Venue™ Family

Lung Ultrasound for Assisting in the Diagnosis of Pneumonia

A white paper by

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Work Smarter, Not Harder

Key Points

1. Lung Sweep, a rapid visualization tool, provides a dynamic panoramic view of the entire lung.

2. Automatically activated at the start of each sweep when the probe is tapped on the body, Lung Sweep is deactivated at the end of each sweep when the probe is lifted– there is no need to touch the screen.

3. The Auto B-lines tool can be used in conjunction with Lung sweep to highlight B-lines over the entire panoramic view and display the frame with the most B-lines per rib space.

Lung Ultrasound for Assisting in the Diagnosis of Pneumonia

Background

Pneumonia is the leading cause of pediatric mortality worldwide[1] and a prevalent and serious disease in the general population, resulting in high hospitalization and mortality rates.[2] Respiratory infections are the most common cause of sepsis and septic shock, causing approximately half of all episodes[3] and represent a significant healthcare and economic burden globally.[2]

It is imperative to diagnose pneumonia early to initiate treatment and prevent complications.[4] There are many approaches to evaluate patients with suspected pneumonia, and every diagnostic tool has its own benefits and limitations:[5]

1. **Clinical diagnosis** – Patient presentation and a physical exam with auscultation remains the hallmark of the physician's diagnostic tools. This approach is limited to lower sensitivity and specificity with high rates of interobserver variability.
2. **Laboratory testing** – Blood tests, swabs, expectorate collections, serologic tests or bronchoalveolar lavage can directly or indirectly identify signs of inflammation or identify microbiologic etiology of pneumonia. Lack of specificity, sensitivity and long turnaround time can significantly impact, and delay a timely diagnosis of pneumonia.
3. **Chest Radiograph (X-ray)** – This is the most common diagnostic tool used in daily clinical practice for the diagnosis of pneumonia, especially in critically ill patients. The primary limitations of chest x-ray are nonspecific findings, inability to distinguish between viral and bacterial pneumonia, high time pressure in the emergency departments, ionizing radiation exposure and a limited role in follow-up or ongoing patient management.
4. **CT** – This is the gold standard. CT may be performed for detecting lung masses or cavitary lung lesions and acute or chronic lung diseases such as pneumonia, pulmonary fibrosis, COPD, and malignancy. However, CT is not routinely used to detect pneumonia due to associated ionizing radiation hazards, high cost, and the challenges of transferring critically ill patients to radiology suite.
5. **Ultrasound** -- This is a readily available, user friendly and convenient method, providing rapid, real-time feedback to support medical decision making at the patient's bedside. Physicians are frequently using lung ultrasound in a wide variety of clinical settings for detecting different lung findings associated with pneumonia. Point-of-care lung ultrasound has been reported to be a precise tool to assist the clinician in diagnosing pneumonia. Additionally, it is cost-effective and easily repeatable without exposing the patient to ionizing radiation.

The primary limitation of lung ultrasound is that standard lung scanning techniques can make comprehensive visualization of the entire lung in real-time challenging. This limitation is elaborated in the **Current standard lung scanning techniques section** of this paper and addressed in the **Venue solution to standard lung scanning technique limitations.**

This paper will elaborate on the advantage of using lung ultrasound to assist the clinician in diagnosis of pneumonia.

Lung Ultrasound as a practical and beneficial diagnostic tool to evaluate Pneumonia and lung patterns.[6]

Point-of-care lung ultrasound can be considered an efficient and beneficial tool in the diagnosis of lung conditions such as pneumonia.[5] Lung ultrasound can be used at the bed side.[2] It is a portable imaging modality that is safer, more cost-effective[7] and has a better reproducible profile than CT. Furthermore, when clinical presentations combined with CT was set as the gold standard, it has a high (95%) sensitivity and specificity (91.3%) rate in the diagnosis of pneumonia.[4] Finally, several pathological lung findings (e.g. pleural effusion, consolidations and interstitial lung disease) have been diagnosed more accurately with lung ultrasound compared to bedside Chest X-ray.[7]

Pneumonia indicators that can be detected with lung ultrasound:

- B-line patterns (Fig. 1)
- Hepatization
- Shred sign (irregular consolidation)
- Air bronchograms
- Subpleural consolidation
- Pleural effusion

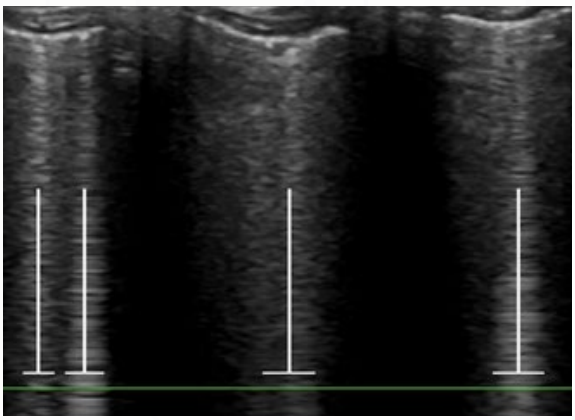

Figure 1: Ultrasound image of irregularly spaced B-lines in lateral view, suggesting early pneumonia.

During the 2009 H1N1 influenza pandemic in New York City (NYC), the demand for chest X-ray for patient with severe lung disease was associated with an increase in length of stay for patients with suspected or less severe lungs disease. The use of lung ultrasound during the pandemic played a significant role for immediate point-of-care triage and management of patients (adults and pediatric).[8]

Healthcare providers often face a diagnostic dilemma in differentiating influenza from various acute respiratory diseases. Relying only on clinical presentation may not be sufficient to differentiate these diseases. Additionally, the cost-benefit ratio is too high for executing quick viral antigen testing for diagnosis in pandemic situations.

Point-of-care ultrasound has been shown to be highly accurate in assessing several lung diseases such as typical/atypical pneumonia[9], viral pneumonia and acute respiratory distress syndrome (ARDS), in real-time. Furthermore, it is also possible to differentiate between bacterial pneumonia vs. viral pneumonia or atypical pneumonia.[9]

The Bedside Lung Ultrasound in Emergency (BLUE) protocol, described by Lichtenstein et al. (Fig. 2) [8] assists in differentiating different lung diseases based on sonographic findings.[9]

Summary: Lung Ultrasound Benefits vs. other imaging tools

- No Ionizing radiation exposure
- Low cost
- Images can be interpreted rapidly at the bedside
- Easily repeatable
- Highly sensitive in Identifying small consolidations compared to other imaging modalities
- Earlier detection of lung findings
- Potentially shorter stay in the emergency department and other acute care settings
- Cost and time savings in patient follow-up

Current standard lung scanning techniques

There are two standard techniques for lung scanning, and they are based on the two different methods of acquiring imaging - by *zones* or by *sweep*. The standard ultrasound technique for scanning the lungs is by zone (for adults and pediatrics) or by sweep, which is primarily done in pediatrics due to small body size and anatomy.

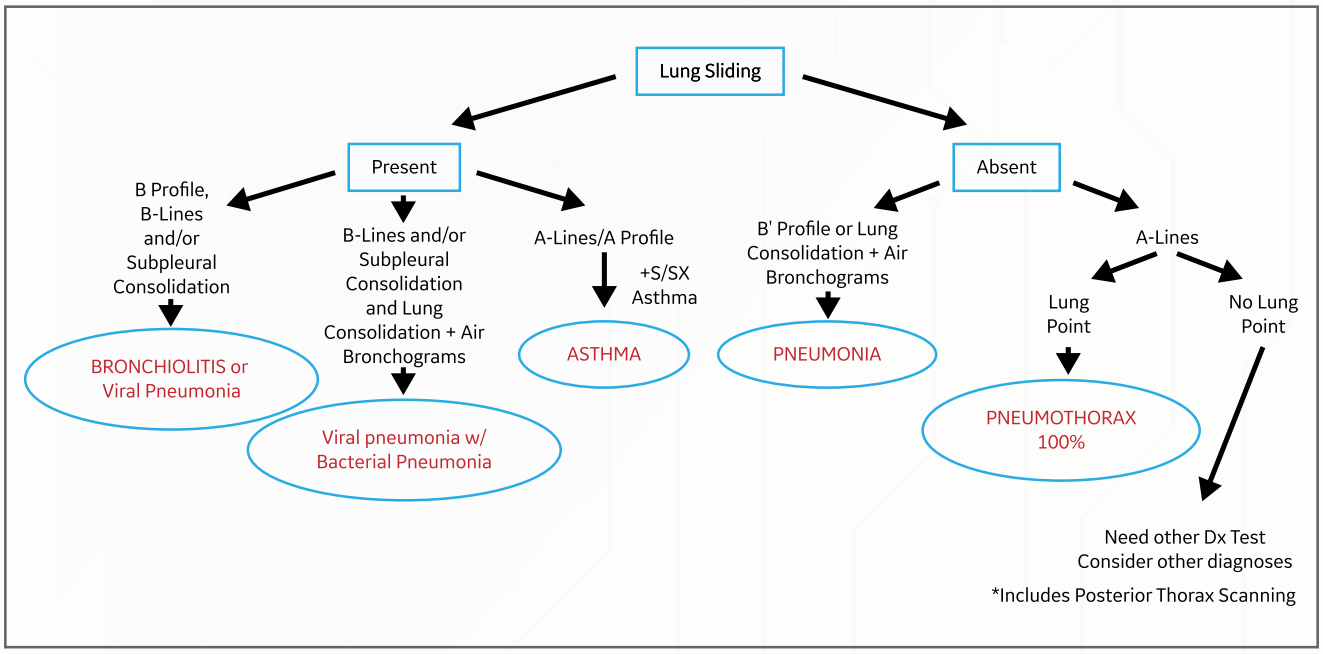

Figure 2: BLUE Protocol

The ability to differentiate between bacterial and viral pneumonia using bedside lung ultrasound supports immediate decision-making regarding the proper management. For example, identifying lung consolidation with air bronchograms allows rapid disposition of antibiotic treatment, often while waiting for other diagnostic test results. Furthermore, detecting viral pneumonia facilitates clinical decision making to provide empiric treatment with antiviral medication, especially during epidemic and pandemic situations.[9]

One of the many limitations to lung image acquisition and interpretation at the bedside is the inability to review a comprehensive view of the lungs simultaneously in real-time as well post-imaging assessment similar to a chest radiograph. The view is limited to the active zone being scanned or reviewed. As a result, the comprehensive view of the entire lung is often left to the imagination as the physician reviews the image in a compartmentalized fashion, zone by zone.

The main limitation of the zone technique is the lack of continuity due to compartmentalization which results in variability from image to image. This makes comprehensive visualization of the entire lung in real-time challenging.

The main limitation of the sweep technique is that it is difficult to determine the location of lung portion scanned during review because the full length of the lung is not displayed during live scanning.

Venue solution to standard lung scanning technique limitations

The standard techniques for scanning the lungs make it difficult to review and reach a quick conclusion.

The **Venue Family** offers the following solutions:

1. **Lung Diagram:** (Fig. 3) Enables the user to view various patterns related to different levels of lung aeration, on various zones of the lungs, and express these aeration levels as a score (See more details in "Real Time documentation White Paper").

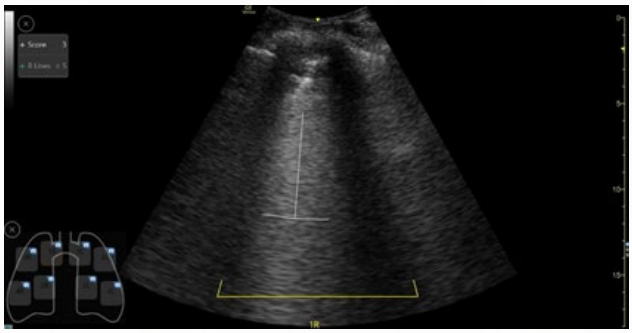

Figure 3 : Lung Diagram screen layout.

2. **Lung Sweep:** The Venue Family offers an enhanced approach to standard lung scanning technique, enabling the user to see the whole view simultaneously by creating a dynamic panoramic view of the lung (Anterior, Lateral, Posterior per left/right side)

   Lung Sweep tool
   The Lung Sweep tool, available exclusively with Venue Family, creates a dynamic panoramic view of the lung (Fig. 4) (Anterior, Lateral, Posterior per left/right side). – These views allow 2D coronal and sagittal coverage of the entire lung parenchyma which assists the physicians in the diagnosis of pneumonia. (Fig. 5, Fig. 6).[10]

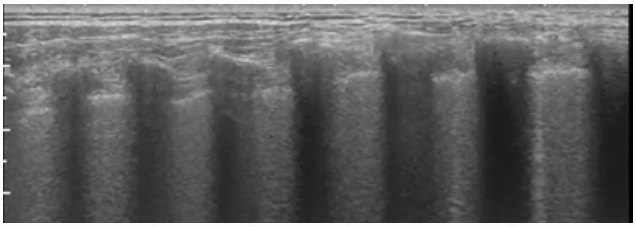

Figure 4: Lung Sweep panoramic view

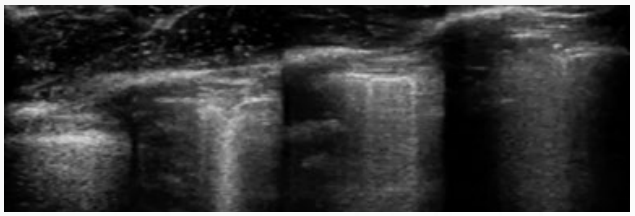

Figure 5: Subpleural consolidation in the 2nd intercostal space in anterior thoracic view.

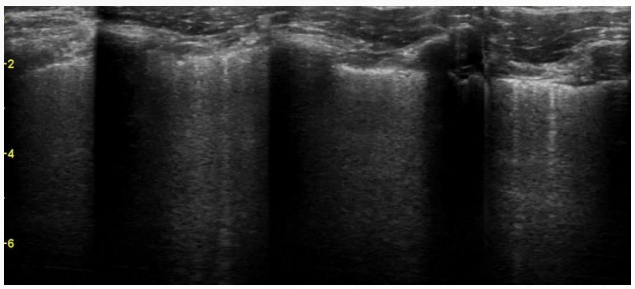

Figure 6: Lung sweep of Covid-19 pneumonia

How does Lung Sweep tool work?

A. The tool detects the ribs sequentially and presents all intercostal spaces of a specific view in panoramic display. The clinician may then review all intercostal spaces simultaneously in the selected view. Utilizing this tool, examinations can be completed with **minimum taps on the screen**-
   I. An option to start the sweep by lifting the probe and placing back on the thorax.
   II. Auto stop the sweep by lifting the probe from the skin
   III. Auto play the panoramic intercostal spaces once the sweep has stopped.

B. The Lung Sweep tool can be used when scanning the patient with linear or curvilinear probes. The "build-up" panorama view is done in real time and each view (anterior, lateral, posterior) is displayed separately on the screen. The user can then view each side of the lungs simultaneously and switch between the sides by tapping on a "lung" control button.

3. **Internal Quality Control**
   Two quality indicators are built into the system to support adoption and accurate use.

   a. The speed-quality indicator is represented by displaying a message on the screen. If the operator is scanning too fast, a message "Slow down" appears on the screen.
   b. The skin-contact quality indicator varies between green/yellow/red according to the level of contact between the probe and the patient's skin. The relative lengths of the green/yellow/red sections depend on the detected skin-contact section within the current live frame (Green marks the portion of the frame with skin contact and yellow/red marks the portion of the frame with minimal contact or air).

"Nobody wants to review 12 or more clips of the lungs. The layout makes it easy to review, similar to reading a chest x-ray"

Dr. Davinder Ramsingh, Loma Linda University Medical Center

How is this done?

Steps for activating the Lung Sweep tool:

1. Begin a new exam
2. Choose a linear or curvilinear probe and the lung preset
3. Activate the Lung Sweep tool
4. Sweep the lung (accordingly to the selected view and side, displayed on the screen)
   *You may change a different lung side and view before starting the sweep.
   *The sweep will proceed only if the probe marker is pointing cephalic.
5. After completing a specific sweep, review the playback and store (Fig. 7).
   * You may sweep again in the same view.
6. Sweep the next view until you have completed all views
   *You may take a snapshot of the whole screen by storing while in pause mode.

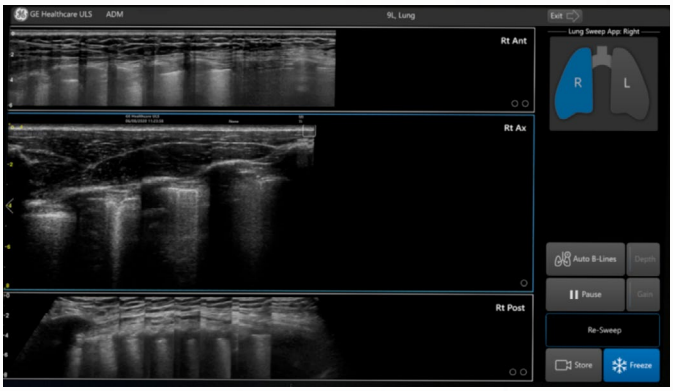

Figure 7: Right Lung with all three lung sweeps

What are the main benefits of the Lung Sweep tool?

The Lung Sweep tool enables the user to view the entire lung along with its dynamics and provides organized images.

The panoramic display may be used as a more natural form of documentation to facilitate communication within the healthcare team.

It may also advance the learning curve in performing and interpreting lung ultrasound scans, and allow for better standardization of lung ultrasound visualization. Lung Sweep may be considered as a fast and convenient tool in pediatric patients due to their small thorax and constant movement during the exam. It could improve compliance with lung ultrasound protocol.

Strategy for validating

How have we validated internally?

We conducted internal accuracy tests (using Lung sweeps in which the Quality Indicators indicated high quality). The vertical distance and horizontal/vertical ratio matched the calibrated test equipment with a deviation of up to 10%.[12]

How do we evaluate externally?

We select external evaluation sites in which physicians use our systems in acute care settings and provide feedback based on their clinical expertise and experience with ultrasound studies.

Conclusion

Imaging has been a crucial component of the diagnostic workup of pneumonia. Lung ultrasound is a quick, bedside-based, affordable, reproducible method, and it is supported by recent literature as a primary imaging modality in the process of diagnosing pediatric and adult pneumonia.[2,11]

The **Venue Family** systems offer an enhanced approach to lung ultrasound enabling the user to review the whole lung comprehensively and simultaneously, ultimately enabling to improved patient care.

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