A Practical Approach to Ultrasound Assessment of Respiratory Distress

Yanick Beaulieu, MD, FRCPC

Director, Bedside Ultrasound Curriculum
Division of Cardiology and Critical Care
Hôpital du Sacré-Coeur de Montréal
Assistant Professor, Department of Medicine
University of Montreal, Qc, Canada
A Practical Approach to Respiratory Distress

Plan

1-) Introduction

2-) Assessment of the thoracic space

3-) Assessment of the cardiac and vascular systems

4-) Summary

5-) Conclusion
A Practical Approach to Respiratory Distress

1-) Introduction

2-) Assessment of the thoracic space

3-) Assessment of the cardiac and vascular systems

4-) Summary

5-) Conclusion
A Practical Approach to Respiratory Distress

The challenge is to achieve an as accurate presumptive diagnosis as possible and to differentiate between the most common causes for acute respiratory failure.

Most of the diseases commonly seen in patients with acute respiratory symptoms can be diagnosed with sonography.
A Practical Approach to Respiratory Distress

The cause of acute respiratory failure most often originate from the heart, lungs, and deep veins of the leg.

All three can be directly visualized using ultrasound:

- **Focused Echocardiography**
- **Lung Sonography**
- **Limited Vascular Compression Ultrasonography**
Goal-Focused Transthoracic Echo Protocols

Royse et al. Core Review: Physician-performed ultrasound: the time has come for routine use in acute care medicine. Anaesth Analgesia 2012.
Relevance of Lung Ultrasound in the Diagnosis of Acute Respiratory Failure*

The BLUE Protocol

Daniel A. Lichtenstein, MD, FCCP; and Gilbert A. Mezière, MD

Background: This study assesses the potential of lung ultrasonography to diagnose acute respiratory failure.

Methods: This observational study was conducted in university-affiliated teaching-hospital ICUs. We performed ultrasonography on consecutive patients admitted to the ICU with acute respiratory failure, comparing lung ultrasonography results on initial presentation with the final diagnosis by the ICU team. Uncertain diagnoses and rare causes (frequency < 2%) were excluded. We included 260 dyspneic patients with a definite diagnosis. Three items were assessed: artifacts (horizontal A lines or vertical B lines indicating interstitial syndrome), lung sliding, and alveolar consolidation and/or pleural effusion. Combined with venous analysis, these items were grouped to assess ultrasound profiles.

Results: Predominant A lines plus lung sliding indicated asthma (n = 34) or COPD (n = 49) with 89% sensitivity and 97% specificity. Multiple anterior diffuse B lines with lung sliding indicated pulmonary edema (n = 64) with 97% sensitivity and 95% specificity. A normal anterior profile plus deep venous thrombosis indicated pulmonary embolism (n = 21) with 81% sensitivity and 99% specificity. Anterior absent lung sliding plus A lines plus lung point indicated pneumothorax (n = 9) with 81% sensitivity and 100% specificity. Anterior alveolar consolidations, anterior diffuse B lines with abolished lung sliding, anterior asymmetric interstitial patterns, posterior consolidations or effusions without anterior diffuse B lines indicated pneumonia (n = 83) with 89% sensitivity and 94% specificity. The use of these profiles would have provided correct diagnoses in 90.5% of cases.

Conclusions: Lung ultrasound can help the clinician make a rapid diagnosis in patients with acute respiratory failure, thus meeting the priority objective of saving time.

(CHEST 2008; 134:117–125)

Keywords: chest ultrasonography; COPD; ICU; interstitial syndrome; lung, ultrasound diagnosis; pneumothorax; pulmonary edema; respiratory failure

Abbreviations: BLUE = Bedside Lung Ultrasound in Emergency; PLAPS = posterolateral alveolar and/or pleural syndrome
An examination combining:

Anterior approach
analyzing artifacts, lung sliding, alveolar consolidation

Lateral subposterior
search for posterolateral alveolar
and/or pleural syndrome (PLAPS)

Venous analysis
The BLUE Protocol

A profile
designates anterior predominant bilateral *A-lines*
associated with lung sliding

B profile
designates anterior predominant bilateral *B-lines*
associated with lung sliding
The BLUE Protocol

Table 2—Comprehensive Results*

<table>
<thead>
<tr>
<th>Anterior Pattern</th>
<th>Bilateral-Predominant A Lines</th>
<th>Bilateral-Predominant B + Lines</th>
<th>Alveolar Consolidation</th>
<th>Predominant A Lines on One Side, and Predominant B + Lines on Other Side</th>
<th>A Lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung sliding</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>PLAPS</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Pulmonary edema</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>COPD</td>
<td>1</td>
<td>1</td>
<td>38</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Asthma</td>
<td>1</td>
<td>0</td>
<td>33</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>10^-6</td>
<td>0</td>
<td>10^-6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>34</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Exponent indicates No. of cases with venous thrombosis (datum without exponent means negative venous exploration).
“Triple scan”
rapid 3-view sonographic evaluation of
• Heart
• Lungs
• Inferior vena cava
Rapid evaluation by lung-cardiac-inferior vena cava (LCI) integrated ultrasound for differentiating heart failure from pulmonary disease as the cause of acute dyspnea in the emergency setting

Katsuya Kajimoto¹*, Keiko Madeen¹, Tomoko Nakayama², Hiroki Tsudo³, Tadahide Kuroda¹ and Takashi Abe³
Rapid evaluation by lung-cardiac-inferior vena cava (LCI) integrated ultrasound for differentiating heart failure from pulmonary disease as the cause of acute dyspnea in the emergency setting.

Figure 1 Algorithm for the diagnosis of acute dyspnea based on the lung-cardiac-inferior vena cava integrated ultrasound. LVEF = left ventricular ejection fraction; MR = mitral regurgitation; TR = tricuspid regurgitation; IVC = inferior vena cava.
Focused Ultrasound Study

Goal-directed

Systematic
Focused Ultrasound Study

Specific clinical setting

Differential diagnosis

« Pre-test probability »
Main Causes of Acute Respiratory Failure
Differential Diagnosis

Cardiac etiologies
- **Left heart failure**
  - Systolic / Diastolic
  - Valvular problem
  - Fluid overload
- **Right heart failure**
  - Systolic / Diastolic
  - Valvular problem
  - Fluid overload
  - Pulmonary emboli
- Tamponade

Thoracic etiologies
- **Lungs**
  - Pneumothorax
  - Interstitial syndromes
    - Pulmonary edema
    - ARDS
    - Interstitial diseases
  - Pneumonia
  - Asthma / Decompensation of chronic disease

- **Pleura**
  - Pleural effusion
    - Hydrothorax
    - Hemothorax
    - Empyema

Other etiologies
- Metabolic acidosis
- Anxiety / Agitation
- Salicylate intoxication
- Sepsis
- Etc…
Specific ultrasound signs are sought to answer specific clinical questions.
Findings from the focused ultrasound examination have to be correctly integrated in clinical decision making.
Focused Ultrasound Study for Respiratory Distress

Main systems to be assessed:

Cardiac
Thoracic (lung + pleura)
Vascular

In which order should the exam proceed??
In which order should the exam proceed??

Undifferentiated shock $\rightarrow$ start by the heart

Undifferentiated respiratory distress $\rightarrow$ start by the thorax
Plan

1-) Introduction

2-) Assessment of the thoracic space

3-) Assessment of the cardiac and vascular systems

4-) Summary

5-) Conclusion
Rapid bedside sonographic diagnosis of various conditions

- Pneumothorax
- Interstitial syndromes
- Atelectasis, consolidation
- Pleural effusion
Sonographic examination of the lung and pleural space

**Ultrasound findings**

- Lung sliding / pneumothorax
  - Normal aeration
- Alveolar interstitial pattern
- Alveolar consolidation
- Pleural effusions
Sonographic examination of the lung and pleural space

**Ultrasound findings**

- Lung sliding / pneumothorax
  - Normal aeration
- Alveolar interstitial pattern
- Alveolar consolidation
- Pleural effusions
Sequential scan lines allow examiner to form a 3-D image based on multiple 2-D images.
Sonographic examination of the lung
Scanning technique

**Imaging controls**

- Adjust gain to a low-moderate level
  → *if too high, pleural line will not be well visualized*

- Depth setting should be low (4.5-7.5 cm)
Sonographic examination of the lung
Basic terminology

“Sliding lung” Represents the movement of visceral against parietal pleura

Sonographic examination of the lung

Pneumothorax

• Look for the absence of lung sliding
Sonographic examination of the lung
Assess for lung sliding

Normal lung

Pneumothorax

Lung sliding present

Lung sliding absent
Sonographic examination of the lung

Pneumothorax

• Look for the absence of lung sliding

However, absence of lung sliding only indicates the possibility of pneumothorax

Other causes of absent lung sliding:
  • Apnea
  • Mainstem intubation
  • Mainstem occlusion
  • Very severe parenchymal lung disease
  • Pleural adhesions
Sonographic examination of the lung

Pneumothorax

• Lung sliding means no pneumothorax with 100% certainty but only at the site of the transducer

• Absence of lung sliding means possible pneumothorax
Sonographic examination of the lung

**Ultrasound findings**

- Lung sliding / pneumothorax
  - Normal aeration
- Alveolar interstitial pattern
- Alveolar consolidation
  - Pleural effusion
Sonographic examination of the lung
Normal aeration

A-lines

- Horizontal line that arise from the pleural line
- Localized at the exact distance separating the probe from the pleural line.
- Can be repeated multiple times
- Represents a reverberation of the pleural line
Sonographic examination of the lung
Normal aeration

A-lines

Clinical utility of A-lines

- The presence of A-line pattern with sliding lung is a normal aeration pattern
- The presence of A-line pattern without sliding lung indicates the possibility of pneumothorax
Sonographic examination of the lung and pleural space

**Ultrasound findings**

- Lung sliding / pneumothorax
  - Normal aeration
- Alveolar interstitial pattern
- Alveolar consolidation
- Pleural effusions
Sonographic examination of the lung
Alveolar interstitial pattern

**B-lines** («lung rockets », « comet tail artifact »)

- Long, vertical, hyperechoic, ray-like lines that originate at the pleural interface.
- Extend to the bottom of the screen
- Move with sliding lung
- Efface A-lines
- A few B lines may be normally found in the lower lateral thorax (*in up to 27% of patients*)
Sonographic examination of the lung
Alveolar interstitial pattern

**B-lines** («lung rockets», «comet tail artifact»)
Sonographic examination of the lung
Alveolar interstitial pattern

**B-lines** («lung rockets », « comet tail artifact »)

---

### Clinical utility of B-lines

- The presence of B-lines is strongly associated with findings of alveolar **interstitial pattern** on chest CT
- Generalized B-lines indicate a « wet » lung: CHF, ARDS, ILD
- Useful for immediate evaluation of respiratory failure and to clarify ambiguous CXR
- B-lines excludes pneumothorax

---

Pulmonary edema

ARDS
To be diagnostic of pulmonary edema (or other interstitial lung pathologies), the B-lines need to be present bilaterally in various areas of the chest.
Sonographic examination of the lung
Alveolar interstitial pattern

To be diagnostic of pulmonary edema (or other interstitial lung pathologies), the B-lines need to be present bilaterally in various areas of the chest. The more severe the interstitial pathology, the more B-lines will be present.
Sonographic examination of the lung and pleural space

**Ultrasound findings**

- Lung sliding / pneumothorax
  - Normal aeration
- Alveolar interstitial pattern
  - Alveolar consolidation
- Pleural effusions
Sonographic examination of the lung
Alveolar consolidation

- Airless lung appears with tissue density
- Consolidated lung looks like liver (« sonographic hepatization »)
- The findings of alveolar consolidation is purely descriptive; it does not imply a specific diagnosis such as pneumonia.
Sonographic examination of the lung
Alveolar consolidation

• Occurs with **standard pneumonia** or **other alveolar filling process**.

• Also occurs **with atelectasis** from any cause:
  - *Compressive* (pleural effusion) or
  - *Resorptive* (bronchial block)

LLL pneumonia (radiology view)

Right pleural effusion (radiology view)
Sonographic examination of the lung
Alveolar consolidation

- Sonographic *air bronchograms*:
  - indicate whether the bronchus is open
  - appear as punctate echogenic foci
Sonographic examination of the lung and pleural space

**Ultrasound findings**

- Lung sliding / pneumothorax
  - Normal aeration
- Alveolar interstitial pattern
- Alveolar consolidation
  - Pleural effusions
Sonographic examination of the lung

Pleural effusion

Right pleural effusion
(radiology view)
Assessment of the pleural space for effusion
Ultrasonographic diagnosis

• The sonographic appearance of a pleural effusion will depend on its cause, nature and chronicity.

Simple vs Complex
Assessment of the pleural space for effusion
Ultrasonographic diagnosis

Simple effusion

- Typically are anechoic (echo-free)

Variable etiologies
- Fluid overload
- Heart failure
- Parapneumonic
- Hepatic hydrothorax
- Hypoalbuminemia
Assessment of the pleural space for effusion

Ultrasonographic diagnosis

Complex effusion

These effusions may be « echogenic » because of proteinaceous or highly cellular material in the exudate

ex: blood, pus, fibrin,…
Assessment of the pleural space for effusion
Ultrasonographic diagnosis
Complex effusion with septations
American College of Chest Physicians/
La Société de Réanimation de Langue Française Statement on Competence in Critical Care Ultrasonography*

Paul H. Mayo, MD; Yannick Beaulieu, MD; Peter Doelken, MD;
David Feller-Kopman, MD; Christopher Harrod, MS; Adolfo Kaplan, MD;
John Oropello, MD; Antoine Vieillard-Baron, MD; Olivier Axler, MD;
Daniel Lichtenstein, MD; Eric Maury, MD; Michel Slama, MD;
and Philippe Vignon, MD
ACCP / SRLF competency statement on critical care ultrasonography

GCCU

Pleural ultrasonography
Lung ultrasonography
Abdominal ultrasonography
Vascular ultrasonography: guidance of vascular access
Vascular ultrasonography: diagnosis of venous thrombosis
Sonographic examination of the lung

Giovanni Volpicelli
Mahmoud Elbarbary
Michael Blaivas
Daniel A. Lichtenstein
Gebhard Mathis
Andrew W. Kirkpatrick
Lawrence Melniker
Luna Gargani
Vicki E. Noble
Gabriele Via
Anthony Dean
James W. Tsung
Gino Soldati
Roberto Copetti
Belaid Bouhemad
Angelika Reissig
Eustachio Agricola
Jean-Jacques Rouby
Charlotte Arbelot
Andrew Litepllo
Ashot Sargsyan
Fernando Silva
Richard Hoppmann
Raoul Breitkreutz
Armin Seibel
Luca Neri
Enrico Storti
Tomislav Petrovic
International Liaison Committee on Lung Ultrasound (ILC-LUS) for the International Consensus Conference on Lung Ultrasound (ICC-LUS)

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

A Practical Approach to Respiratory Distress

Plan

1-) Introduction

2-) Assessment of the thoracic space

3-) Assessment of the cardiac and vascular systems

4-) Summary

5-) Conclusion
FOcused Cardiac Ultrasound Study

Systematic assessment of

- LV size and function
- RV size and function
- Pericardial space

fluid $\rightarrow$ tamponade

- Inferior vena cava
Venous Focused Compression Technique

Assessment of vessel collapsibility with probe pressure

Presence of heterogenous, irregular echo-dense material (thrombus) in the lumen of the vein

Not fully collapsible

Normal vein

Fully collapsible
A Practical Approach to Respiratory Distress

Plan

1-) Introduction

2-) Assessment of the thoracic space

3-) Assessment of the cardiac and vascular systems

4-) Summary

5-) Conclusion
Summary
Assessment of the thoracic space

1-) Is there a pneumothorax?

Lung sliding

- Present
  - No pneumothorax

- Absent
  - Suspect pneumothorax

** Keep in mind the false +
2-) Is there an interstitial syndrome?

Summary
Assessment of the thoracic space

Absence                                  Presence
Focal                Diffuse

Assess LV function
Cardiogenic         Non-cardiogenic

- Normal
- Local disease

B lines
Summary
Assessment of the thoracic space

3-) Is there a pulmonary consolidation?

- Yes
  - Differential diagnosis
- No
Summary
Assessment of the thoracic space

4-) Is there a pleural effusion?

Yes                                   No

Simple       Complex

Differential diagnosis
Summary

5-) **Focused cardiac examination**

6-) **Focused vascular compression study**

7-) **If the complete ultrasound examination is normal, assess for non cardio-pulmonary causes of respiratory distress**

- Metabolic acidosis
- Salicylate intoxication
- Early sepsis
- Neurologic cause
A Practical Approach to Respiratory Distress

Plan

1-) Introduction

2-) Assessment of the thoracic space

3-) Assessment of the cardiac and vascular systems

4-) Summary

5-) Conclusion
A systematic, algorithmic approach simplifying the use of ultrasound could lead to better and more efficient management of undifferentiated respiratory distress.

Such an approach integrates concepts from the BLUE protocol, the focused cardiac exam, the E-FAST exam, and the focused compression technique for vessels.