Lung Ultrasound in the Critically Ill

LUCI

Ten signs : the alphabet of lung ultrasound in the critically ill

An introduction to the BLUE-protocol (and main derived products)

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Videos of lung ultrasound can be consulted on

www. CEURF.net

(section BLUE-protocol)

Last update March 20, 2018

Note regarding the neonate

There is no needed adaptation when scanning neonates when compared to adults. The slide #39 expresses a few words regarding the neonate, but all slides of this PDF are valuable for any patient of any age.

Issues on equipment asepsis are already answered.

The only important adaptation regards the probe, where definitely adult abdominal probes will not be preferred. Some authors advocate vascular probes, we ask the users to compare just once with good-quality microconvex ones.

The diseases of neonates are not the same than in adults, but the basis of the lung ultrasound semiotics is unchanged.

The lung, unsuitable 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

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 this article, sent in 1991 and defining critical ultrasound, i.e., a philosophy on a new use : one diagnosis, one immediate life-saving therapy. Once this concept created, once the physician (intensivist first) is the first-line user, the suitable applications come naturally : lung as the main target, venous canulation, simple heart a.m.o.

Holistic ultrasound
One critical point to understand

CEURF positioning, which aims at simplifying, works at creating the basis of a round table on the really suitable equipment.

On this round table will sit only those experts who have zero conflict of interest with the industry.

Waiting this (unlikely) event, please read the following slides for making a different opinion, independent from current fashions.

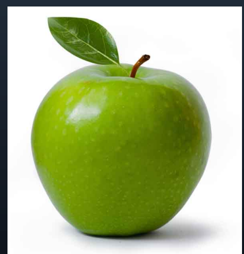
Meanwhile, the voice of CEURF begins to be heard by some manufacturers who begin to build suitable machines

Holistic ultrasound
One critical point to understand

CEURF shares a different point of view regarding the choice of equipment, which is integrated in the concept of *holistic ultrasound.*

CEURF defines a discipline as holistic when each of its parts (type of machine, type of probe, type of setting, type of priority, applications....) is permanently connected to the others. It is mandatory to understand each of these parts for understanding that the whole can be simplified for optimal efficiency, creating a *harmonious* discipline*.

The equipment is a critical step. It can make critical ultrasound a simple or complicate field...



Just scan different

Holistic ultrasound can be compared to personal computers, two main kinds being available today. They are opposed by their level of simplicity, and the most user-friendly has long been underused, before the trend reverses

* Basic example: lung ultrasound allows to limit the need for expert Doppler echocardiography

Which equipment for lung and whole body ultrasound in the critically ill ?

Critical ultrasound has been developed using simple machines

ADR-4000 (1982-1992) A 42-cm width, not larger than many nowadays laptops, the revolution 20 years before the laptops. Image resolution was suitable for lung ultrasound. Some images from this system are featuring in the present document

Hitachi-405 (1992-2010) 30-cm width. Perfect on-site machine 10 years before the laptop advent

Why does CEURF teach a different point of view

Laptop machines, very popular in ERs and ICUs since the mid 2000s are good.

The japanese technology we use since 1992 is just superior.

Since manufacturers of laptop machines have copy-pasted traditional radiological and cardiological cultures, not taking into account the *lung*, the result was a suboptimal access to the lung. The inclusion of this vital organ changes the vision of ultrasound. Doppler gets less mandatory (for respiratory and circulatory concerns). Filters (useful to radiologists) have destructive effects for lung ultrasound. The absence of cardiac windows is no longer a problem in most cases. The rules of critical ultrasound change from A to Z when the lung is included.

Not only the lung but many areas are concerned in this vision (mainly venous assessment).

Why does CEURF teach a different point of view

The 7 mandatory requirements for making critical ultrasound as taught at CEURF

1) Our unit is smaller than laptops. Not in height (of minor interest within a hospital) but in width, the only important dimension : 29 cm (33 cm with cart). Perfect for bedside use. Note that as opposed to laptops, our unit has a top. On a top, probes etc. can be located, maybe increasing height (not a problem), but mostly decreasing *width*.

2) Our unit is faster : 7 seconds (the fastest start-on time).

3) Our unit is cleaner : flat keyboard, easy to clean.

4) Our unit is simpler : few buttons, no Doppler, no harmonics etc... precisely the best for efficient lung ultrasound, and perfect for a whole body use in critical settings.

5) Our unit has analogic image quality, i.e., a resolution image which the reader can see (and compare) in this document.

6) One unique probe (see next section)

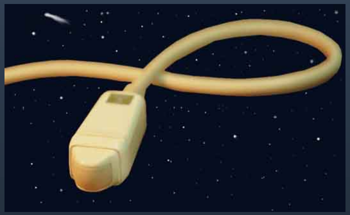
7) A cost-effective unit, consequence of points 4 and 6, allowing to save more lives.

Why does CEURF teach a different point of view

The probe

Our 5 MHz microconvex probe is perfect for lung imaging, because of its small footprint and its wide range: from 0,6 to 17 cm. It makes an ideal compromise in these fast protocols of whole body assessment, with the advantage of imaging *lung, heart, veins, belly* (even optic nerve), of critical interest in acute settings (cardiac arrest, or routine) : a whole body integration without compromise to patient's safety

Its short length is an advantage for scanning posterior areas of the lung in ventilated patients



Note : vascular probes are traditionally used for lungs and veins. Our universal probe can assess all veins (superficial like jugular, deep like IVC) in all sections (not restricted to one axis because of the probe dimension, which makes a permanent hindrance).

Beware : Some microconvex probes found in the market have poor image resolution and/or poor depth (usually not more than 8-10 cm).

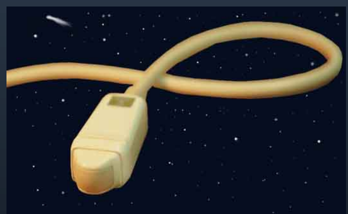
Why does CEURF teach a different point of view

An example of holistic ultrasound

The "SESAME" configuration allows our machine to be operational in a few seconds in cardiac arrest.

Switch on of unit : 7 seconds

Choice of the probe : zero second, a huge advantage when the cause is not clear. Gas tamponade ? The literature advises vascular probes. Pericardial tamponade ? The literature advises cardiac probes. Abdominal bleeding ? Literature uses abdominal probes. CEURF uses the same probe for each.



Settings of the machine : zero second, the machine is permanently on a "cardiac arrest" configuration, which works the same for routine tasks.

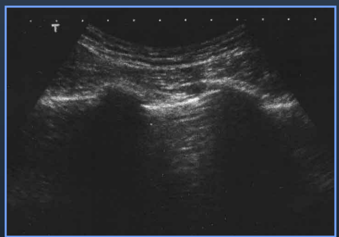
One probe : cost-effective, time-sparing, decreases risk of infections

How to do anyway for whose already equipped with traditional laptop machines

One can do critical (and lung) ultrasound with any equipment. It will just be more difficult (from slightly to highly), in terms of size, ergonomy, image resolution, start-on time, cost, mainly. Our 1992 unit is paradoxically superior in all respects to up-to-date machines.

First get rid of all filters (provided they are not irreversible)

Then bet on the suitable probe, *time permitting*, an issue in the case of cardiac arrest : Vascular if thinking of pneumothorax, phased array if thinking of tamponade, abdominal if thinking of hemorrhage. Some cardiac probes are better than others, if patients not too skinny. Please care at disinfecting each probe for each change. By cleverly swaping probes, one can decrease the consequence of a bad initial choice. Our universal probe gets rid of this issue (and can be used in any other setting).



The less worse compromise in image resolution is obtained using bulky abdominal probes

The less worse compromise in ergonomics is obtained using ill-defined phased-array probes

Vascular probe : allows it is true superficiel analysis, which is penalizing in the case of extreme shock, cardiac arrest: it is indeed not universal, its ergonomy is not suitable

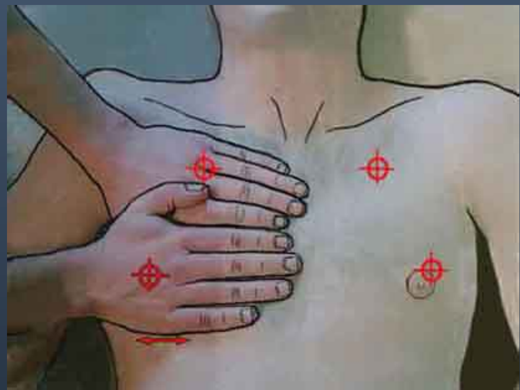
Note that since recently, some machines have all qualities than the ones we are accustomed since 1992 (CEURF makes *no* written advertisement)

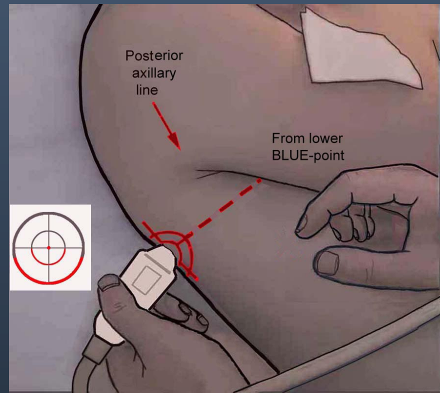
Basic technique
Where to apply the probe on the thorax
The BLUE-points

Upper BLUE-point

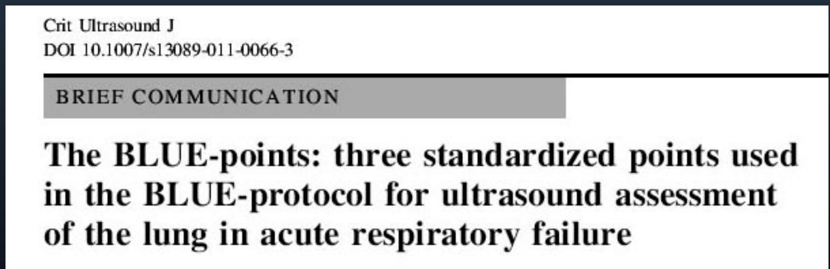
Lower BLUE-point

(BLUE-hands, should have size of patient's hands)





PLAPS-point


Crit Ultrasound J
DOI 10.1007/s13089-011-0066-3

BRIEF COMMUNICATION

The BLUE-points: three standardized points used in the BLUE-protocol for ultrasound assessment of the lung in acute respiratory failure

The lung is the most voluminous organ. As for ECG, standardized areas can be defined. The BLUE-points follow the geometry of the lungs, and avoid the heart usually.

The PLAPS-point is a continuation of the lower BLUE-point, as far as possible behind the posterior axillary line. A short probe allows to keep tangential, a basic detail for optimizing image quality, a critical point for scanning ventilated, sedated patients.

The ten basic signs

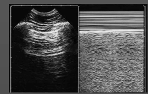
Important note

This is not a DVD. 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. For those who want videos : go to CEURF.net (www. first) (BLUE-protocol)

The bat sign

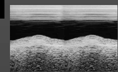
The A-line

Lung sliding



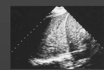
The quad sign

The sinusoid sign

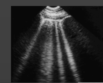


The fractal sign

The lung sign

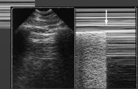


The B-line (& lung rockets)



The stratosphere sign

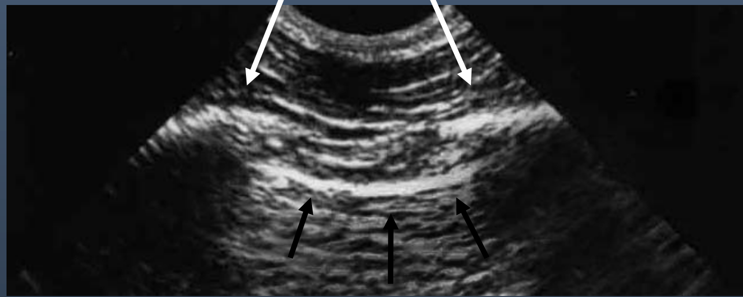
The lung point

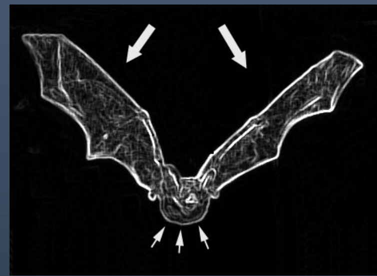


The mastery of 10 signs allows control of multiple settings : acute respiratory failure, ARDS management, hemodynamic therapy in shocked patient, neonates, traumatized patients. It works in up-to-date ICUs as well as austere areas or spaceships.

Two other signs of LUCI (lung pulse, dynamic air bronchogram), are not dealt with here, for simplifying

1) The pleural line





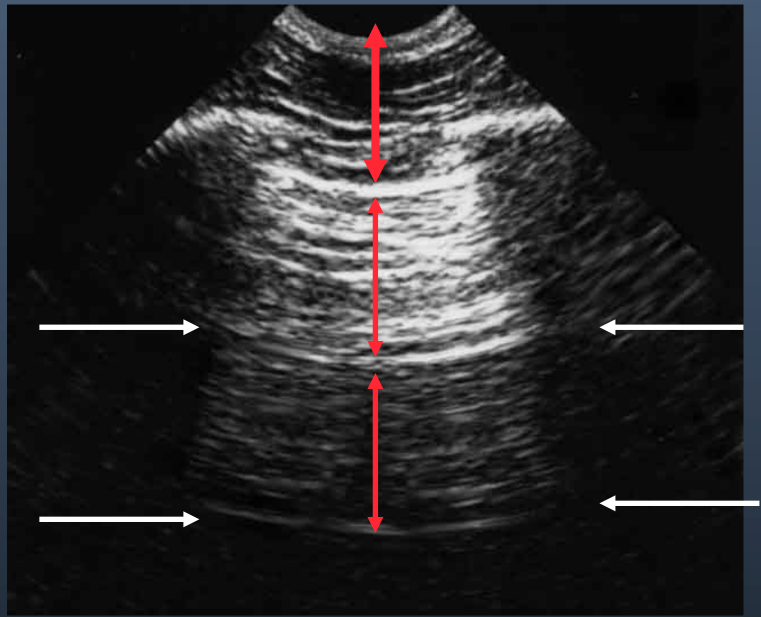
The bat sign

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

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

Critical note. The approach is longitudinal, slightly corrected in rib axis. This makes two ribs symmetrical, and a constant length of pleural line (25 mm in standard adults). CEURF carefully advises for this longitudinal approach.

2) The A-line

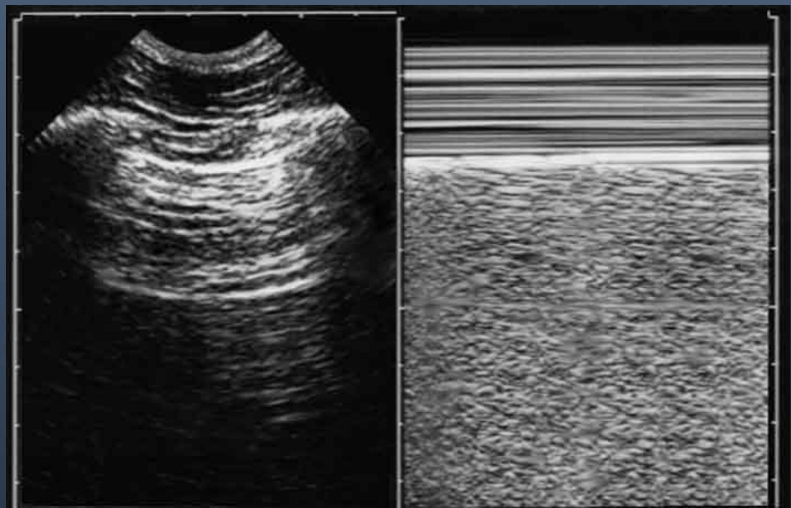


Hyperechoic equidistant horizontal artifacts arising from the pleural line

A-lines indicate air*, whether physiologic or pathologic

* For purists, the term *gas* is more appropriate

3) Lung sliding & seashore sign



(Above the arrow, the Keye's space.

Below, the Merlin's space)

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

Note : accuracy of lung sliding ?
Ultrasound is the gold standard

KJCCM The Korean Journal of Critical Care Medicine

OPEN

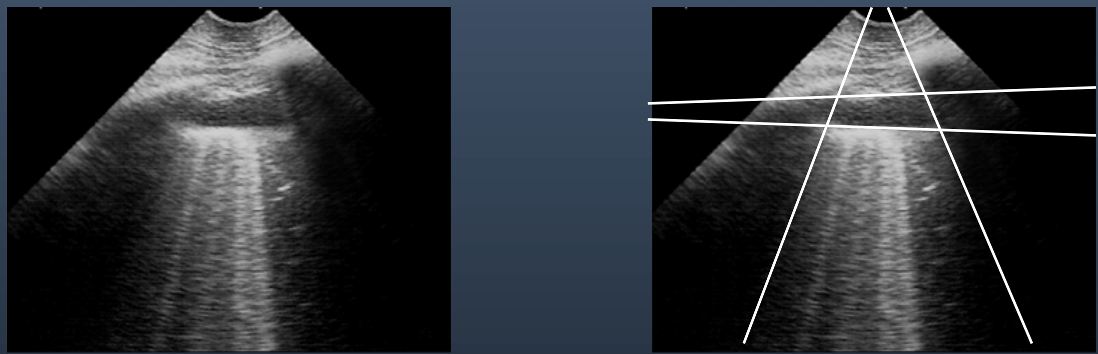
pISSN : 2383-4870 | eISSN

Review
Korean Journal of Critical Care Medicine (in press)

CrossMark

Lung Ultrasound in the Critically Ill (LUCI) is a gold standard.
The example of lung sliding

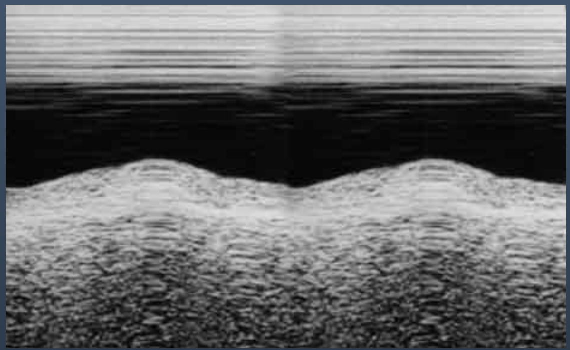
4) Pleural effusion
The quad sign



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

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

5) Pleural effusion
The 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

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

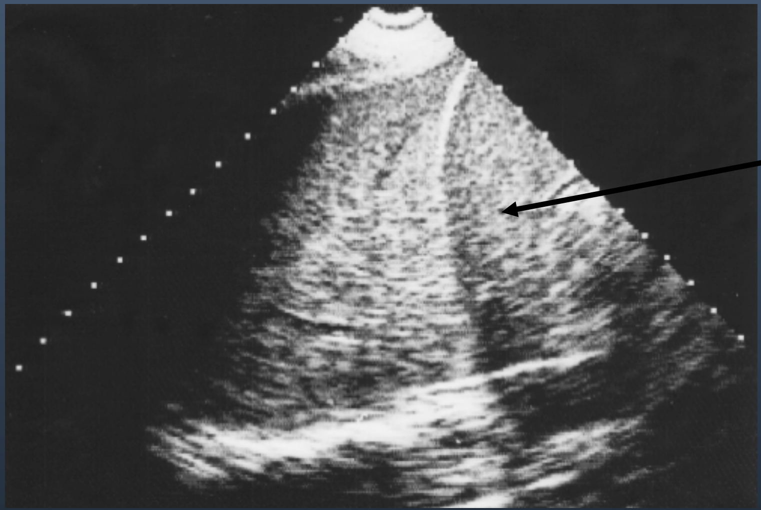
6) Lung consolidation (alveolar syndrome) Nontranslobar ones : the shred sign

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

The shred (or fractal) line is the boundary between consolidated lung and aerated underlying lung. This line is quite always irregular, allowing immediate diagnosis

(Please : forget the term “subpleural” often seen. Each time a lung consolidation is seen using ultrasound, *it is subpleural)*. Save one word in your manuscripts !)

7) Lung consolidation (alveolar syndrome) Translobar ones : the lung sign



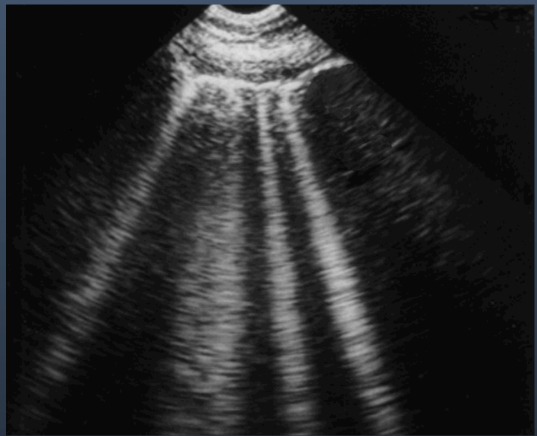
spleen
or liver

A fluid disorder mimicking a solid organ

When the consolidation is translobar (i.e., fills the whole lobe), no fractal sign can be generated.
The lung sign : the lung appears as a plain organ.
Anatomic shape of an organ.
Motionless ultrastructure, like a plain tissue.

An example of PLAPS, associating lung consolidation and pleural effusion (see at BLUE-protocol section)

8) Interstitial syndrome
The B-line
(before the lung rockets)



Lung rockets
(1992's technology)

The B-line is

1- a comet-tail artifact (always)
2 - arising from the pleural line (always)
3 - moves with lung sliding (always)
(and when there is lung sliding)

4 - long without fading (most often)
5 - well-defined - laser-ray like (most often)
6 - erases A lines (most often)
7 - hyperechoic (most often)

Using these 7 features, we have a universal definition which distinguishes the B-line from all other comet-tail artifacts

8) Interstitial syndrome
(After the B-line)
Lung rockets

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 among many others

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 simple fissura

Lung rockets

Three (or more) B-lines between two ribs
They define interstitial syndrome (can be focal)

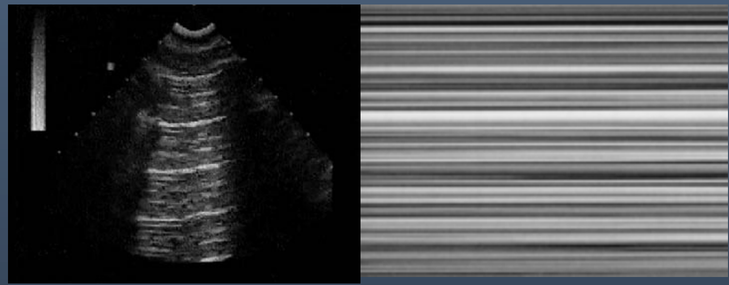
Diffuse lung rockets

Lung rockets at the four points of anterior chest wall
They define pulmonary edema (hemodynamic or inflammatory - see BLUE-protocol) mainly

9) Pneumothorax and A'-profile

Pneumothorax, a *sequential* diagnosis

The A'-profile must first be identified



Stratosphere sign

At anterior chest wall :

1) Abolished lung sliding (fully sensitive, not specific)

2) Exclusive A-lines (already described), a sign of very poor specificity but mandatory

The whole has been called A'-profile

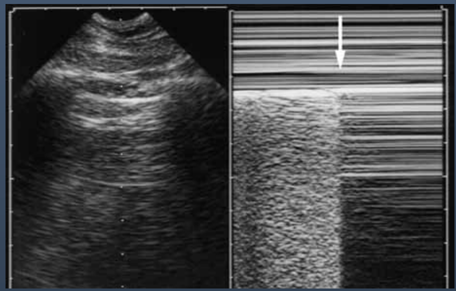
The association of both signs at the anterior chest defines the A'-profile, a constant sign in pneumothorax.

The slightest lung sliding, the slightest lung pulse, the slightest B-line rule out pneumothorax (where the probe is applied)

10) Pneumothorax and lung point

TO BE SOUGHT FOR ONCE AND ONLY ONCE AN A'-PROFILE HAS BEEN DETECTED

Sudden visualization of any sign (lung sliding, B-lines, pleural fluid, heart...) at a precise point, replacing an A'-profile, when the probe gradually turns around the thorax.



Lung point : specific to pneumothorax, therefore mandatory for accurate and safe use in the critically ill. In its absence, it is cautious not to draw any conclusion. In case of extreme emergency, the "australian variant" can be used : an A'-profile associated with the slightest clinical sign (tympanism, ...) makes a highly suggestive association.

Lung point : indicates pneumothorax volume (anterior, radio-occult. Lateral, moderate. At PLAPS-point, substantial. Absent, major).

The lung point also shows that signs (especially abolished lung sliding) are not due to technical inadequacies of machine (beware some too sophisticated machines, not designed for lung)

* The BLUE-protocol is permanently integrated in the basic management (physical examination first)

Pneumothorax
The diagnosis of *air within air*
A basic decision tree

Lung sliding (or any equivalent such as lung pulse)

Present : pneumothorax ruled out

Absent

B lines present : Pneumothorax ruled out

Only A lines

Lung point : pneumothorax is confirmed

No lung point : use usual tools (X-ray or even CT) (and clinical tools in case of extreme emergency)

Value of the signs used

	Sensitivity (%)	Specificity (%)	Source (CT as gold standard)
Pleural effusion	94	97	Intensive Care Med (1999) 25: 955–958 © Springer-Verlag 1999 ORIGINAL — Feasibility and safety of ultrasound-aided thoracentesis in mechanically ventilated patients
Lung 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

Critical semantic details

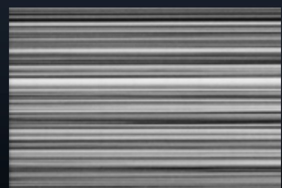
Literature can enrich, but sometimes confuse. Please note.

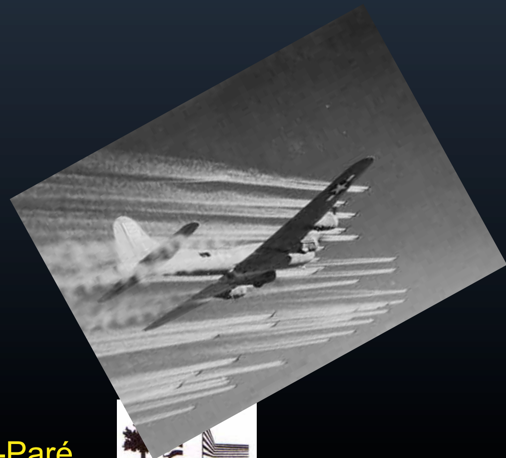
"Lung comets" are not lung rockets. The physiopathologic meaning of these two labels is fully different

"Comet-tail artifact". This term is not representative for interstitial syndrome

"Alveolar-interstitial syndrome". This term is radiological. It is inappropriate for ultrasound, which detects either interstitial syndrome (artefactual) or alveolar syndrome (structural), fully distinctly.

"Barcode sign" is used by some teams instead of stratosfere sign. We highly suggest to be cautious for avoiding deadly confusions generated by the new barcodes





Respiratory 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

I - Avoid Referral to CT

II - Limit Bedside Radiographies

III - Decrease Radiation Doses

IV - Safe Thoracentesis

V - Pneumothorax

VI - Pulmonary Edema vs COPD

VII - Pulmonary Embolism

VIII - Trauma

IX - Cardiac Arrest

X - Acute Dyspnea

Intensive Care Med 24:1331-1334

Chest 123:2154

Chest 130:533-538 (F. Silva)

Chest 134:117-125

Circulatory application of lung ultrasound

Chest 2009;136:1014-1020

A-lines & B-lines: lung ultrasound as a bedside tool for predicting PAOP in the critically ill

EXPERT REVIEWS

Fluid administration limited by lung sonography: place of lung ultrasound in assessment of acute circulatory failure (the FALLS-protocol)

Expert Rev. Respir. Med. 6(2), 155-162 (2012)

Recent Advances in Chest Medicine

CHEST

BLUE-Protocol and FALLS-Protocol

Two Applications of Lung Ultrasound in the Critically Ill

LUCI, some clinical applications...

Countless applications are accessible.

The Pink-protocol (ARDS assessment), including :

Nature and volume of pleural effusion - pulmonary abscess - distinction between thickened interlobular septa and ground-glass areas - lung contusion - overdistension - alveolar recruitment... – volume of pneumothorax

The CLOT-protocol – how to diagnose pulmonary embolism in untransportable ARDS

The Extended BLUE-protocol (e.g., immediate diagnosis of atelectasis when still aerated - phrenic function – a.m.o.)

Ultrasound-assisted thoracentesis, in mechanically ventilated patients

The FAT-protocol (lung ultrasound in the bariatric patient)

ETC

Recently published:

(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

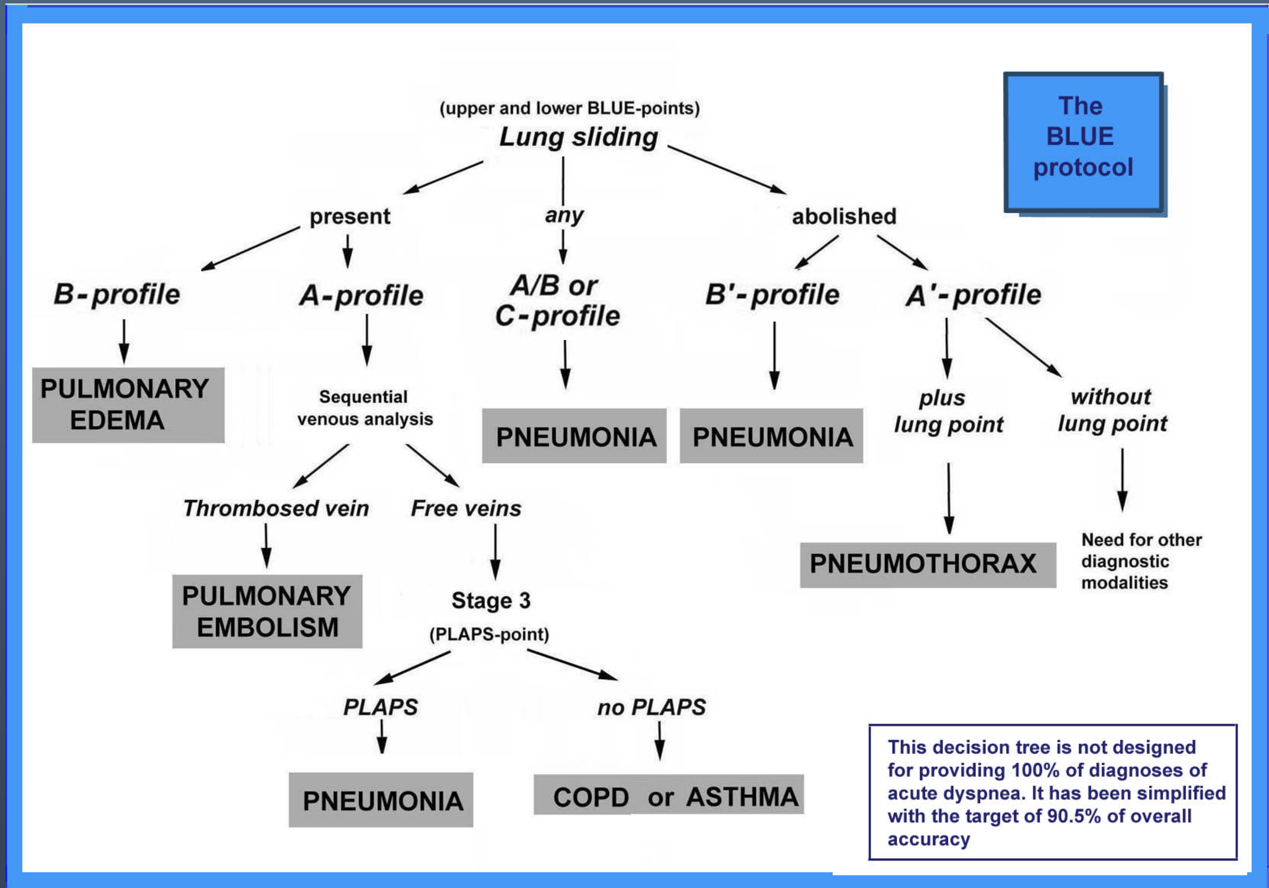
(PCCM 2009) : Lung ultrasound in the critically ill neonate

(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

(CHEST 2015) : a synthesis of the BLUE-protocol and FALLS-protocol

The BLUE-protocol decision tree



Video-clips of the *BLUE-profiles* can be seen on www.CEURF.net, section BLUE-protocol

The BLUE-protocol : acute respiratory failure

Main principle : An ultrasound analysis of lungs (and veins in suitable cases) allows to define eight characteristic profiles representative of the 6 most frequent causes of acute respiratory failure (seen in 97% of patients). The BLUE-protocol accuracy (90.5%) is enhanced once integrated in the history, physical examination, basic tests (EKG, venous blood tests), and simple echocardiography.

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

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

Methodology

Patients : all patients seen at E.R. for acute respiratory failure and admitted to I.C.U.
Gold standard : final diagnosis on medical report (written by university team of medical ICU)
Excluded patients : multiple diagnoses, absence of diagnosis, rare (<3%) diagnoses
Material : ADR-4000 and Hitachi-405, sectorial probe 3 MHz and microconvex probe 5 MHz

Chest 2008; 134:117-125

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

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

After history and physical examination, 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 anterior pattern observed in 97% of cases is diffuse lung rockets associated with lung sliding : the B-profile, a pattern obtained in 20 seconds.

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

Chronic interstitial diseases are not included since BLUE-protocol included the 97% of patients having the 6 most frequent groups of diseases: pneumonia - pulmonary edema - COPD - asthma - pulmonary embolism - pneumothorax. Countless diseases make the 3% of remaining cases).

Notes : facing a B-profile, the BLUE-protocol is concluded. Posterior lung and venous analysis can be done at will by the physician. They usually provide redundant information (show free veins etc), but can on occasion have some relevance (this is the Extended BLUE-protocol). 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. Reminder : this is a rare cause.   All this is included in the Extended BLUE-protocol.

BLUE-protocol and PLAPS

The BLUE-protocol associates signs with signs, and signs with locations. The detection of an image combining pleural effusion and/or lung consolidation at a posterior area (supine patient) has basic relevance. The practical term *PLAPS* (postero-lateral alveolar and/or pleural syndrome) indicates that the image can be pleural, or alveolar, or both. Unilateral or not, trace or substantial, in acute respiratory failure, if A-profile (anterior normal lung surface) and free venous network, a PLAPS indicates pneumonia with high accuracy.

The concept of PLAPS allows to bring 10 signs (including quad sign, sinusoid sign, fractal sign & lung sign) to 7 signs.

Four profiles make the diagnosis of pneumonia and/or ARDS (associated in BLUE-protocol). BLUE-protocol allows distinction between hemodynamic edema and ARDS in most cases

This PLAPS, seen at the PLAPS-point, associates here minute pleural effusion and minute consolidation of the end of lower lobe. Note if the image is too ill-defined for distinguishing effusion from consolidation (bariatric patient e.g.), this does not change the concept: it is a PLAPS.

The BLUE-protocol is one application of holistic ultrasound

One critical example : embolism

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

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

It carefully focuses on calf veins, which are usually neglected, but are of high accessibility using our probe and adapted approach. Isolated calf deep venous thrombosis (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 echocardiography. 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.

FALLS-protocol

The main derived product of the BLUE-protocol. Is a fast protocol for causal diagnosis of a circulatory failure, initiates fluid therapy. Allows to define which patient in acute circulatory failure should receive fluid therapy, and when to discontinue it. Can be used in absence of suitable cardiac window. Provides a direct parameter of clinical volemia

Special Report

Expert Reviews

Fluid administration limited by lung sonography: the place of lung ultrasound in assessment of acute circulatory failure (the FALLS-protocol)

Expert Rev. Respir. Med. 6(2), 155–162 (2012)

Daniel Lichtenstein

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The FALLS-protocol is included in a limited investigation to diagnose the cause of shock. After simple echocardiography has ruled out obstructive shock (tamponade, pulmonary embolism, pneumothorax), the lung is investigated. Absence of disseminated lung rockets rules out cardiogenic shock. At this point, hypovolemic and septic shock are differential diagnoses (rarities apart), and the FALLS-protocol provides fluid therapy with constant monitoring of lung artifacts. Hypovolemic shock will eventually improve – septic shock will not, and the slight excess fluid creates an early, silent stage of interstitial edema, demonstrated by B-lines, demanding interruption of fluid therapy. This sequential approach, combined with the usual, clinical, biochemical and echocardiographic parameters, must be evaluated in multicenter studies.

Keywords: acute circulatory failure • fluid responsiveness • hemodynamic assessment • lung ultrasound

HEART LUNG and VESSELS

• Vol. 5 - N. 3 - Sep. 2013 • Heart, Lung and Vessels 2013; 5(3): 142-147

REVIEW-ARTICLE

Heart, Lung and Vessels 2013; 5(3): 142-147

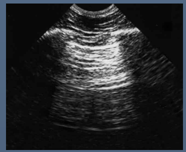
FALLS-protocol: lung ultrasound in hemodynamic assessment of shock

Recent Advances in Chest Medicine

CHEST

BLUE-Protocol and FALLS-Protocol

Two Applications of Lung Ultrasound in the Critically Ill

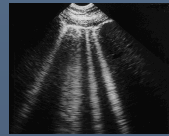


Clearance for fluid therapy

FALLS-protocol

Fluid Administration Limited by Lung Sonography

Its principle in one slide...



Endpoint for fluid therapy

FALLS-protocol uses Weil's classification for sequentially ruling out the cause of a circulatory failure with no orientation.

Native indication : when the usual tools do not work (e.g., poor cardiac window)

A simple cardiac sonography (microconvex probe, no Doppler) and some BLUE-protocol rule out obstructive shock in the absence of substantial pericardial fluid, dilated right cavities suggesting pulmonary embolism (and all cases of dilatation, pulmonary hypertension etc), & pneumothorax.

The absence of B-profile rules out a cardiogenic shock of left origin, i.e., the huge majority.

Patients at this step are labelled "FALLS-responders" (they have usually the A-profile or FALLS-equivalents : A/B profile, C-profile on A...). They receive fluid therapy. Those who respond (clinical, biological evolution) had hypovolemic shock.

If not improving clinical signs of shock, fluid therapy will eventually generate an interstitial syndrome (B-profile), which is immediately recognized, at an early, infra-clinical, interstitial step. The change from A-lines to B-lines defines the FALLS-endpoint. Such a situation defines, by default, distributive shock, i.e. in daily practice, septic shock.

Note that FALLS-protocol saved time. The patient benefited from an early and controlled (not massive) fluid therapy, even before the diagnosis of septic shock. At this step, blood tests are done, including several blood cultures. This procedure allows to withdraw the slight fluid excess (generated by the FALLS-protocol), aiming at positioning the heart at the ideal point of the volume-pressure curve.

Note two main limitations : B-profile on admission, usually hemodynamic pulmonary edema (FALLS-protocol cannot be used). RV dilatation on admission (FALLS should not be used, unless this limitation is invalidated. Meanwhile, use tradional tools for defining needs in fluids).

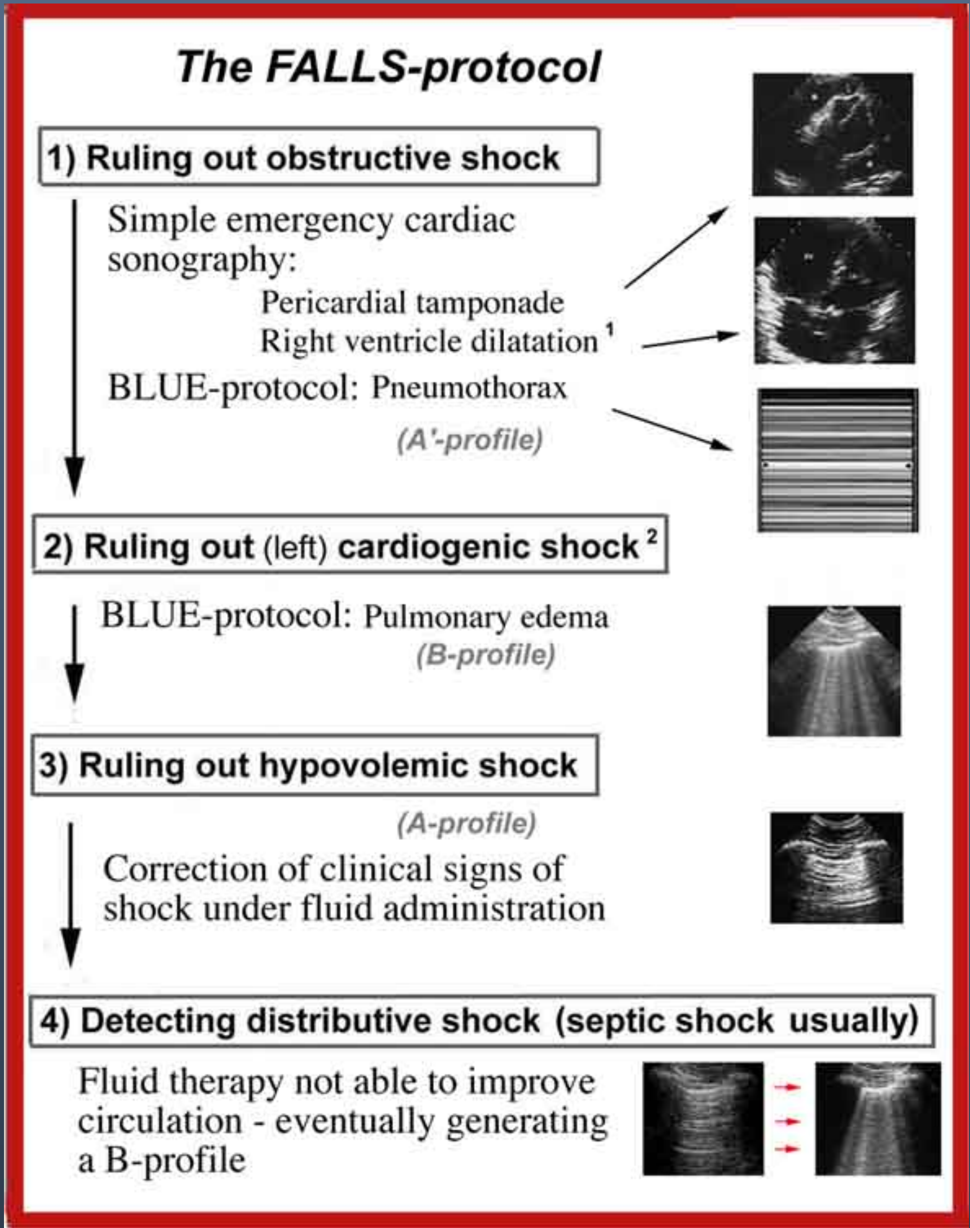
FALLS-protocol

Fluid Administration Limited by Lung Sonography
A *schematical* decision tree

CRITICAL NOTE

Hemodynamic assessment is a highly complex field. The FALLS-protocol does not pretend to solve all issues. It is open to any criticism. Just read some development at CEURF.net or CHEST 2015;147:1659-1670.

Many Frequently Asked Questions are answered in *Lung Ultrasound in the Critically Ill*, Chap 30, Springer 2016



SESAME-protocol and cardiac arrest

Practical contraction of SESAMOOSSIC, "Sequential Emergency Sonography Assessing Mechanism *Or* Origin of Severe Shock of Indistinct Cause" (shockable causes are put aside). Indication : extreme circulatory failure, cardiac arrest. Main peculiarity : SESAME begins at lung (ends with heart). The best illustration of holistic ultrasound. Unit switch-on in 7 sec. A universal probe. No knobology to be used at the first 4 steps. Protocol expedited using Echolight®*.

Step 1 : Lung, because : lung windows always present (unlike heart). Pneumothorax immediately (< 2 sec) ruled out or suspected. The quiet breathing makes the best condition. Clearance is given for immediate fluid therapy. Pulmonary edema is ruled out if A-profile.

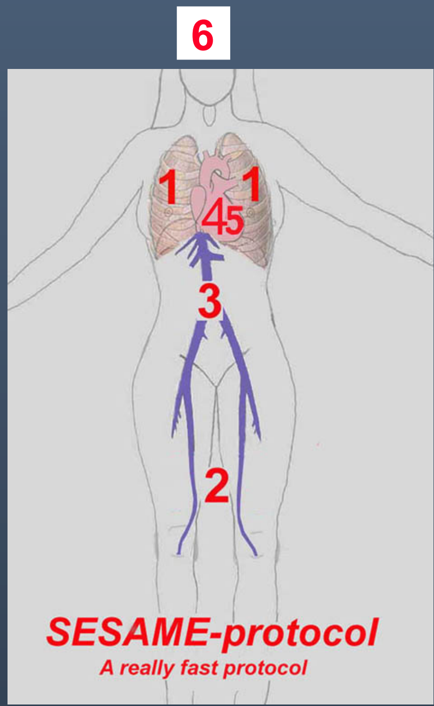
Step 2 : Veins. BLUE-protocol at lower femoral veins for (if finding DVT) diagnosing pulmonary embolism (specificity with A-profile, 99%).

Step 3 : Belly. Search for substantial amounts of free blood (GI-tract, peritoneum, pleura...).

Step 4 : Pericardium

Step 5 : Heart (windows permitting, using first simple cardiac sonography). Note well : resuscitation must be interrupted. Asystole has poor prognosis. Kissing heart, *déjà vu* on steps 1 & 3. Dancing heart, *déjà vu* on step 4. Dilated RV with embolism, *déjà vu* on step 2 (but high interest if no DVT).

(Step 6 in neonates : search for brain haemorrhage)



* Echolite®: a coupling agent with the critical advantage (apart from vanishing spontaneously after 2 minutes) of extremely fast protocols, less than two seconds is necessay from one area to another, remote area (lungs/calf e.g.). Avoids slippery thorax, a hindrance in cardiac arrest. Soon available.

Maybe our main message : the *neonate*

The whole of the 12 signs (carefully assessed in the adult using CT) are found again *with no difference* in the critically ill neonate. This includes two signs not described here : dynamic air bronchogram and lung pulse

If these signs are present in both adults and neonates, likely they are present in intermediate ages (toddler etc). We do not intent to irradiate neonates for proving our point, we just invite the community, using standardized ultrasound signs (fractal, rockets...) in neonates with non informative radiograph, to consider that ultrasound provides informations occult to radiograph.

Regarding ultrasound, the neonate's lung is a miniature adult's lung

Pediatric Crit Care Med 2009;10:693-698

Review Article

Ultrasound examination of the lungs in the intensive care unit

Review Article

Ultrasound examination of the lungs in the intensive care unit

Daniel A. Lichtenstein, MD

Objective: Lung ultrasound is increasingly used in the critically ill adult. It allows prompt management based upon reproducible data and generates fewer computed tomography (CT) examinations, therefore decreasing irradiation, delays, cost, and discomfort to the patient. The aim of this article is to describe the value of ultrasound for lung imaging in the critically ill and state our experience in neonates.

Methods: Review of studies published in the peer-reviewed international literature analyzing consecutive critically ill adults admitted to intensive care units, assessing pleural effusion, alveolar consolidation, interstitial syndrome, and pneumothorax, using a standardized ultrasound approach to the lung, with CT as the reference.

Data Synthesis: The sensitivity and specificity of ultrasound are 92% and 93% for pleural effusion, 90% and 98% for alveolar consolidation, 93% and 93% for interstitial syndrome, 100% and 96% for complete pneumothorax, 79% and 100% for radio-occult pneumothorax.

Discussion: This article reviews data that validate the scientific value of lung ultrasound in adult medical intensive care units. We then present observations in the critically ill neonate. The discussion points to the methodologic issues raised in lung ultrasound in the neonate, i.e. mainly the limited access to a pertinent gold standard (CT). Some CT correlations are presented, confirming the value of lung ultrasound in the neonate.

Conclusions: The standardized signs assessed in the adult are also found in the critically ill neonate, meaning a potential use in this field. Awaiting confirmatory CT studies, lung ultrasound can be taken into consideration as a possible bedside tool for completing bedside radiography. (Pediatr Crit Care Med 2009; 10:693–698)

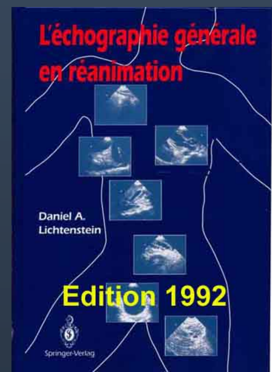
Key Words: chest ultrasonography; pulmonary edema; lung; ultrasound diagnosis; respiratory failure; intensive care unit; pneumothorax; interstitial syndrome

Note : lung ultrasound is a small part of critical ultrasound

Critical ultrasound, defined in our 1992 edition, used a 1982 technology.

This edition did not make use of acronyms. It simply described search for free blood, simple cardiac sonography (know usually under the name of FAST or FATE/FEER protocols), inferior caval vein, optic nerve, subclavian vein canulation...

The SLAM (Section of the Limitation of Acronyms in Medicine), subsequently created, accepts acronyms if they first describe original research, second do not create confusion in daily talks. SLAM does not advise the use of US (confusing) nor LUS (for logical & esthetical purpose), suggesting to write "lung ultrasound" in whole letters. Or, for hurried colleagues: "LUCI", which specifies a whole world, the world of the critical care. Note in addition that the term LUS should be devoted to a published concept, the Lung Ultrasound Score, forbidding the use of LUS in any other setting.



One positive side effect of the laptop technology

The recent burst of laptop technology (years 2005) had anyway a positive outcome, in spite of their large width : making known ultrasound to emergency physicians. Countless papers have been published, all confirming the value of LUCI.

Here are quoted some, apologizing for missing works since the field is now exploding

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

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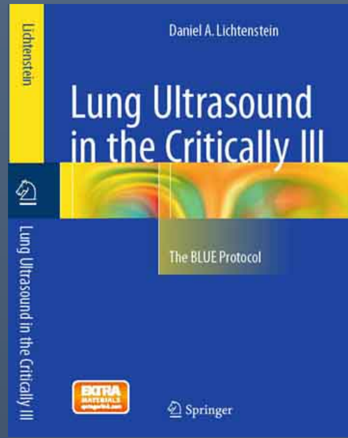
Vignon P, Chastagner C, Berkane V, Chardac E, Francois B, Normand S, Bonnivard M, Clavel M, Pichon N, Preux PM, Maubon A, Gastinne H. Quantitative assessment of pleural effusion in critically ill patients by means of ultrasonography. Crit Care Med 2005;33:1757-1763

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, including the first international consensus conference (2012), and today, hundreds or articles per day.

For making one step beyond

Detailed applications are available in "Lung Ultrasound in the Critically Ill – the BLUE-protocol" (2016, Springer)
(6th Ed since 1992)



An adapted training to LUCI at the bedside of the critically ill is accessible in medical ICU of Hospital Ambroise-Paré, using personnalized teaching (www.ceurf.net)

CEURF (Cercle des Echographistes d'Urgence et de Réanimation Francophones) trains in french and in english. One didactic day and a half details what is holistic critical ultrasound.

The bedside stage includes not more than two attendees, at the bedside in the ICU. One (basic), two (advanced) or three (expert) mornings are possible.

There is a pre-session and a post-session evaluation tests.

After the session, CEURFers can communicate with the bureau with no limitation in time (advise on given patients, help in publications...).

CEURF is a non-profit association (1901 law), aiming at widespreading a different vision of ultrasound.

CEURF

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