Focused Lung Ultrasound (FLUS): Comprehensive Educational Instructions for Novice Practitioners

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1. Basic Ultrasound Physics for Lung Imaging

Fundamentals of Ultrasound Physics

Ultrasound imaging works by transmitting high-frequency sound waves (typically 2–15 MHz) from a probe into the body. These waves encounter tissues of varying density and are reflected back to the probe, which converts them into images. The strength and timing of the returning echoes form the basis of the image.

Acoustic Impedance

- Acoustic impedance is a property of tissue that determines how much sound is reflected at the interface between two structures.
- Air has a **very low impedance**, while soft tissue has a **higher impedance**.
- The large difference at the **pleural surface (where air meets soft tissue)** causes most sound waves to reflect back, preventing deeper lung visualization.

Reflection and Artifact Generation

- In lung imaging, **strong reflections** from the pleura and **air-tissue interfaces** create characteristic **artifacts**, not anatomical images.
- These artifacts, such as **A-lines** and **B-lines**, are diagnostically important and represent normal and abnormal lung aeration, respectively.

Why Lungs Appear Different

- Unlike solid organs, the air-filled lung does not transmit sound well.
- This creates **reverberation artifacts** instead of direct anatomical images.

- Learners must be taught to **interpret patterns of artifacts** and motion rather than expect to see “pictures” of lungs.

Teaching Tips

- Use visual analogies (e.g., sonar in submarines).
- Demonstrate differences between scanning a water-filled balloon (good transmission) vs. an air-filled balloon (high reflection).

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2. Probe Selection and Positioning

Recommended Probes

- **Linear Probe (5–15 MHz):**
    - High-resolution, shallow depth.
    - Ideal for evaluating **pleura** and **pleural sliding**.
- **Curvilinear Probe (2–5 MHz):**
    - Wider field of view and deeper penetration.
    - Useful for assessing **pleural effusion**, **B-lines**, and **consolidations**.
- **Phased Array Probe (1–5 MHz):**
    - Compact footprint, good for **critically ill** patients.
    - Used when **space is limited** (e.g., between ribs).

Probe Handling and Orientation

- Hold like a pencil or stylus—grip should be steady but relaxed.
- Apply gel liberally to ensure good contact with the skin.
- Orient probe with marker:
    - **Cephalad** (toward the head) in **longitudinal views**.

    - **Rightward** in **transverse views**.

Scanning Positions and Landmarks

- Divide thorax into **anterior, lateral, and posterior** zones using the **anterior axillary** and **posterior axillary lines**.
- Use **rib spaces** as acoustic windows.
- Begin at **second intercostal space, midclavicular line**, for pneumothorax screening.
- Position patient **sitting or semi-recumbent** when possible for optimal imaging.

Practical Guidance

- Label zones and sides on your images to maintain consistency.
- Mark scanning zones on the patient's skin to build spatial awareness during training.

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3. Normal Lung Ultrasound Appearance

Key Anatomical Landmarks

- **Rib Shadows**: Appear as two dark vertical stripes (acoustic shadows) with a bright line (pleural line) in between.
- **Pleural Line**: A bright, horizontal echogenic line just beneath the rib shadows, representing the **interface between visceral and parietal pleura**.

Normal Artifacts

- **A-lines**: Repetitive, horizontal lines below the pleural line at regular intervals. Represent reverberation of sound in a normally aerated lung.
- **Pleural Sliding**: A shimmering or gliding motion seen at the pleural line in real time, representing lung movement during respiration.

Teaching Tips

- Show learners a “normal scan” before pathology.
- Use M-mode to demonstrate motion: pleural sliding creates a “**seashore sign**” pattern.

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4. Identifying Pleural Sliding

Definition and Importance

- **Pleural sliding** is the back-and-forth movement of the visceral pleura over the parietal pleura during breathing.
- Presence of sliding **rules out pneumothorax** at the scanned site.

How to Recognize

- Real-time B-mode: Look for shimmering or dynamic movement at the pleural line.
- M-mode: Seashore sign (granular pattern below pleural line) confirms pleural sliding.
- Absence of sliding may suggest pneumothorax, pleurodesis, or apnea.

Confirmation Techniques

- Ask patient to take a deep breath to enhance sliding.
- Switch to M-mode for visual confirmation.
- Use color Doppler (“power slide” technique) to confirm motion if unclear.

Troubleshooting

- No sliding could be due to:
    - Mainstem intubation (unilateral)
    - Pleurodesis or lung adhesion
    - Breath-holding or apnea

    - Poor probe contact or incorrect depth

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5. Recognizing B-Lines and Their Significance

What Are B-Lines?

- Vertical, hyperechoic (bright), laser-like lines originating from the pleural line and extending to the bottom of the screen.
- Move with respiration and erase A-lines.
- Also known as **comet-tail artifacts** when prominent.

How to Identify and Quantify

- Use a low-frequency probe (curvilinear or phased array).
- B-lines should be **well-defined**, **vertical**, and **move with breathing**.
- Count B-lines per intercostal space:
    - **<3 B-lines**: Normal
    - **≥3 B-lines per space**: Pathological (“lung rockets”)

Clinical Significance

- **Pulmonary edema**: Bilateral, diffuse B-lines
- **Interstitial syndrome**: Localized or patchy B-lines
- **ARDS**: Patchy or confluent B-lines with spared areas
- **Pneumonia**: B-lines may surround a consolidation
- **Normal variant**: 1–2 B-lines in dependent regions

Teaching Aid

- “Bee lines buzz in a wet lung” – a mnemonic to associate B-lines with fluid.

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6. Detecting Pneumothorax

Key Ultrasound Signs

- **Absent pleural sliding**
- **Absent B-lines**
- **Presence of A-lines**
- **Lung point**: The location where normal lung sliding meets non-sliding pleura—**100% specific** for pneumothorax.
- **Barcode sign** on M-mode (no motion)

Scanning Technique

- Use **linear or curvilinear probe** at **second intercostal space, midclavicular line**, with the patient supine.
- Scan **bilaterally** to compare findings.

Confirmatory Signs

- **Lung point**: Transition zone of sliding and no sliding.
- **M-mode barcode sign** (stratosphere sign): Horizontal lines above and below pleura, indicating absence of motion.

Clinical Pearls

- Ultrasound is **more sensitive than chest X-ray** in detecting pneumothorax.
- Rule out pneumothorax only at the **scanned area**—no sliding = suspicious, but not always diagnostic.

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7. Assessing Pleural Effusion

Ultrasound Appearance

- Anechoic (black) or hypoechoic fluid collection above diaphragm and below lung.
- May contain internal echoes (complex effusions).
- Lung may appear as a floating or compressed structure (“jellyfish sign” or “lung flapping”).

Scanning Technique

- Use **curvilinear or phased array** probe.
- Best views obtained **posteriorly or in dependent areas**.
- Patient should be **sitting up** if possible, or semi-recumbent.
- Scan just above the diaphragm in the posterior axillary line.

Quantifying Effusion

- **Small**: Sliver of fluid in costophrenic angle.
- **Moderate**: Fluid surrounds lung base.
- **Large**: Fluid fills entire posterior thorax.

Teaching Tip

- Use diaphragm as a landmark—effusion always sits **above** it.
- Introduce concept of **echogenicity** for distinguishing transudate (anechoic) from exudate (complex).

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8. Lung Consolidation Patterns

What is Consolidation?

- Replacement of air in alveoli with fluid or inflammatory material.

- Ultrasound waves can now penetrate and show solid-like lung tissue.

Ultrasound Characteristics

- **Tissue-like echotexture** (“hepatization” of the lung).
- **Air bronchograms**: Hyperechoic punctate or linear structures—air in bronchi.
    - **Dynamic** air bronchograms suggest pneumonia (air moving with breaths).
    - **Static** bronchograms may indicate atelectasis.

Types of Consolidation

- **Focal consolidation**: Pneumonia
- **Diffuse consolidation**: Severe ARDS
- **Subpleural consolidation**: Small, wedge-shaped lesions seen in COVID-19

Teaching Aids

- Show video clips of pneumonia and atelectasis.
- Use “liver lung” analogy to reinforce hepatization concept.

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9. Common Artifacts and Troubleshooting

Artifacts to Recognize

- **A-lines**: Normal reverberation pattern.
- **B-lines**: Sign of interstitial fluid.
- **Mirror artifact**: Duplication of structures below diaphragm.
- **Comet-tail**: Often used interchangeably with B-lines, though more variable.

Troubleshooting Image Quality

- **Poor contact**: Reapply gel, adjust pressure.
- **Incorrect depth**: Adjust so pleural line is 1–2 cm from top of screen.
- **Rib shadows**: Angle slightly to scan between ribs.
- **Too much gain**: Artifacts may be obscured or overemphasized.

Optimization Tips

- Start with auto-gain or default settings.
- Use shallow depth for pleural assessment.
- Move slowly and watch in real-time—lung is dynamic.

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10. Clinical Integration and Decision-Making

When to Use Lung Ultrasound

- Acute respiratory distress or hypoxia
- Unexplained chest pain
- Suspected pneumothorax or pleural effusion
- Ventilator weaning assessments
- Guiding thoracentesis

Integrating with Clinical Findings

- Combine with vital signs, auscultation, and clinical context.
- Do not rely solely on ultrasound—interpret within the full clinical picture.
- Document findings systematically.

Safety Considerations

- No known risks from diagnostic ultrasound.
- Use appropriate probe cleaning between patients.
- Ensure **infection control protocols** are followed.

Limitations

- Difficult in obese or uncooperative patients.
- Cannot fully evaluate deep lung or mediastinum.
- Operator-dependent—requires training and supervision.

Teaching Tip

- Use **SOAP** model (Subjective, Objective, Assessment, Plan) to frame ultrasound findings in clinical reasoning.
- Emphasize serial exams for dynamic conditions like ARDS or fluid overload.

Conclusion

Focused Lung Ultrasound (FLUS) is a powerful, bedside diagnostic tool. For novice practitioners, mastering FLUS begins with understanding basic physics, probe handling, artifact recognition, and safe, clinically integrated practice. With structured training and supervised scanning, learners can become confident in applying FLUS to enhance patient care.

Suggested Next Steps for Learners:

1. Practice with normal volunteers to master probe positioning.
2. Use image logbooks for feedback and skill tracking.
3. Participate in supervised scanning sessions in real clinical settings.

Clinical Pearl: *“If you see sliding, the lung is touching the chest wall—no pneumothorax there.”*