

Lung Ultrasound: Breaking Free from Artifact Labels and Misnomers

Running Title: *A Revision Toward a New Era in Lung Ultrasound Interpretation*

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Abstract

Background

Lung ultrasound (LU) has now become an indispensable diagnostic tool, fulfilling his prediction. However, outdated concepts and terminologies in LU interpretation require reevaluation to align with current clinical knowledge.

Aim of Study

The study aims to modernize lung ultrasound (LU) interpretation by transitioning from artifact-based terminologies, such as A-lines and B-lines, to nomenclature that emphasizes anatomical and clinical significance. This approach seeks to enhance diagnostic precision and utility in critical care and respiratory medicine.

Method

After CT examination a review and reinterpretation of LU findings were performed, integrating insights from over 600 patient ultrasound examinations. The study redefined common terminologies like A-lines, B-lines, and C-lines based on their anatomical origins and clinical relevance. A novel diagnostic framework—Merlin's space, including the Healthy and Sick Bat Signs—was introduced to differentiate normal from pathological lung conditions.

Results

- **A-lines** were redefined as horizontal hyperechoic lines representing air-tissue interfaces, observed in both healthy lungs and pathological states (e.g., abscesses, COPD, asthma, pulmonary embolism, bronchiectasis hydropneumothorax).
- **B-lines** were interpreted as vertical streaks indicating interstitial fluid, with the number reflecting the severity of conditions like pulmonary edema and inflammation. Advanced cases exhibited a "waterfall sign."
- **C-lines** were clarified as pleural irregularities rather than artifacts, indicative of structural changes such as fibrosis or chronic inflammation.
- **Merlin's space** was systematically evaluated through its components: the twinkling white area, grey-in-black zone, and rib shadows, enabling rapid differentiation between healthy (Healthy Bat Sign) and diseased states (Sick Bat Sign)

Conclusions

This study advocates for a paradigm shift in LU interpretation, focusing on anatomical and clinical findings rather than artifact-based descriptions. By adopting descriptive and pathology-oriented nomenclature, clinicians can improve diagnostic accuracy and make timely, informed decisions. The proposed framework—incorporating the Healthy and Sick Bat Signs—offers a practical, radiation-sparing alternative to traditional imaging methods, aligning LU practice with modern medical standards. This distinct approach to pulmonary ultrasound interpretation draws upon the groundbreaking work of Prof. Daniel Lichtenstein and the efforts of all who have championed the value of this examination. While this paradigm shift may not be immediately embraced, the article trusts in the ethical understanding of its audience and draws inspiration from the wisdom of Charles Sidney Burwell:

“Half of what we are going to teach you is wrong, and half of it is right. Our problem is that we don't know which half is which.”

Keywords: lung ultrasound; artifacts; healthy bat sign; sick bat sign; twinkling white area

Introduction

In 2009, Daniel Lichtenstein highlighted that it typically takes 15–20 years for new medical concepts to overcome established opinions and achieve widespread acceptance. Today, lung ultrasound (LU) has indeed become an indispensable diagnostic tool, confirming Lichtenstein's prediction [1]. However, as more than two decades have passed, some concepts and terminologies in LU interpretation have become outdated, necessitating a critical reevaluation to align with current knowledge and practices.

Method:

After CT examination of the patients, a review and reinterpretation of LU findings were performed, integrating insights from over 600 patient ultrasound examinations. The study redefined common terminologies like A-lines, B-lines, and C-lines based on their anatomical origins and clinical relevance. These ultrasound examinations are performed by handheld Clarius scan, mode – lung. A novel diagnostic framework—Merlin's space, including the Healthy and Sick Bat Signs—was introduced to differentiate normal from pathological lung conditions.

Results

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- **C-lines** were clarified as pleural irregularities rather than artifacts, indicative of structural changes such as fibrosis or chronic inflammation.
- **Merlin's space** was systematically evaluated through its components: the twinkling white area, grey-in-black zone, and rib shadows, enabling rapid differentiation between healthy (Healthy Bat Sign) and diseased states (Sick Bat Sign).

- The A-line and B-line profiles represent patterns associated with specific clinical scenarios, but other diagnostic possibilities should also be explored.
- We think that A, A' -profile and B, B'-profile continues to be useful definition in practice.

Discussion:

Artifacts vs. Anatomical Reality

An artifact in medical imaging is defined as a feature that does not correspond to the physical properties of the subject being imaged. While this concept has been historically applied to lung ultrasound findings like A-lines and B-lines [2], such classifications often fail to capture the clinical and anatomical realities these patterns represent.

The Problem with Artifact Labels:

Labeling findings as artifacts focuses on the technical processes behind their creation rather than their clinical or anatomical significance.

This approach risks overshadowing the diagnostic value of LU patterns, particularly when these patterns directly reflect underlying pathology.

Reevaluating Lung Ultrasound Nomenclature

A-Lines:

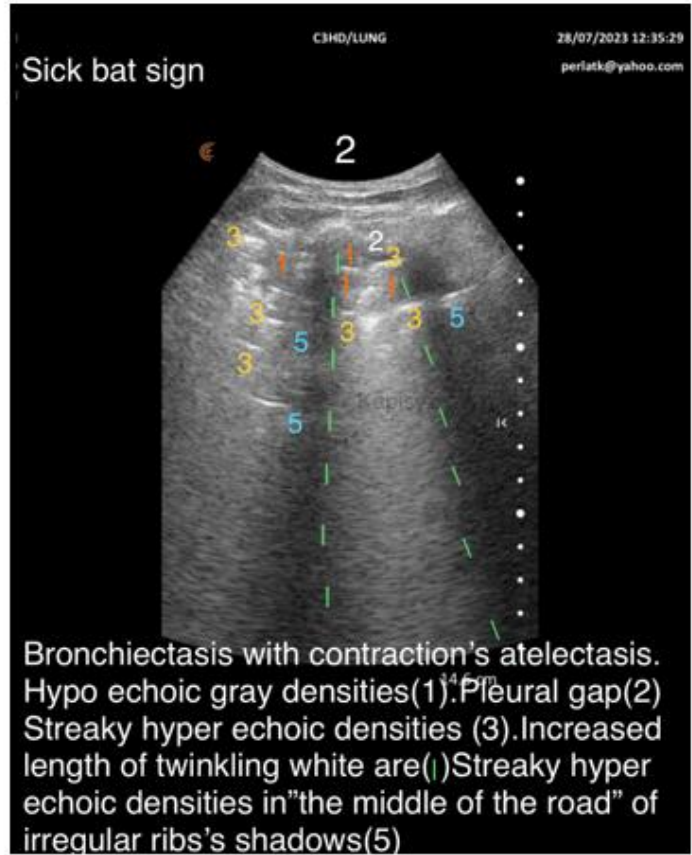
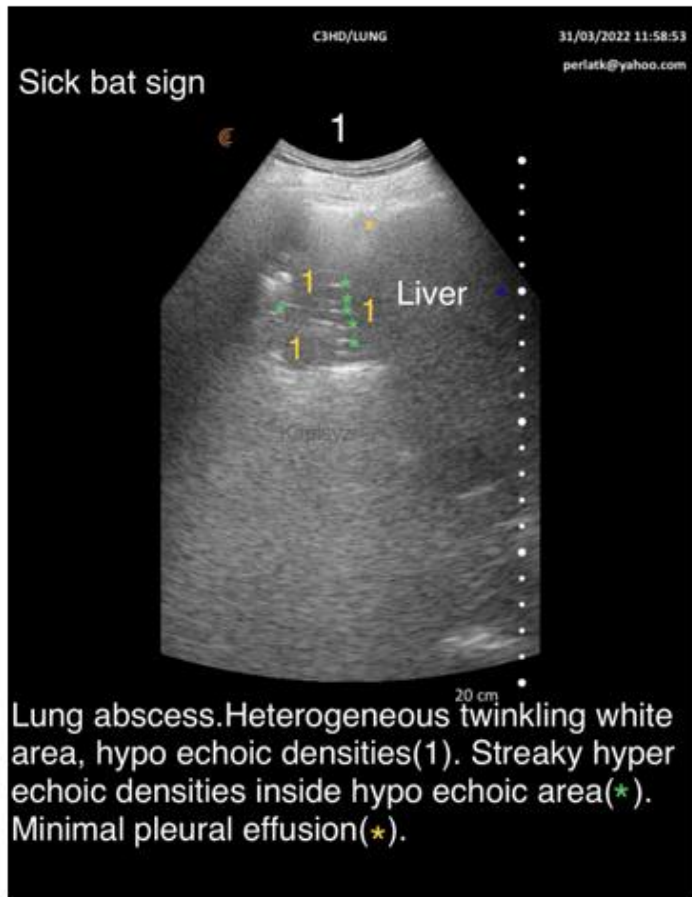
Traditionally considered an artifact, [3,4,5,6,7,8,9,10,11,12] the A-lines are horizontal streaky hyper echoic densities that occur equidistant from the pleural lines due to the interface between air and tissue(pleura). While often seen in healthy lung aeration, horizontal streaky hyper echoic density (not A- profile) also appear in pathological conditions such as:

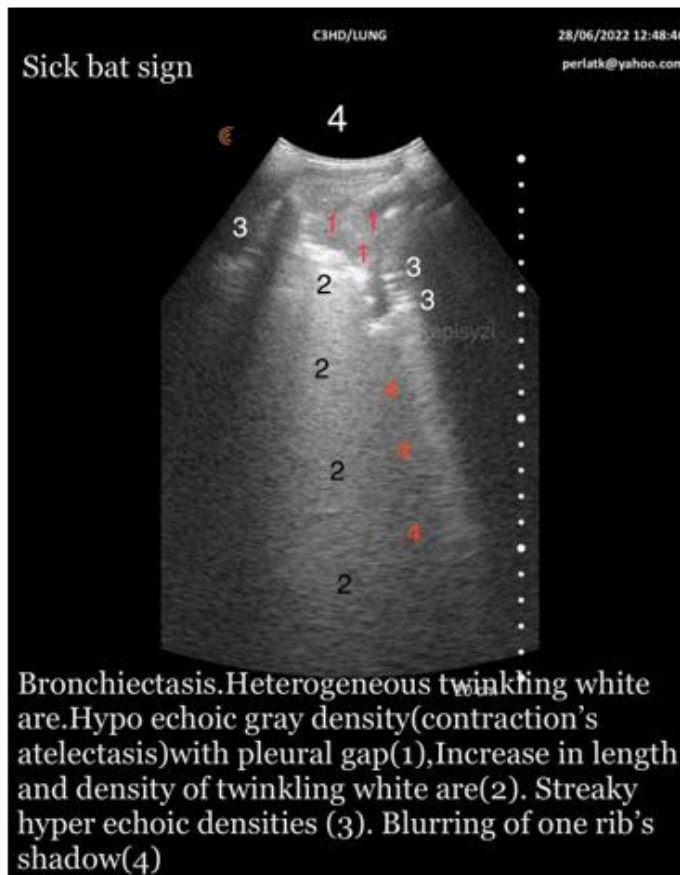
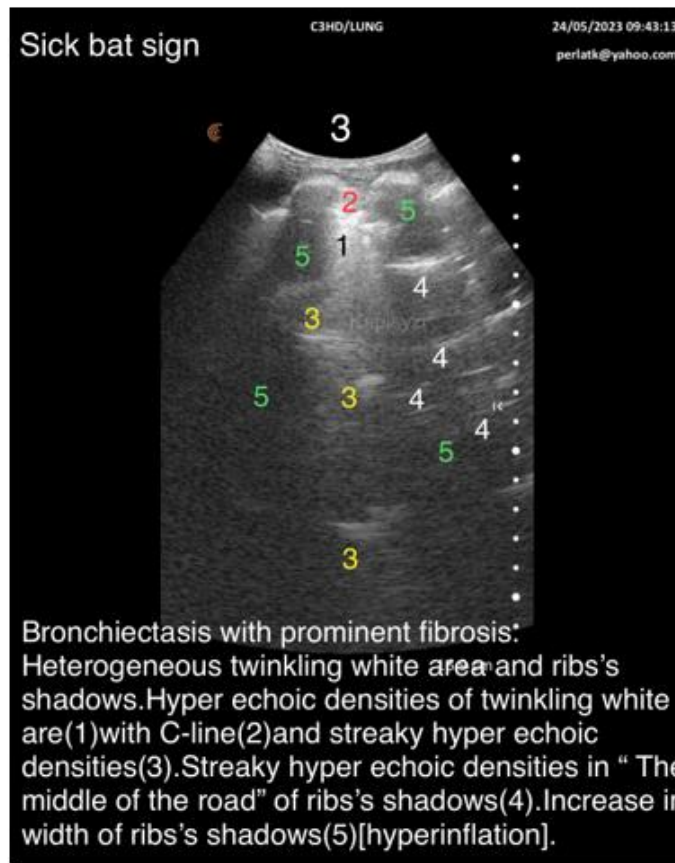
Lung abscesses

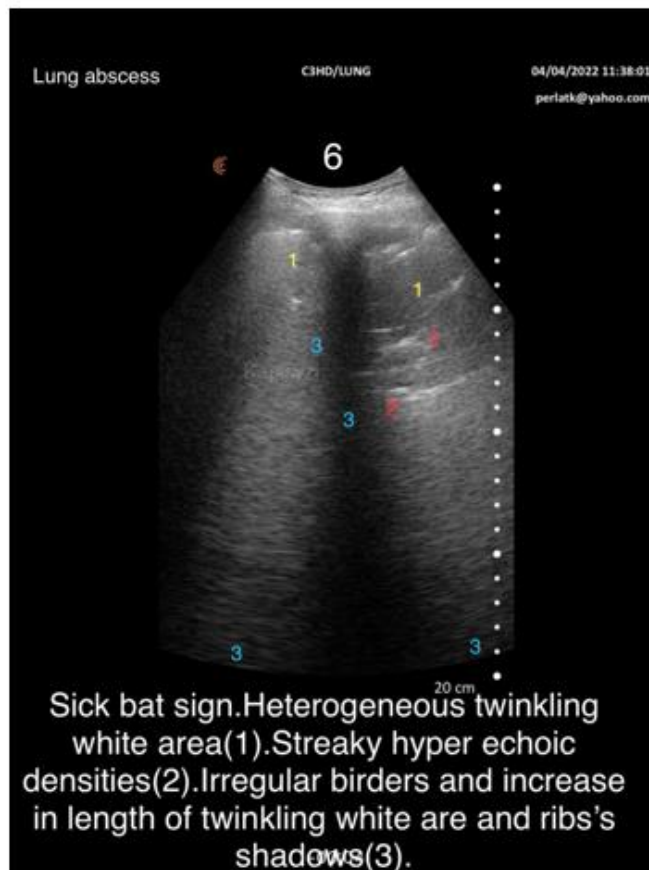
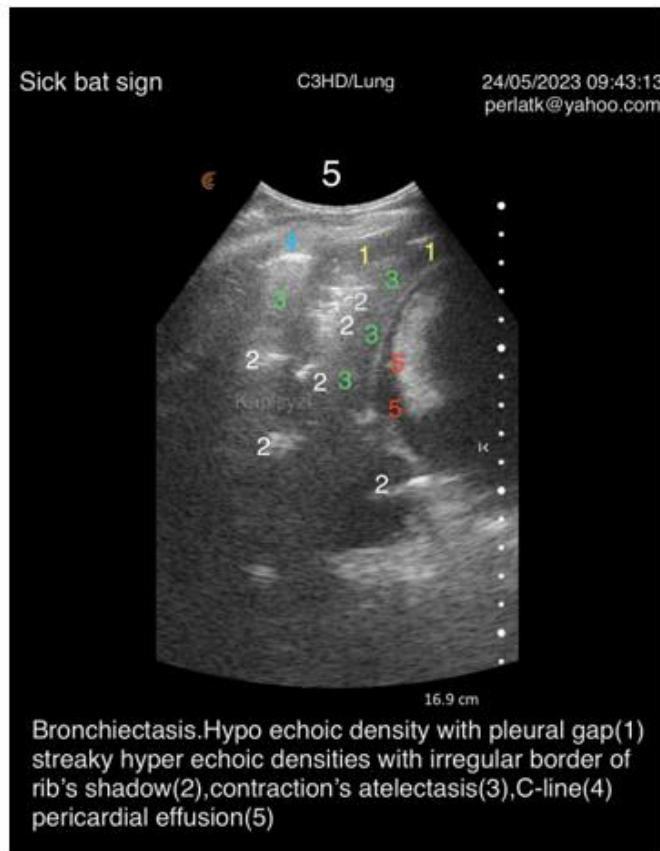
Hydropneumothorax

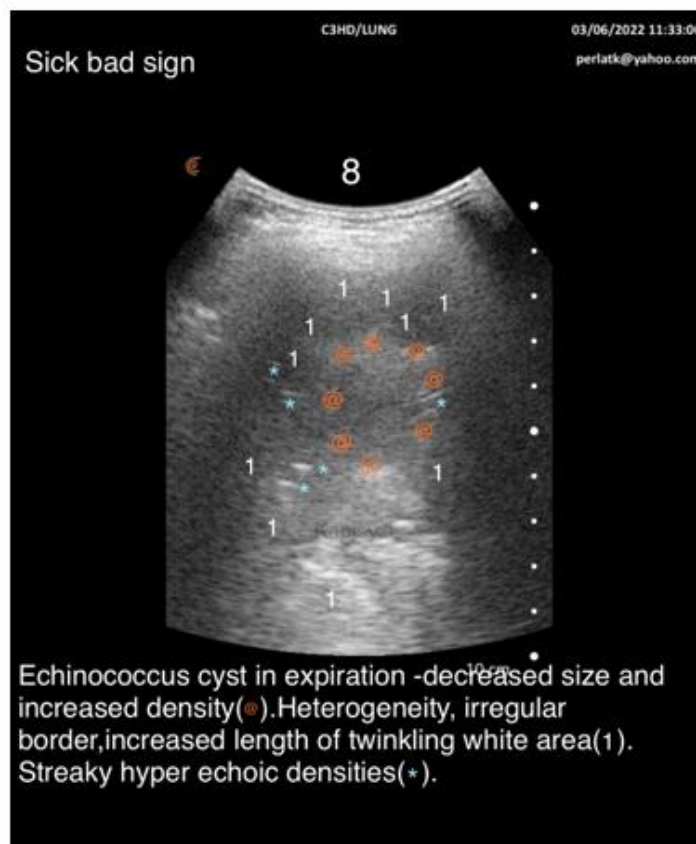
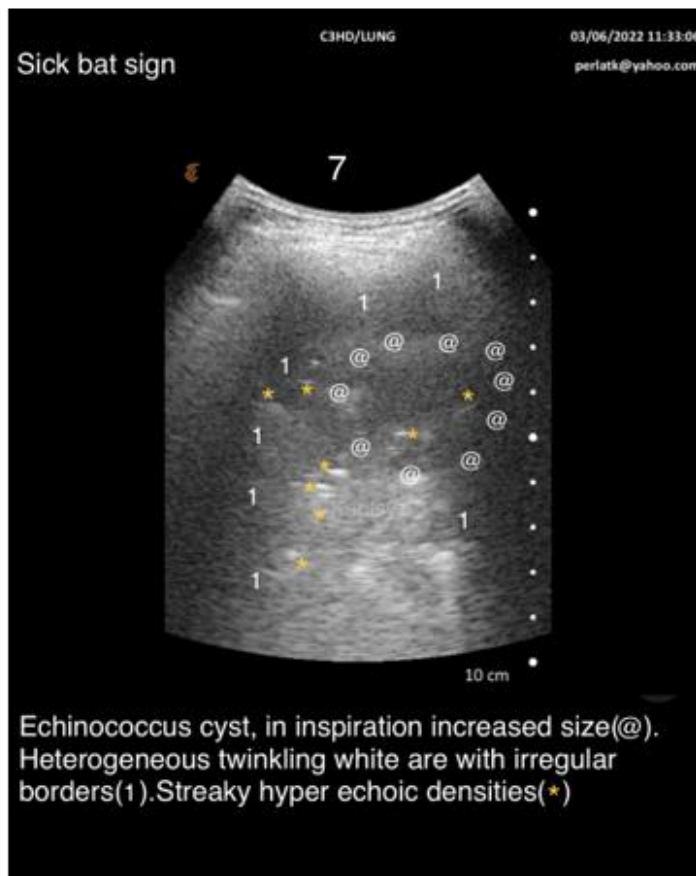
Infected bullae

And echinococcus cyst. [Figure 1,2,3,4,5,6,7,8]









Rather than dismissing A-lines as artifacts, they should be understood as anatomic reflections of the air-tissue interface. This distinction underscores their diagnostic significance. (Not rarely, horizontal streaky hyper-echoic densities simulate A-line, or A-line does not repeat itself in the depth of the twinkling white zone)

B-Lines:

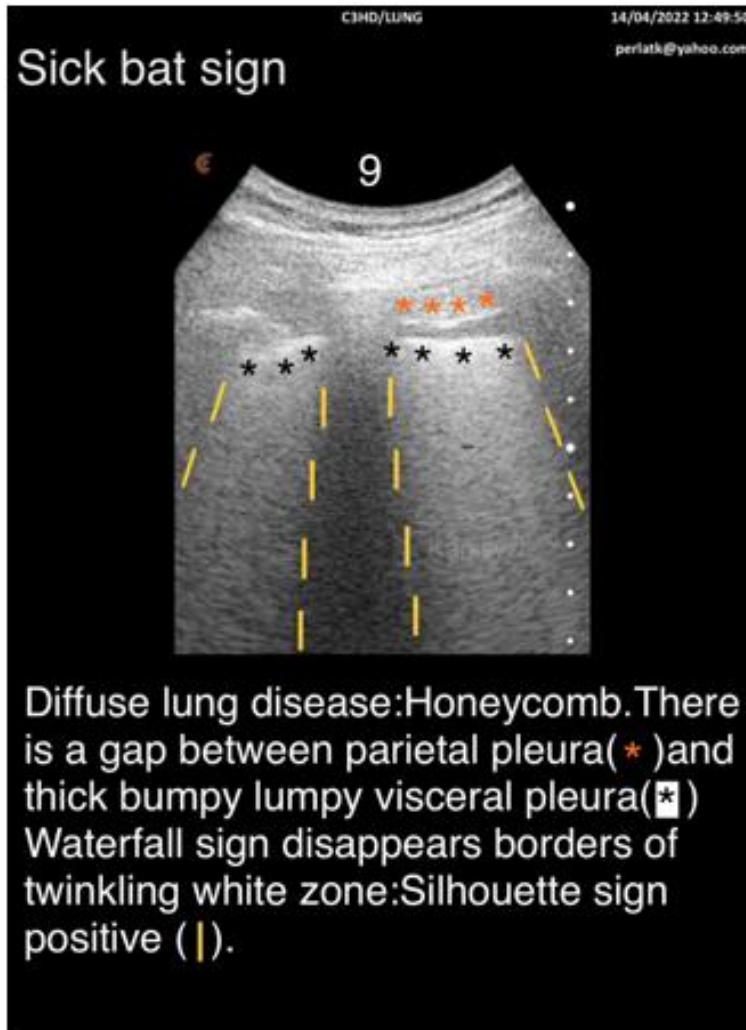
B-lines are vertical, hyper-echoic streaks extending from the pleura up to the end of the screen and have traditionally been labeled as artifacts [13]. However, they are caused by tissue impedance mismatches due to interstitial fluid, such as in:

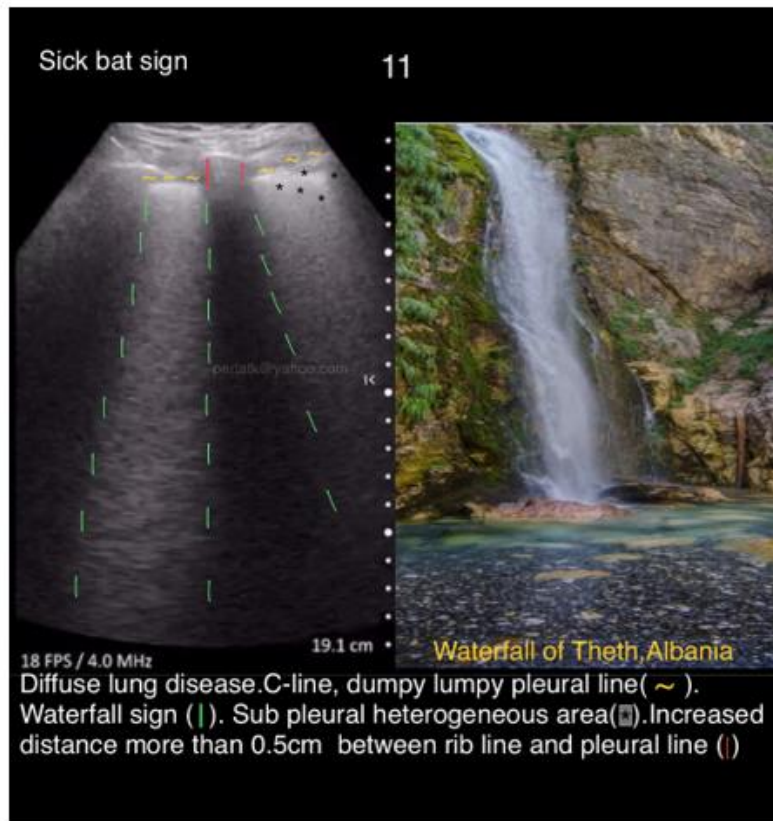
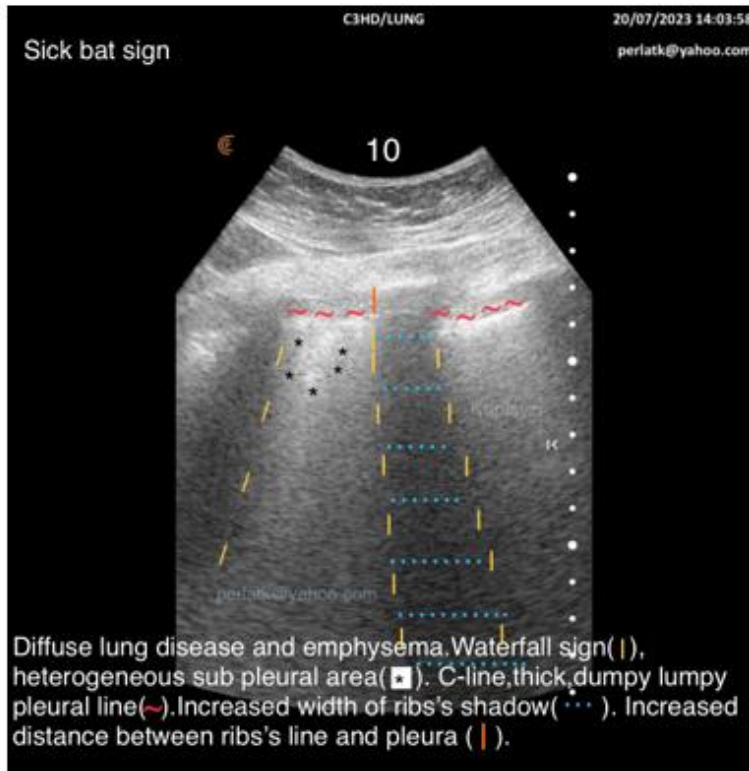
Pulmonary edema Interstitial syndromes [13].

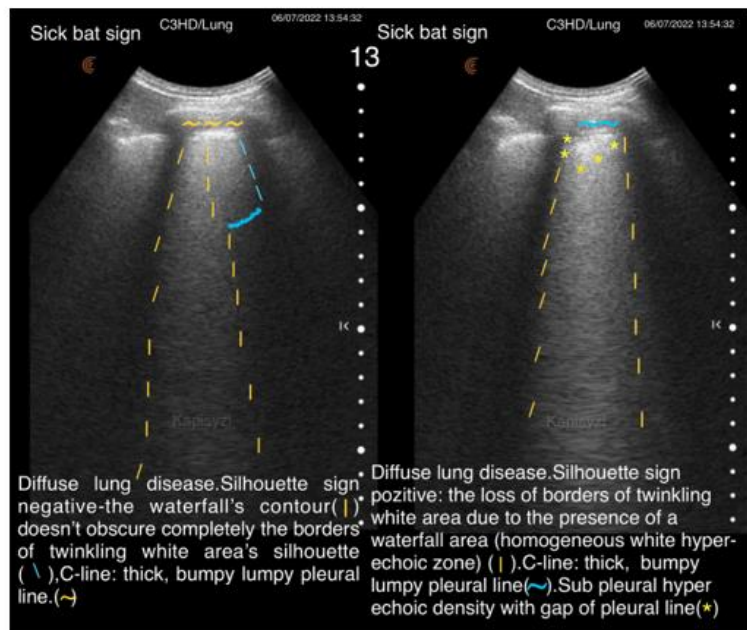
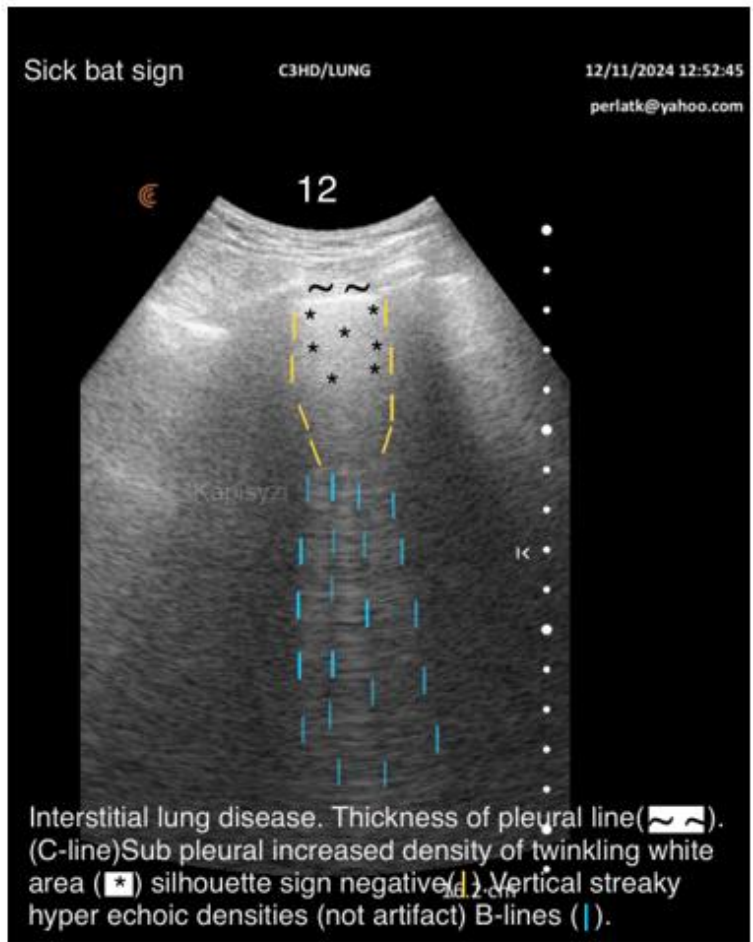
By emphasizing their anatomical origins, B-lines can be redefined in terms of their clinical relevance, providing critical insights into lung pathology

The number of B-lines, according to Lichtenstein, indicates the degree of inflammation. Three to four B-lines, referred to as a "septal rocket," originate from the subpleural tissue and interlobular septa. Meanwhile, five to ten B-lines, termed a "ground-glass rocket," correspond to ground-glass lesions.[14]

Sometimes after I failed, I din't find a colleague to be able to number the B- lines because of waterfall sign (homogeneous white hyper-echoic zone). [Fig 9,10,11,12,13]







Based on our experience with ultrasound examinations of over 600 patients, we have observed that the number of B-lines depends not only on the involvement of lobular structures but also on the extent of inflammation along the subpleural and interlobular spaces. The presence of more than three B-lines that do not cause a "positive silhouette sign"

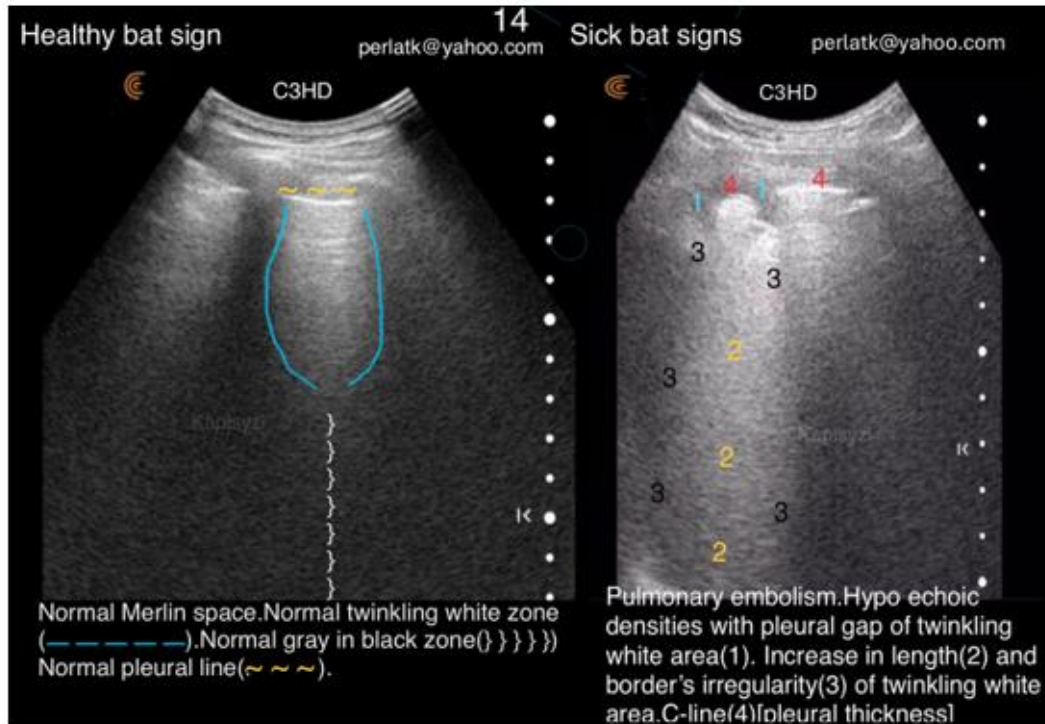
with the borders of twinkling white area indicates that the inflammation has not widely spread to the intralobular structures.

When the borders of the twinkling white area are obscured by a cluster of B-lines, resulting in a "positive silhouette sign," regardless of their number, this is a definitive indicator of the ground-glass pattern of

pulmonary injury. The typical presentation of advanced ground-glass pattern is the ultrasound "waterfall sign," characterized by such a high number and intensity of B-lines that they merge into a homogeneous, hyper-echoic white zone starting at the pleural line and expanding downward toward the bottom of the screen. [Fig 10,11,12,13]

C-Lines:

C-lines are hypo echoic subpleural focal images generated by condensed lung tissue [15]. These findings often indicate conditions like pneumonia or chronic inflammation. However, the term "C-line" is somewhat misleading, as these features are not true lines. A more precise description, such as hypo echoic densities with pleural interruptions, better captures their appearance and diagnostic significance. [fig 14]



A Pathology-Oriented Approach

Lung ultrasound interpretation can benefit from adopting a descriptive, pathology-focused terminology, akin to approaches used in advanced imaging techniques like CT or MRI. These modalities emphasize anatomical and pathological findings over the technical processes that generate the images. For example:

CT reports describe "ground-glass opacities" or "hyperdense masses," without referring to imaging mechanisms like iterative reconstruction.

Similarly, LU should prioritize findings' clinical relevance over their physical origins.

Proposed Terminological Changes:

A-Lines: Describe as horizontal hyper-echoic lines (not as artifact) indicating (except normal lung) increased air/fluid ratios, observed in conditions like COPD, asthma, or pulmonary embolism.

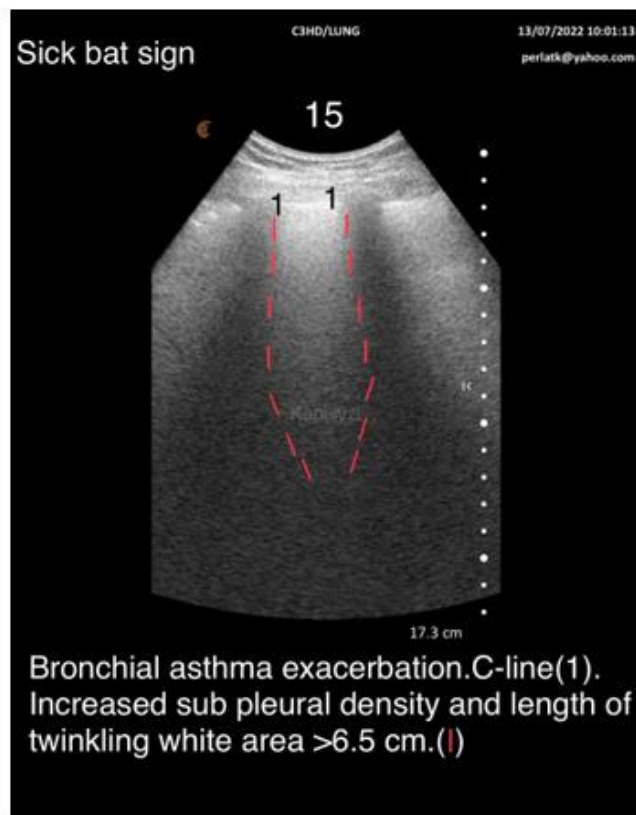
B-Lines more than three refer to as vertical streaky hyper-echoic densities (not as artifact), reflecting interstitial fluid accumulation.

C-Lines: Describe as pleural thickening, irregularities without hypo or hyper echoic densities with pleural interruptions to improve precision.

Merlin's Space: A Comprehensive Framework

Lichtenstein defines lung sliding as a homogeneous twinkling (shimmering, sparkling, or glittering) of Merlin's space.[16] However, Merlin's space is not a homogeneous twinkling area but a heterogeneous one, including two distinct components: the twinkling white area that begins from the pleural line, a grey area inside the black region beneath the twinkling white area, extending toward the screen's edge. [17]

When evaluating a normal lung ultrasound, it is important to consider not just the A-profile but also the structural characteristics of Merlin's space. These include the twinkling white area, the grey inside black region, and the ribs' shadows. [Fig 14;15]



Evaluating the structural and functional components of Merlin's space provides a holistic understanding of lung ultrasound findings:

Twinkling White Area: Analyze its configuration, density, homogeneity, and border regularity.

Grey Area Inside Black Region: Assess its relationship with surrounding structures.

Rib Shadows: Evaluate their width, length, and distance from the pleural line.

This systematic approach helps identify the healthy bat sign, a hallmark of normal lung ultrasound findings. Deviations from this pattern may indicate the "sick bat sign," associated with underlying pathologies like pneumonia, atelectasis, COPD, asthma, pleural thickness, etc. [18].

Implications for Clinical Practice

Healthy vs. Sick Bat Sign:

The healthy bat sign consists of uniform features in Merlin's space, including the twinkling white area, grey-black transitions, and rib shadows.

The sick bat sign represents deviations from these norms, which may suggest diseases such as airtrapping, discrete consolidation, effusion, or interstitial syndromes.[18]

Sick Bat sign refers to any ultrasound image in which one or more of the following components are observed, either together or separately:

- Thickened, irregular, serrated, or partially/fully absent pleural line.
- Absence or reduction of lung sliding.

- Identification of the gap between the two pleural lines: the parietal and visceral pleura.
 - A "twinkling white" zone shortened or extended beyond the range of 3.5–6.5 cm.
 - Expansion of the conical portion of the "twinkling white" zone.
 - Heterogeneity of the "twinkling white" zone with vertical or horizontal hyper- or hypoechoic densities.
 - Negative silhouette sign at the borders of the "twinkling white" zone. Fig
 - "Waterfall" sign with a positive silhouette sign at the borders of the "twinkling white" zone.
 - Absence, gap of twinkling white zone.
 - Irregular contours of the "twinkling white" zone.
 - Increased distance between the rib lines and the pleural line exceeding 0.5 cm.
 - Position of the rib's lines appearing almost adjacent and parallel to pleural line.
 - Widening of rib shadows, with irregular rib contour visualization.
 - Extension of rib shadows to the bottom of the screen, with or without hyper-echoic densities visible within the rib shadows.[18]
 - Missing of gray in black zone. [Fig 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15]
- Beyond the A-Profile and B-profile

While the A-profile is characteristic of normal aerated lung tissue, it can also appear in pathologies like pulmonary embolism, COPD, asthma or bronchiectasis, infected bullae, echinococcus cyst or hydropneumothorax.

Missing of B-profile, or heterogeneity of subpleural area doesn't exclude the discrete changes.

Thorough evaluation of components of Merlin's space provides additional diagnostic clarity, revealing subtle pathological changes.

Conclusion:

To advance lung ultrasound interpretation, we must move beyond artifact-based terminology and adopt a descriptive, pathology-oriented approach. This shift emphasizes the clinical and anatomical significance of findings, promoting more precise and effective diagnoses. This distinct approach to pulmonary ultrasound interpretation draws upon the groundbreaking work of Prof. Daniel Lichtenstein and the efforts of all who have championed the value of this examination.

Key changes include:

Replacing artifact labels (e.g., A-lines, B-lines) with terms that reflect their structural and clinical relevance.

Reframing the C-line to distinguish pleural irregularities from consolidations.

Expanding the evaluation of Merlin's space to include its structural components and deviations.

Introducing the concepts of the Healthy and Sick Bat signs, which indicate whether there is an abnormality in the lung. These signs assist in making quick decisions regarding the need for a CT scan, helping to avoid unnecessary radiation exposure, lower sensitivity and delays associated with X-ray examination.

By refining nomenclature and focusing on the true visual characteristics of LU findings, clinicians can improve diagnostic accuracy and enhance the utility of lung ultrasound in critical care and respiratory medicine.

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