Focused Lung Ultrasound (FLUS) Training Instructions

1. Basic Ultrasound Physics for Lung Imaging

Understanding lung ultrasound requires grasping why air-filled lungs behave differently from other organs. Unlike solid organs that transmit sound waves well, healthy lungs contain air that creates a strong acoustic impedance mismatch at the pleural surface.

Key Physics Principles:

- **Acoustic impedance**: The resistance to sound wave transmission. Air has very low acoustic impedance compared to soft tissue
- **Total reflection**: When sound waves hit the pleural surface, most are reflected back rather than penetrating the lung
- **Reverberation artifacts**: Multiple reflections between the probe and pleural surface create the characteristic "A-lines"
- **Frequency selection**: Higher frequencies (5-10 MHz) provide better resolution for superficial structures like the pleura

Clinical Pearl: The absence of normal lung artifacts often indicates pathology. When you see clear images "through" the lung, this suggests fluid or consolidation has replaced the air.

2. Probe Selection and Positioning

Probe Selection:

- **Linear probe (5-10 MHz)**: First choice for lung ultrasound
    - Provides excellent near-field resolution
    - Wide footprint allows visualization of pleural movement
    - Best for detecting pneumothorax and pleural abnormalities
- **Curved probe (2-5 MHz)**: Secondary option
    - Better penetration for deeper pathology
    - Useful for large pleural effusions
    - Narrower field of view may miss subtle findings

Optimal Positioning Technique:

1. **Probe orientation**: Place longitudinally (sagittally) along intercostal spaces
2. **Angle adjustment**: Perpendicular to chest wall initially, then slight angulation toward the heart
3. **Pressure**: Light contact only - excessive pressure can compress intercostal spaces
4. **Stabilization**: Rest your hand holding the probe against the patient's chest for stability

Standard Scanning Positions:

- **Anterior**: 2nd-3rd intercostal space, mid-clavicular line
- **Lateral**: 4th-5th intercostal space, anterior axillary line
- **Posterior**: 8th-9th intercostal space, posterior axillary line (patient sitting)

3. Normal Lung Ultrasound Appearance

The Bat Sign: The first landmark you should identify

- Two adjacent ribs appear as hyperechoic (bright) curved lines
- The intercostal space between them represents your "acoustic window"
- The pleural line appears as a bright horizontal line just beneath the ribs

Pleural Line Characteristics:

- Located 0.5-1 cm below the rib shadows
- Smooth, hyperechoic, horizontal line
- Represents the parietal-visceral pleural interface
- Should be visible across the entire probe width

A-Lines (Normal Pattern):

- Horizontal hyperechoic lines parallel to and below the pleural line
- Equally spaced intervals (mirror the pleural line)
- Created by reverberation artifacts between probe and pleural surface
- Indicate normal air-filled lung beneath

Clinical Significance: A-lines with pleural sliding represent normal lung. The presence of A-lines alone without pleural sliding may indicate pneumothorax.

4. Identifying Pleural Sliding

What is Pleural Sliding? Pleural sliding represents the rhythmic movement of visceral pleura against parietal pleura during respiration. It appears as a shimmering or sparkling motion along the pleural line during inspiration.

Visual Assessment:

- **Real-time observation**: Watch the pleural line during patient breathing
- **Subtle movement**: May appear as slight twinkling or gliding motion
- **Synchronous with breathing**: Movement should correspond to respiratory cycle
- **Bilateral comparison**: Always compare both sides

M-Mode Confirmation (Seashore Sign):

1. Place M-mode cursor perpendicular to pleural line
2. **Normal pattern**:

    - Above pleural line: horizontal parallel lines (stationary chest wall)
    - Below pleural line: granular "sandy" pattern (lung movement)
3. **Absent sliding**: Parallel horizontal lines both above and below pleural line

Clinical Pearl: Pleural sliding can be absent in several conditions:

- Pneumothorax (most concerning)
- Severe COPD with bullae
- Pleural adhesions
- Apnea or breath-holding

5. Recognizing B-Lines and Their Significance

B-Line Definition: B-lines are laser-like vertical hyperechoic artifacts that extend from the pleural line to the bottom of the screen without fading.

Identification Criteria (Must meet ALL):

1. **Origin**: Arise from pleural line
2. **Direction**: Vertical orientation
3. **Movement**: Move synchronously with pleural sliding
4. **Persistence**: Extend to bottom of screen without fading
5. **Erasure**: Erase A-lines when present

Quantification:

- **Normal**: 0-2 B-lines per intercostal space
- **Mild increase**: 3-5 B-lines per space
- **Severe increase**: >5 B-lines or confluent B-lines

Clinical Significance:

- **Pulmonary edema**: Bilateral, symmetric B-lines
- **Pneumonia**: Focal B-lines with consolidation
- **Pulmonary fibrosis**: Bilateral lower lobe predominance
- **ARDS**: Bilateral, heterogeneous distribution

Important Distinction: B-lines represent increased lung water or decreased aeration. They are pathological when increased in number or bilateral.

6. Detecting Pneumothorax

Primary Signs:

- **Absent pleural sliding**: No movement along pleural line
- **Absent B-lines**: No vertical artifacts present
- **A-lines only**: Persistent horizontal reverberation artifacts

Confirmatory Tests:

M-Mode Assessment (Barcode/Stratosphere Sign):

- Horizontal parallel lines both above and below pleural line
- Loss of normal "seashore" pattern
- Indicates absence of lung movement

Lung Point Technique:

1. **Definition**: Boundary between pneumothorax and normal lung
2. **Identification**: Area where pleural sliding intermittently appears and disappears
3. **Clinical value**: Confirms pneumothorax diagnosis and estimates size
4. **Location significance**: More lateral lung points suggest larger pneumothorax

Scanning Strategy for Pneumothorax:

1. Start at most anterior, superior chest position
2. Systematic scanning from anterior to lateral
3. Look for transition from absent to present pleural sliding
4. Document lung point location if found

Clinical Pearl: A single anterior intercostal space showing absent pleural sliding without B-lines strongly suggests pneumothorax, especially in high-risk patients.

7. Assessing Pleural Effusion

Ultrasound Appearance:

- **Anechoic (black) space**: Between chest wall and lung
- **Dependent location**: Fluid collects in gravity-dependent areas
- **Dynamic movement**: Fluid shifts with patient positioning and breathing

Scanning Technique:

1. **Patient positioning**: Sitting upright or lateral decubitus
2. **Probe location**: Posterior axillary line, low intercostal spaces
3. **Probe orientation**: Initially longitudinal, then transverse for confirmation
4. **Depth adjustment**: Ensure adequate penetration to visualize diaphragm

Quantification Methods:

- **Small**: <2 cm separation between lung and chest wall
- **Moderate**: 2-5 cm separation
- **Large**: >5 cm separation or complete lung compression

Additional Features to Assess:

- **Complex vs. simple**: Presence of septations, echogenic material

- **Loculated vs. free-flowing**: Response to patient positioning
- **Associated consolidation**: Lung abnormalities adjacent to effusion

Clinical Considerations:

- Small effusions may only be visible posteriorly
- Always correlate with clinical context
- Consider diagnostic thoracentesis for complex effusions

8. Lung Consolidation Patterns

Definition: Consolidation represents replacement of air in alveoli with fluid, blood, pus, or cells, creating tissue-like ultrasound appearance.

Ultrasound Characteristics:

- **Hepatization**: Lung tissue appears similar to liver (hypoechoic with internal echoes)
- **Air bronchograms**: Hyperechoic branching structures within consolidation
- **Irregular borders**: Unlike effusion, consolidation has irregular, shaggy margins
- **Associated B-lines**: Often present at consolidation periphery

Types of Air Bronchograms:

- **Static**: Non-moving air in bronchi (concerning for obstruction)
- **Dynamic**: Moving air bronchograms with breathing (patent airways)
- **Fluid bronchograms**: Fluid-filled bronchi appearing as anechoic tubes

Scanning Approach:

1. **Systematic survey**: Multiple intercostal spaces over affected area
2. **Depth assessment**: Determine extent toward hilum
3. **Border definition**: Map consolidation boundaries
4. **Associated findings**: Look for effusion, pneumothorax

Clinical Patterns:

- **Pneumonia**: Focal consolidation with dynamic air bronchograms
- **Pulmonary edema**: Bilateral consolidation with B-lines
- **Atelectasis**: Consolidation without air bronchograms
- **Pulmonary embolism**: Wedge-shaped peripheral consolidation

9. Common Artifacts and Troubleshooting

Artifact Recognition and Management:

Z-Lines (False B-Lines):

- **Appearance**: Vertical artifacts that fade before reaching screen bottom

- **Cause**: Subcutaneous emphysema, chest wall edema
- **Solution**: Reduce gain, change probe position
- **Clinical significance**: Not pathological lung findings

Rib Shadowing:

- **Problem**: Acoustic shadows from ribs obscure pleural line
- **Solution**: Adjust probe angle, move to different intercostal space
- **Prevention**: Ensure probe is positioned between ribs, not over them

Gain Issues:

- **Too high**: Everything appears bright, artifacts obscure real pathology
- **Too low**: Miss subtle pleural sliding, B-lines appear faint
- **Optimization**: Adjust so pleural line is clearly visible but not oversaturated

Patient-Related Challenges:

- **Obesity**: Use lower frequency probe, increase gain, apply more gel
- **Chest wall deformity**: Multiple probe positions, use gel standoff
- **Inability to position**: Adapt scanning positions to patient limitations

Technical Troubleshooting:

1. **No image**: Check probe connection, gel application, power settings
2. **Poor penetration**: Lower frequency, increase power, optimize gain
3. **Motion artifacts**: Ensure probe stability, coach patient breathing

10. Clinical Integration and Decision-Making

The FALLS Protocol (Fluid Administration Limited by Lung Sonography):

- **Concept**: Use lung ultrasound to guide fluid therapy
- **B-line monitoring**: Increasing B-lines suggest fluid overload
- **Clinical application**: Stop fluid when B-lines appear or increase significantly

BLUE Protocol (Bedside Lung Ultrasound in Emergency):

- **A-profile**: A-lines + pleural sliding = normal or asthma
- **B-profile**: B-lines bilaterally = pulmonary edema
- **C-profile**: Consolidation = pneumonia
- **A-profile + absent sliding = pneumothorax

Clinical Decision Points:

Dyspnea Evaluation:

1. **Bilateral B-lines**: Consider heart failure, pulmonary edema
2. **Unilateral consolidation**: Pneumonia likely

3. **Absent pleural sliding**: Rule out pneumothorax
4. **Pleural effusion**: Consider thoracentesis if large

Shock Assessment:

- **Hypovolemic**: Minimal B-lines, small heart chambers
- **Cardiogenic**: Bilateral B-lines, enlarged heart
- **Septic**: Variable findings, consider lung source

Integration with Clinical Assessment:

- Always correlate ultrasound findings with clinical presentation
- Use lung ultrasound as part of comprehensive assessment, not in isolation
- Document findings clearly for clinical team communication
- Recognize limitations and when to seek expert consultation

Quality Assurance Principles:

1. **Adequate image acquisition**: Ensure optimal probe positioning and settings
2. **Systematic approach**: Follow standardized scanning protocols
3. **Pattern recognition**: Focus on characteristic findings rather than subtle variations
4. **Clinical correlation**: Always integrate findings with patient presentation
5. **Documentation**: Record findings clearly with relevant images when possible

Safety Considerations:

- Lung ultrasound is generally safe with no contraindications
- Avoid excessive pressure that might cause patient discomfort
- Maintain infection control standards with appropriate probe cleaning
- Recognize when findings require immediate clinical action (tension pneumothorax)

Continuing Education:

- Regular practice maintains skill proficiency
- Seek feedback from experienced practitioners
- Participate in quality improvement initiatives
- Stay updated with evolving evidence and guidelines

These instructions provide a comprehensive foundation for focused lung ultrasound training. Practical hands-on experience under expert supervision remains essential for developing competency in this important diagnostic skill.