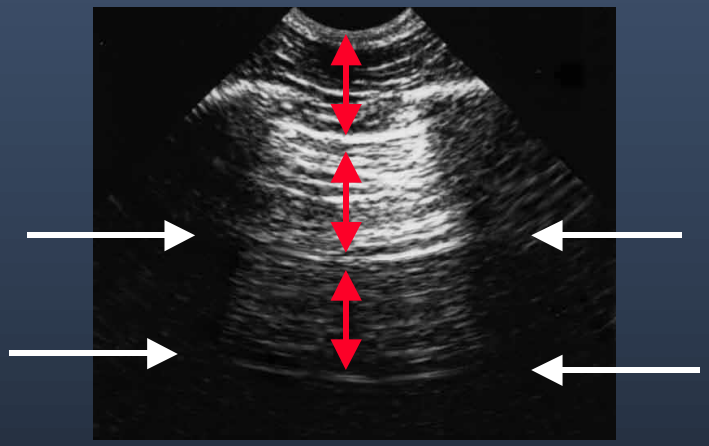
The bat sign

The pleural line and the upper and lower ribs make a permanent landmark

The bat sign is a basic step. It allows to locate the lung surface in any circumstances (acute dyspnea, subcutaneous emphysema...)

2) The A-line



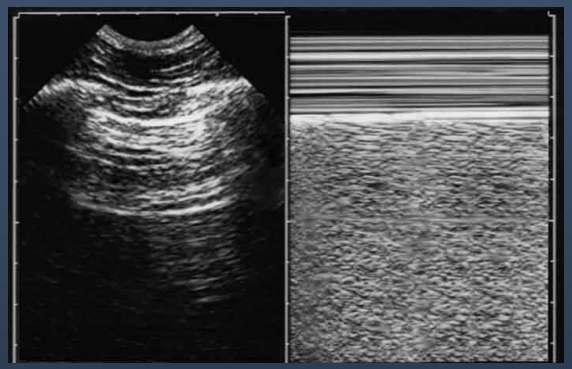


Hyperechoic horizontal artifact arising from the pleural line

A-lines indicate air*, whether physiologic or pathologic

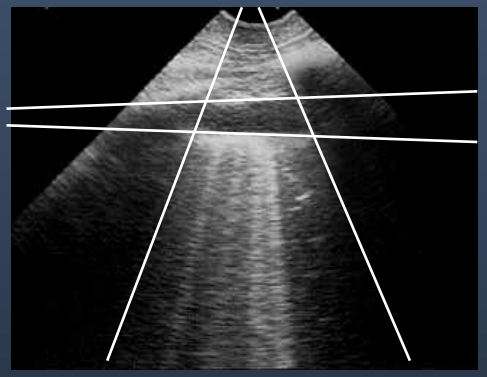
* For purists, the term ***gas*** is better

3) Lung sliding and seashore sign



The pleural line normally separates two distinct patterns (in M-mode).
This demonstrates lung sliding, without Doppler

4) Pleural effusion: The quad sign

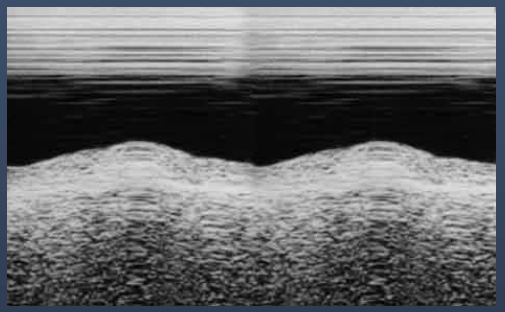


Lung line

Quad image between pleural line, shadow of ribs, and the lung line (deep border, always regular)

Quad sign and sinusoid sign are universal signs allowing to define any kind of pleural effusion regardless its echogenicity

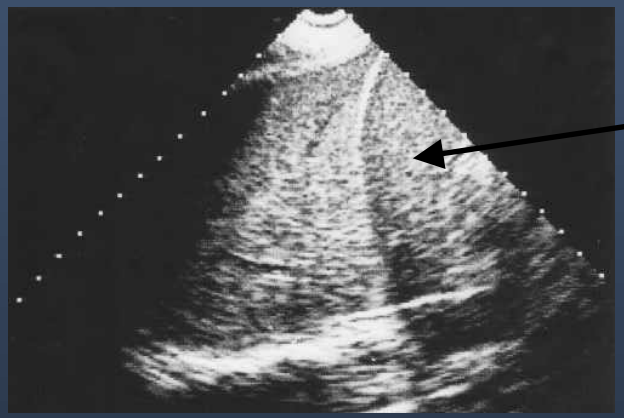
5) Pleural effusion: Sinusoid sign



Inspiratory movement of lung line toward pleural line

Sinusoid sign allows not only full confidence in the diagnosis of pleural effusion (associated with quad sign), but also indicates possibility of using ***small*** needle for withdrawing fluid

6) Lung consolidation (alveolar syndrome)
The tissue-like sign



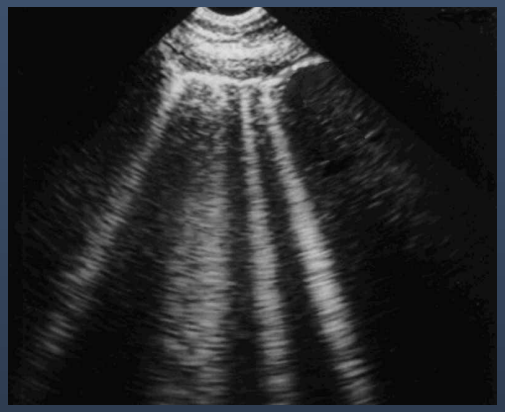
spleen
or liver

A fluid disorder with a solid appearance

7) Lung consolidation (alveolar syndrome)
The shred sign

A shredded line, instead of the lung line: a specific sign

8) B-lines, lung rockets and interstitial syndrome



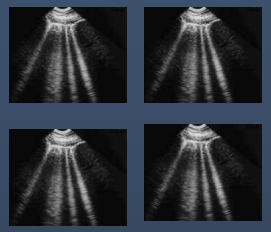
Example of 4 or 5 B-lines
(1992's technology)

The B-line is

1- a comet-tail artifact
2 - arising from the pleural line
3 - well-defined - laser-ray like
4 - hyperechoic
5 - long (does not fade)
6 - erases A lines
7 - moves with lung sliding

Using these 7 features, the B-line is distinct from all other comet-tail artifacts

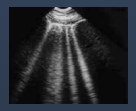
8) B-lines, lung rockets and interstitial syndrome
Important semantic note



Diffuse lung rockets

Lung rockets at the four points of anterior chest wall

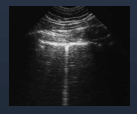
They define pulmonary edema (hemodynamic or inflammatory - see BLUE-protocol)



Lung rockets

Three (or more) B-lines between two ribs

They define interstitial syndrome (can be focal)



B-lines

A certain type of comet-tail artifact (see definition previous slide)

Defines mingling of air and fluid abuting pleura. Can be isolated and mean normal fissura

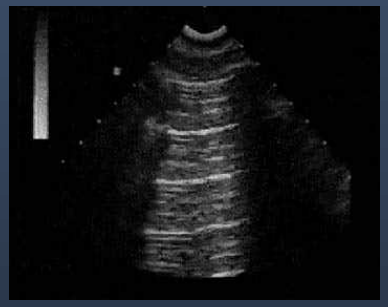
Comet-tail artifact

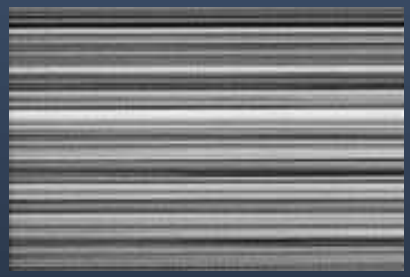
Vertical artifact, visible at the lung surface or elsewhere, can be due to multiples causes (gas, metallic materials), called E-lines, Z-lines (see left), K-lines, S-lines, W-lines....). Includes the B-line, but is not "the" B-line

9) Pneumothorax
Three signs - Signs 1 & 2

1) Abolished lung sliding
Yielding stratosphere sign on M-mode

1982
technology





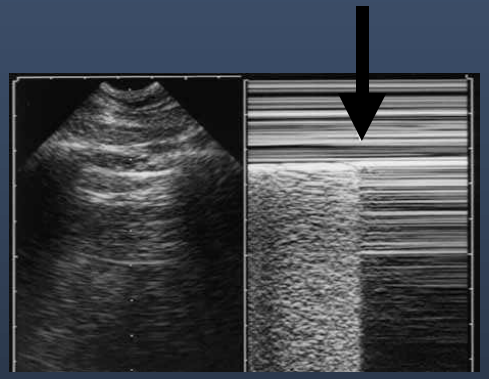
2) The A-line sign: already in the scale (see A-line slide)

One B-line is enough for ruling out the diagnosis, confidently, where probe is applied

Detection of abolished lung sliding with the A-line sign allows immediate ***suspicion*** of all cases of pneumothorax

10) Pneumothorax
Three signs - Sign 3: the lung point

Lung point: specific to pneumothorax, therefore mandatory for accurate and safe use in the critically ill



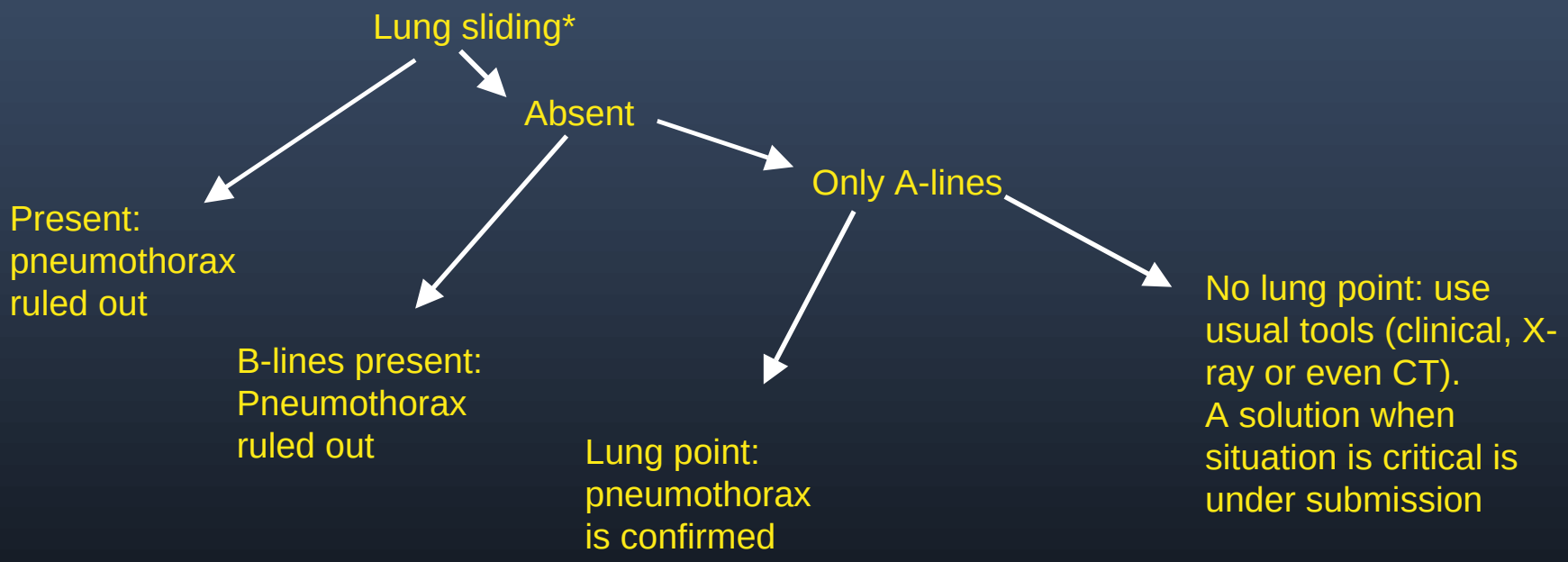
Sudden, on-off visualization of a lung pattern (lung sliding and/or B-lines) at a precise area where the collapsed expiratory lung slightly increases its surface of contact on inspiration

Lung point indicates volume of pneumothorax

Note that the label "lung point" assumes absent anterior lung sliding and the A-line sign at the anterior chest wall

The lung point allows checking that signs (especially abolished lung sliding) are not due to technical inadequacies of machine (beware modern machines not designed for lung)

Pneumothorax
The diagnosis of air within air
A simple decision tree



* Or equivalent, such as the lung pulse

Value of the signs used

	Sensitivity (%) Specificity (%)	Source (CT as gold standard)
Pleural effusion	97 - 94	Intensive Care Med (1999) 25: 955–958 © Springer-Verlag 1999 — ORIGINAL — Feasibility and safety of ultrasound-aided thoracentesis in mechanically ventilated patients
Alveolar consolidation	90 - 98	Intensive Care Med (2004) 30:276–281 DOI 10.1007/s00134-003-2075-6 — ORIGINAL — Ultrasound diagnosis of alveolar consolidation in the critically ill
Interstitial syndrome	100 - 100*	AM J RESPIR CRIT CARE MED 1997;156:1640–1646. — The Comet-Tail Artifact — An Ultrasound Sign of Alveolar-Interstitial Syndrome
Complete pneumothorax	100 - 91	Chest (1995) 108:1345-1348 — A Bedside Ultrasound Sign Ruling Out Pneumothorax in the Critically Ill: Lung Sliding
		Intensive Care Med (1999) 25: 383–388 © Springer-Verlag 1999 — ORIGINAL — The comet-tail artifact: an ultrasound sign ruling out pneumothorax
Occult pneumothorax	79 - 100	Intensive Care Med (2000) 26: 1434–1440 DOI 10.1007/s001340000627 — ORIGINAL — The "lung point": an ultrasound sign specific to pneumothorax
		Crit Care Med 2005 Vol. 33, No. 6 — Clinical Investigations — Ultrasound diagnosis of occult pneumothorax*

* 93/93 in Abstract when compared with radiograph, 100/100 in Results when compared with CT

Some semantic details

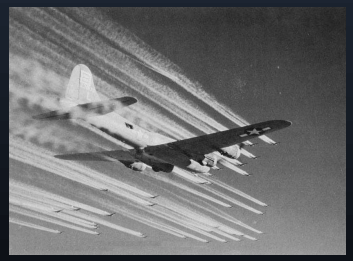
Literature can enrich, but sometimes confuse. Please note:

Lung comets are not lung rockets. The physiopathologic meaning of these two labels is fully different

The term ***comet-tail artifact*** is not representative for interstitial syndrome

The term ***"alveolar-interstitial syndrome"*** is radiological, but inappropriate in ultrasound world. Ultrasound detects either interstitial syndrome (lung rockets) or alveolar syndrome (shred sign), fully distinctly.

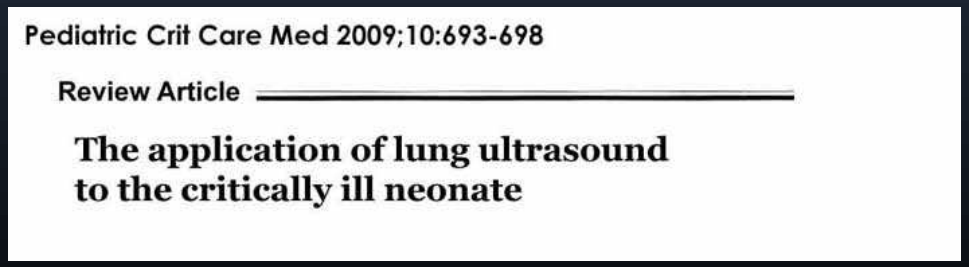
The term ***barcode sign*** is sometimes used instead of stratosphere sign, but we suggest to be cautious for avoiding deadly confusions generated by the new barcodes:



Maybe our main message

The whole of these ten signs (also signs not described here, dynamic air bronchogramand lung pulse) are found again ***with no difference*** in the critically ill neonate.

These signs have been carefully assessed in the adult, using irradiating tool: CT. We do not intent to publish data in neonates (meaning CT use*, of poor interest for the involved neonate), but invite pediatricians working in neonate ICUs to understand, when they will see a quad sign (shred sign, lung point, etc) in a neonate with normal or ill-defined bedside radiograph, that ultrasound describes the true disorder.



* We currently compile all cases where CT has been already ordered and performed

The instrument
Basic technique
Normal lung
Pleural effusion
Alveolar consolidation
Interstitial syndrome
Pneumothorax
Clinical applications

Lung ultrasound, the sequel...

Many applications are accessible - nature and volume of pleural effusion - pulmonary abscess - distinction between thickened interlobular septa and ground-glass areas - lung contusion - overdistension - alveolar recruitment - immediate diagnosis of atelectasis when still aerated - distinction between hemodynamic and permeability-induced pulmonary edema - phrenic function - ultrasound-assisted thoracenthesis, in mechanically ventilated patients - ETC

Recent works of CEURF:

(Chest 2008) : the BLUE-protocol, a simple approach allowing diagnosis of acute respiratory failure

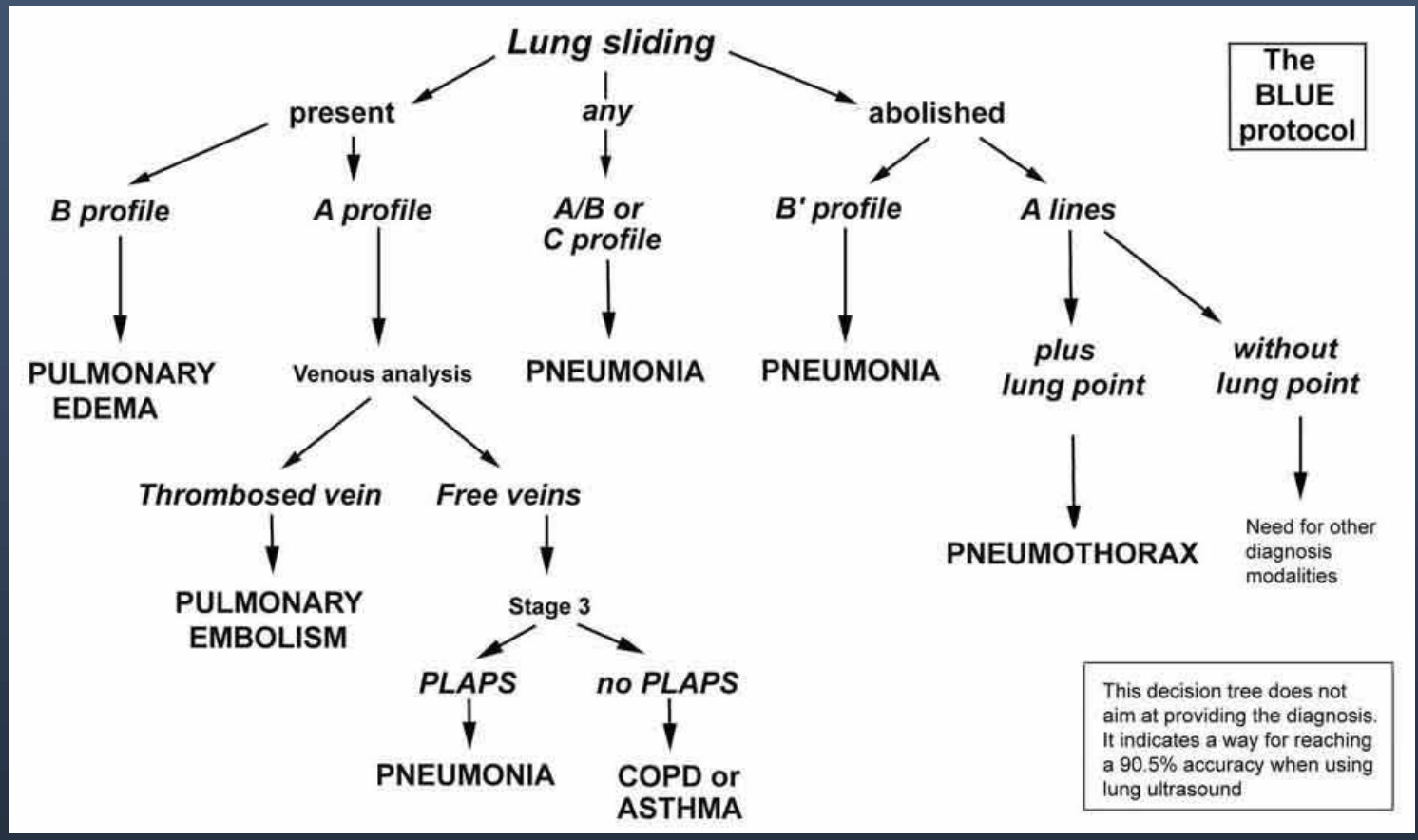
(Chest 2009) : FALLS-protocol. Lung ultrasound as a method for controling fluid therapy in the shocked patient

(PCCM 2009) : Lung ultrasound in the critically ill neonate

(Chest 2009) : Distinction atelectasis versus pneumonia using the dynamic air bronchogram

(Critical Ultrasound Journal 2011) : the BLUE-points, standardized areas of investigation used in the BLUE-protocol

The BLUE-protocol



Chest 2008; 134:117-125

Relevance of Lung Ultrasound in the Diagnosis of Acute Respiratory Failure - the BLUE-protocol

The BLUE-protocol

Main principle : A simple ultrasound analysis of lungs (and veins in suitable cases) allows to categorize the test in one of seven characteristic profiles. The decision tree allows to obtain the diagnosis of the 5 most frequent causes of acute respiratory failure (that make 97% of cases) in 90.5% of cases. The BLUE-protocol is included in the traditional approach which includes history and physical examination. The combination of both yields better performances. The inclusion of basic tests (EKG, venous blood tests) increases the rate. Simple cardiac sonography again increases this rate.

The first aim of the BLUE-protocol is, by providing an immediate diagnosis, a quicker relief of a dyspneic patient.

The second aim is to decrease the need for heavy tests (CT, sophisticated echocardiography), painful tests (arterial blood analysis) and irradiating tests in particular cases (pregnancy), as well as improving care level in scarce resource areas.

The BLUE-protocol, just one example: Fast diagnosis of pulmonary edema

After history and physical examination (which are enough for the diagnosis in most cases), the probe is inserted on two standardized points of the anterior chest wall (i.e., four for both lungs).

In acute hemodynamic pulmonary edema with respiratory failure, the pattern observed in 97% of cases is diffuse lung rockets associated with lung sliding. This pattern, called the B-profile, is obtained in 20 seconds.

Specificity is 95%. False-negatives are usually cases of acute interstitial pneumonia with still conserved lung sliding.

Cases of chronic interstitial disease are not included since BLUE-protocol included the 97% of patients having the 5 most frequent groups of diseases: pneumonia - pulmonary edema - COPD and asthma - pulmonary embolism - pneumothorax. Countless diseases (including chronic interstitial diseases) make the 3% of remaining cases).

Notes: facing a B-profile, the BLUE-protocol is concluded. Posterior lung and venous analysis can be freely done by the physician after this BLUE-protocol. They are not part of it, usually providing redundant information or showing free veins, but can on occasion have some relevance. The aim of the BLUE-protocol is to provide basic piece of information with maximal simplicity.
(e.g., for diagnosing anyway chronic lung disease, the history is usually a major element. Facing a first episode, some elements from lung ultrasound and, of prime importance, simple cardiac sonography will immediately alert the physician - normal left heart contractility, enlarged right heart, and others).

The BLUE-protocol *is* holistic ultrasound

One critical example

Venous ultrasound is central to the BLUE-protocol. It is mandated each time there is an A-profile (normal anterior lung pattern).

It does not require vascular probes. Our microconvex probe sharply assesses all veins (femoral, caval...) in all incidences (long axis, short axis).

It carefully focuses on the calf areas, which are usually neglected, but are of high accessibility using our probe and adapted approach. Isolated calf DVT is a frequent finding in massive pulmonary embolism.

Once a DVT is detected, the association of "A-profile plus DVT" provides diagnosis of massive pulmonary embolism with 81% sensitivity & 99% specificity.

This immediately reduces the needs for sophisticated Doppler echocardiographic approach. A simple visualization of the dilated right chambers using our microconvex probe can be performed at this step.

In extreme emergencies (cardiac arrest etc), the same probe will cover all areas of interest.

One probe, one simple cost-saving machine, the adjunction of the lung, the definition of a simple emergency cardiac sonography...

This is holistic ultrasound.

DVT: deep venous thrombosis

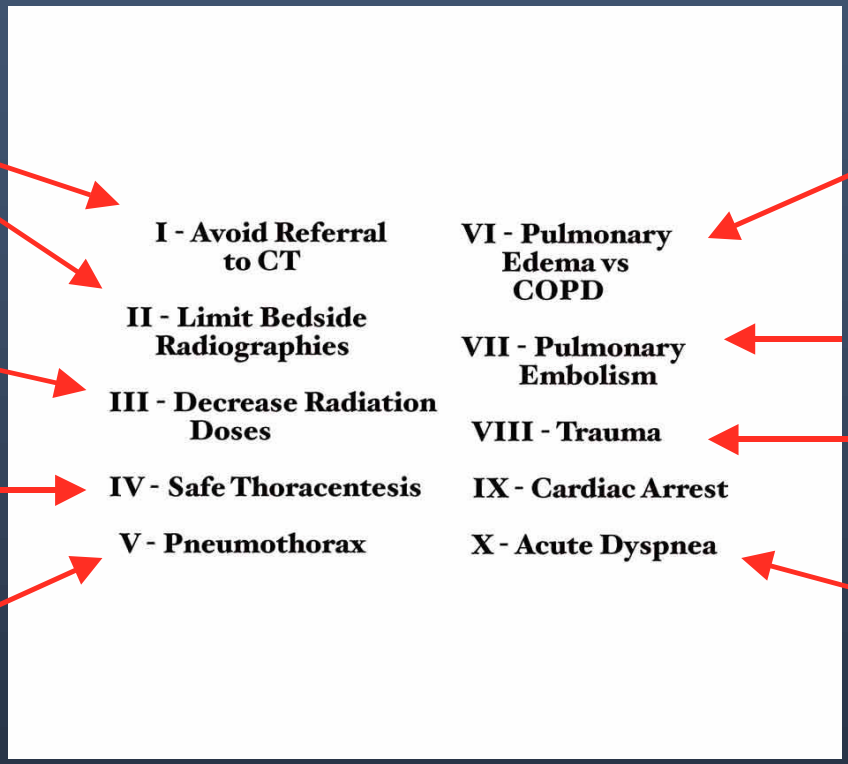
Some clinical applications of lung ultrasound

Anesthesiology 100:9-15

NEJOM 357:2277-2284 (Brenner)

Intensive Care Med 25:955-958

Crit Care Med 33:1231-1238



Intensive Care Med 24:1331-1334

Chest 123:2154

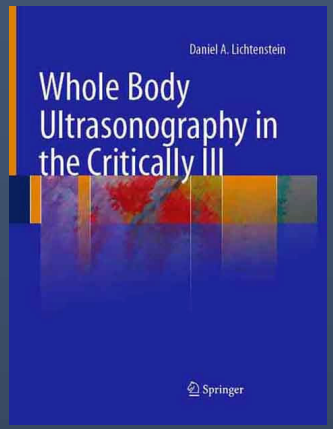
Chest 130:533-538 (F. Silva)

Chest 134:117-125

And the FALLS-protocol, allowing to define needs in fluid therapy in acute circulatory failure. Can be used even in absence of suitable cardiac window, and in addition provides direct parameter of lung volemia (CHEST 136:1014-1020)

For making one step beyond

Detailed applications are available in “Whole body ultrasound in the critically ill” (2010, Springer, 4th Ed since 1992)



An adapted training to lung ultrasound at the bedside of the critically ill is accessible since 1989 in medical ICU of Hospital Ambroise-Paré, using personnalized approach of CEURF (www.ceurf.net)

CEURF (Cercle des Echographistes d’Urgence et de Réanimation Francophones) trains in french and in english. One didactic day details what is holistic critical ultrasound (and why the organs, applications and equipment permanently interact, creating optimal ***harmony***).
The bedside stage includes not more than two attendees, at the bedside. One (basic), two (advanced) or three (expert) mornings are accessible.
After the session, CEURFers can communicate with the bureau with no limitation in time (advise on given patients, help in publications...).
A substitute product for gel is used at CEURF, allowing to make fast protocols (a BLUE-protocol in 3 minutes or less).
CEURF is a non-profit association (1901 law), aiming at widespreading a different vision of ultrasound.

Additional literature

Since recently (advent of laptops), countless works have been published. All confirm the value of lung ultrasound in the critically ill

Not arguing for a comprehensive list, here are quoted some main authors, apologizing for possibly missing works:

Balik M, Plasil P, Waldauf P, Pazout J, Fric M, Otahal M & Pachl J. Ultrasound estimation of volume of pleural fluid in mechanically ventilated patients. Intensive Care Med 2006:318-321

Blaivas M, Lyon M, Duggal S. A prospective comparison of supine chest radiography and bedside ultrasound for the diagnosis of traumatic pneumothorax. Acad Emerg Med 2005 Sep;12(9):844-9

Bouhemad B, Zhang M, Lu Q, Rouby JJ. Clinical review : bedside lung ultrasound in critical care practice. Crit Care 2007;11:205

Copetti R, Cattarossi L. Ultrasound diagnosis of pneumonia in children. Radiol Med (Torino). 2008 Mar 113(2):190-198. Epub 2008 Apr 2

Dulchavsky SA, Hamilton DR, Diebel LN, Sargsyan AE, Billica RD, Williams DR. Thoracic ultrasound diagnosis of pneumothorax. ***J Trauma*** 1999 47:970-971

Fagenholz PJ, Gutman JA, Murray AF, Noble VE, Thomas SH, Harris NS. Chest ultrasonography for the diagnosis and monitoring of high-altitude pulmonary edema. ***Chest*** 2007 131:1013-1018

Gargani L, Lionetti V, Di Cristofano C, et al. Early detection of acute lung injury uncoupled to hypoxemia in pigs using ultrasound lung comets. Crit Care Med 2007; 35: 2769-2774

Lerolle N, Guérot E, Dimassi S, Zegdi R, Faisy C, Fagon JY, Diehl JL. Ultrasonographic diagnosis criterion for severe diaphragmatic dysfunction after cardiac surgery. Chest 2009;135:401-407

Mathis G, Blank W, Reißig A, Lechleitner P, Reuß J, Schuler A, Beckh S (2005) Thoracic ultrasound for diagnosing pulmonary embolism. A prospective multicenter study of 352 patients. Chest 128:1531-1538

Maury E, Guglielminotti J, Alzieu M, Guidet B & Offenstadt G. Ultrasonic examination: an alternative to chest radiography after central venous catheter insertion? ***Am J Respir Crit Care Med*** 2001 164:403-405

Mayo PH, Goltz HR, Tafreshi M & Doelken P. Safety of ultrasound-guided thoracentesis in patients receiving mechanical ventilation. ***Chest*** 2004 125(3):1059-1062

Reissig A, Kroegel C: Transthoracic sonography of diffuse parenchymal lung disease: the role of comet tail artifacts. ***J Ultrasound Med***. 2003 22:173-180

Roch A, Bojan M, Michelet P, Romain F, Bregeon F, Papazian L, Auffray JP. Usefulness of ultrasonography in predicting pleural effusion > 500 mL in patients receiving mechanical ventilation. Chest 2005; 127:224-232

Rowan KR, Kirkpatrick AW, Liu D, Forkheim KE, Mayo JR & Nicolaou S. Traumatic pneumothorax. Detection with thoracic US: Correlation with chest radiography and CT. ***Radiology*** 2002 225: 210-214

Soldati G, Testa A, Silva FR, Carbone L, Portale G, Silveri NG: Chest ultrasonography in lung contusion. ***Chest*** 2006 130(2):533-538

Via G, Lichtenstein D, Mojoli F, Rodi G, Neri L, Storti E, Klersy C, Iotti G & Braschi A. Whole lung lavage: a unique model for ultrasound assessment of lung aeration changes. Intensive Care Med DOI 10.1007/s00134-010-1834-4

Vignon P, Chastagner C, Berkane V, Chardac E, Francois B, Normand S, Bonnivard M, Clavel M, Pichon N, Preux PM, Maubon A, Gastinne H. Quantitative assessment of pleural effusion in critically ill patients by means of ultrasonography. Crit Care Med 2005;33:1757-1763

Volpicelli G, Mussa A, Garofalo G, Cardinale L, Casoli G, Perotto F, Fava C, Frascisco M: Bedside lung ultrasound in the assessment of alveolar-interstitial syndrome. ***Am J Emerg Med*** 2006 24:689-696

And many other publications

CEURF

Tomorrow's medicine using yesterday's tools

May 24, 2011