



## Chest Ultrasound: More Sensitive and Specific than Chest X-ray in Diagnosing Pneumonia

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### Abstract

**Statement of the Problem:** *Community-acquired pneumonia is a common and serious illness worldwide. It is the main cause of mortality, which particularly targets young patients, elderly patients and those with co morbid conditions. Most patients with pneumonia are managed in the outpatient setting but patient admitted in the hospital due to pneumonia have a high mortality. Chest ultrasound (CUS) is being increasingly utilized in emergency and critical settings. Aim of this study was to compare the sensitivity and specificity of chest ultrasound and chest x-ray.*

**Methodology & Theoretical Orientation:** *This was a prospective clinical study. We aimed for a sample size of 96 patients. Patients were enrolled every alternate day to randomise the study. Informed written consent was taken from all enrolled patients or their immediate relatives. The result of chest computerized tomography scan was taken as gold standard. The duration of study was 6 months (from September '16 to February '16). 100 patients were included in the study. Findings: Chest Ultrasound was found to have a higher sensitivity of 0.96 (95% CI 0.85 – 0.99) compared to x-ray which had a sensitivity of 0.57 (95% CI 0.42 – 0.70). Also a higher specificity was found in Chest Ultrasound compared to chest x-ray, 0.95 (95% CI 0.84-0.99) vs 0.85 (95% CI 0.71-0.93). Chest ultrasound was found to have a perfect agreement with the final diagnosis i.e k=0.91 compared to a moderate agreement between chest x-ray and the final diagnosis i.e k=0.42. The two tailed p value was 0.02 and by conventional criteria, this difference was found to be statistically significant.*

**Conclusion & Significance:** *We concluded that chest ultrasound is more sensitive and specific the chest x-ray in diagnosing patients with pneumonia. Chest ultrasound is easily available, less expensive, faster and gives off no radiation when compared to chest x-ray. We recommend that with adequate training chest ultrasound should be preferred over chest x-ray for patients in a critical care setting.*

**Keywords:** *Chest ultrasound, chest x-ray, pneumonia, Community-acquired pneumonia, sensitivity, specificity.*

### Introduction

Community-acquired pneumonia is a common and serious illness worldwide. It is the main cause of mortality, which particularly targets young patients, elderly patients and those with co morbid conditions.

Because of the lack of epidemiological surveys, a clear population-based statistics on the condition is not available among adults in India. In 2004, global estimates on incidence of clinical pneumonia in children younger than 5 years were first generated

and published by Rudan et al.<sup>1</sup> Most patients with pneumonia are managed in the outpatient setting but patient admitted in the hospital due to pneumonia have a high mortality. As the percentage of patients aged more than 65 years is increasing so is the incidence of pneumonia with it. More than 90% death occurs in patients aged more than 65 years of age.<sup>2</sup> The area of lung is approximately 140 m<sup>2</sup> and 10,000 L of air passes through the respiratory tract per day which contains hundreds to thousand micro organisms per meter cube. Despite all this lung is a healthy environment. Emergency department evaluation should be focused on diagnosing the disease and determining the presence of clinical features of pneumonia. Pneumonia generally manifests as cough, fever, shortness of breath and suspected cases are usually confirmed with a chest radiograph. Elderly or debilitated patients usually have atypical symptoms and are more likely to present in advanced stage.

India tops the list of 15 countries across the world with high disease burden.<sup>(1)</sup> Morbidity rates tend to vary between 0.2 to 0.5 episodes per child-year and approximately 10 to 20 per cent of these episodes tend to be severe.<sup>(2)</sup> Among the high burden countries, India has a mortality rate of 322 per 100 000 under-five population compared to China's 86.<sup>(3)</sup> Reliable estimates of incidence or deaths are not available for the adult populations. Various studies including demographic studies and extrapolations from surveillance of "native populations" in developed countries suggest a high burden of pneumococcal disease in the adult populations of developing countries.<sup>(4)</sup> Severe lower respiratory infections were reported to be the cause of deaths in 120 per million men and 76 per million women of 15-59 yr age group, worldwide, in the year 2000.<sup>(5)</sup> In the >60 age group, rates of death from such infections increased by more than two-fold for each decade of life. Much higher incidence of pneumonic illnesses among adults with AIDS not on anti-retroviral therapy (ART) is also a matter of serious concern in the Region. Chronic obstructive pulmonary disease (COPD), which is a major host factor to contribute to acute lower respiratory tract

infection or pneumonia in adults, is estimated to be prevalent in about 4 per cent of the Indian population, with male to female ratio of 1.56:11.<sup>(6)(7)</sup> Lung auscultation and bedside chest x-ray are routinely used to assess the respiratory condition of patients with pneumonia in a critical care setting. Clinical experience suggests that the diagnostic accuracy of these procedures is poor. Accurate evaluation of lung pathology and pulmonary aeration in critically ill patients suspected of having pneumonia remain problematic. Auscultation, which is the first step of the clinical evaluation, can be markedly altered by the intrathoracic transmission of sounds issued from the mechanical ventilator and other sources. Technical limitations like movements of the chest wall, patient rotation, supine position with the x-ray film cassette placed posterior to the thorax, and an x-ray beam originating anteriorly at a shorter distance than recommended and not tangentially to the apex of the hemidiaphragm reduce the quality of bedside chest radiography. Despite all this chest x-ray, still, remains the daily reference for lung imaging. All of these various factors contribute to poor-quality x-ray films and mistaken assessment of pleural effusion, alveolar consolidation, interstitial markings, mediastinum, and cardiac dimensions. Even with careful control of exposure factors, radiographic images remain suboptimal in most of the cases. Therefore, leading to poor correlation to chest CT images. Although it is generally believed that ultrasonography has limited applications in lung diseases, its use is extending in critical care and emergency settings. Over the last two decades, the use of ultrasonography of lung in critically ill patients has gained popularity, and has yielded good results. It helps in diagnosis of several abnormal conditions, including pneumothorax, pneumonia, atelectasis, pleural effusion, and others.

### Materials and Methods

This was a prospective clinical study. 97 ICU Patients were enrolled every alternate day to randomise the study. Informed written consents were taken from all enrolled patients or their

immediate relatives. The duration of study was 6 months.

#### **Inclusion criteria**

- 1) All patients admitted in the medical ICU within the last 24 hours.
- 2) Patients admitted on Monday, Wednesday and Saturday.
- 3) Age more than 18 years.

#### **Exclusion criteria**

- 1) Admission duration more than 24 hours.
- 2) Prior systemic antibiotic therapy.
- 3) Hospital-acquired pneumonia.
- 4) More than 24 h between chest ultrasound and radiography.
- 5) Radiographic findings known to the sonographer.
- 6) Pregnancy or lactation.
- 7) Age less than 18 years.
- 8) Patients admitted on all other days.
- 9) Patients in whom x-ray was not done or indicated.

#### **Case Selection**

All patients admitted in the medical ICU on Monday, Wednesday and Saturday were included in the study from September 2015 to February 2016.

#### **Sample Size**

We aimed to enrol a minimum of 96 patients in our study.

#### **Consent**

Written informed consent was taken from all patients or their immediate relatives in a language they could understand.

#### **Study Protocol**

##### **Chest Radiograph**

All patients underwent portable supine antero-posterior chest radiography on day 0. Radiographs were analyzed by independent experts in chest radiology who were unaware of the lung ultrasound results. X-ray was defined to be positive when consolidation, opacity, haziness, infective etiology and pneumonia were used in the report by the radiologist.<sup>(18)</sup> Exposure time, focus-film distance, and degree of exposure were standardized for each patient to obtain the best radiographic quality. Lung parenchyma was divided into 12 regions by a

cephalocaudal mid-axillary line and a transversal hilar line. Upper lung regions were defined as lung regions delineated by the apex, mid-axillary line, mediastinal line, and hilar line. Upper and lower lateral lung regions were defined as lung regions delineated by the external limit of the chest wall, mid-axillary line, and apex (upper) or diaphragm (lower). Upper and lower posterior lung regions were defined as lung regions with radiologic signs erasing the mediastinum border ("silhouette sign") and delineated by the mediastinum, mid-axillary line, hilar line, and apex (upper) or diaphragm (lower). Alveolar consolidation was defined as the presence in lower lung regions of a homogeneous opacity characterized by the effacement of blood vessel shadows and the presence of air bronchograms.

##### **CT Scan**

In the case of positive, inconclusive radiographic or positive clinical findings and of negative radiographic findings, a low-dose CT scan was performed without contrast medium using 120 kV, 20 to 40 mA, and a reconstructed layer thickness of 4 mm (multislice CT scan; effective radiation dose in the range of 0.4 mSv) or 120 kV, 50 mA, and a reconstructed layer thickness of 5 mm (one-line CT scan; effective radiation dose in the range of 1.2 mSv). If other diagnoses were suspected, a spiral/multislice CT scan with contrast agent was performed. CT scans were analyzed by experts in chest radiology unaware of the sonographic and radiographic results. CT scan was said to be positive when diagnosis of pneumonia was written on the report.

##### **Chest Ultrasound**

Chest ultrasound was performed within 24 hours of ICU admission. Patients in whom a chest radiograph had already been performed at the time of the ultrasound investigation could be enrolled if chest ultrasound was performed within 24 h after the chest x-ray and if the x-ray findings were neither available nor known to the sonographer.

Sonography was conducted using portable machine with a 5 MHz convex scanner. Patients were examined posteriorly in a seated position and anteriorly in a supine position. A systematic examination of all intercostal spaces was performed by the same emergency physician on all patients. Protocol views consisted of four locations of each hemithorax (anterior second intercostal space at the midclavicular line, fourth intercostal space at the anterior axillary line, sixth intercostal space at the midaxillary line, and sixth intercostal space at the posterior axillary line) to assess for the presence of a sliding lung. In the normal lung, the parietal and visceral surfaces can be visualized by US as bright interfaces or echogenic lines. With respiration, these two bright lines slide past each other (fig 1.1).



Figure 1.1: Normal lung transition

Ultrasound images were obtained perpendicular / longitudinal to ribs at the rib interspaces. Depth settings were minimized to approximately 5 cm to optimize magnification of the superficial structures being imaged.<sup>(19)(20)(21)</sup> Horizontal lines, arising from and parallel to the pleural line, were called *A lines* (fig 1.2).

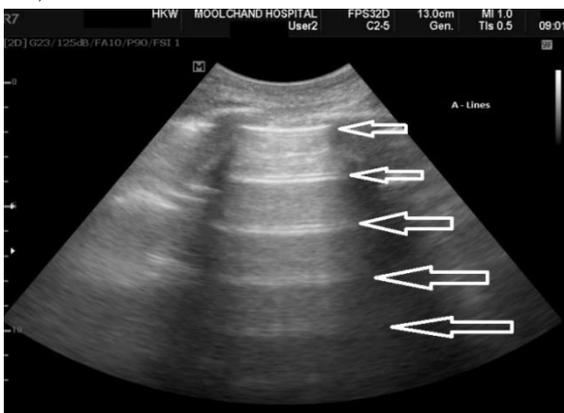


Figure 1.2

Vertical lines, arising from and perpendicular to the pleural line, were called *B lines* or *comet tails* if they reached the edge of the screen; and three or more comet tails visible in a frozen image were called *lung rockets*.<sup>(22)</sup> A single comet tail present in an anterior lung region, or multiple comet tails confined laterally to the tenth or eleventh intercostal space, were considered as normal (fig 1.3).<sup>(23)</sup>



Figure 1.3: B-Lines

Pleural effusion was defined as a dependent collection limited by the diaphragm and the pleura with an inspiratory movement of the visceral pleura from depth to superficialities.<sup>(24)(25)(26)(27)</sup> In the case of abundant effusion, the consolidated and atelectatic lung was visible floating in the pleural effusion. Alveolar consolidation was defined as the presence in one or several lung regions of tissue pattern whose dimensions remained unchanged throughout the respiratory cycle. It contained frequently hyperechoic punctiform images representative of air bronchograms (fig 1.4).<sup>(28)</sup>



Figure 1.4 C-Profile

Each of the lung regions examined per patient was classified into one or several of the four categories defined above.

Chest Ultrasound was defined to be positive when<sup>(29)</sup> –

- 1) Lung sliding absent with B- Lines
- 2) A- Lines with B- Lines with or without lung sliding
- 3) C- Profile (Consolidation) with or without lung sliding

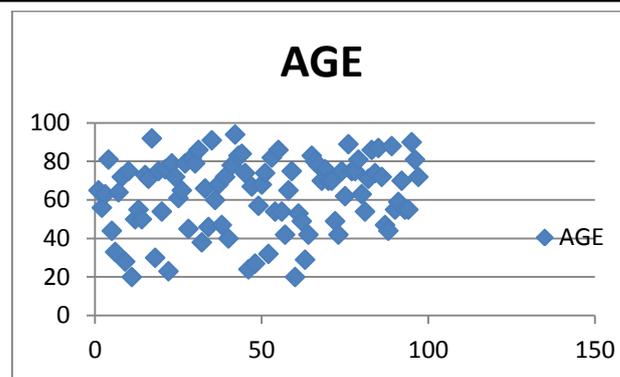
### Statistical Analysis

The primary objective was to estimate the diagnostic accuracy of lung ultrasound as index test (positive, negative, equivocal) compared with chest x-ray followed by CT imaging in case of inconclusive or negative radiographic but positive ultrasonography findings as the reference test (negative, positive). All data were entered in MS excel program and was analysed using the statistical software JMP version 10.0 and Vassarstats on a personal computer. Comparison of difference of means of chest x-ray and chest ultrasound were made with a student t-test and p value was calculated. P value of less than 0.05 was considered to be statistically significant. Data was further analysed with using kappa statistics and kappa coefficient was calculated and was considered to be having significant association if more than 0.70.

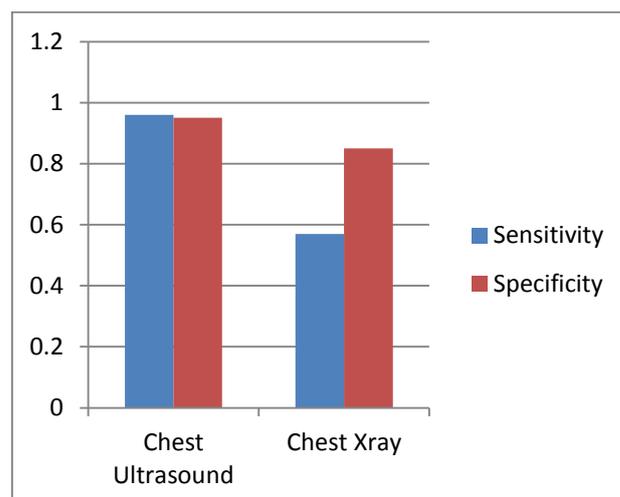
According to the study protocol, sensitivity, specificity, negative and positive predictive value were calculated.

### Result

100 patients were included in the study, out of which no chest x-ray was done in 2 patients and 1 patient went into cardiac arrest before a diagnosis could be made. The mean age was 63.26 with a standard deviation of 18.53.



**Figure 2:** Showing age distribution



**Figure 3:** Sensitivity and specificity of Chest X-ray and Chest Ultrasound

NCCT findings showed 51 patients having pneumonia while chest ultrasound was positive in 51 patients (49 True positives). Chest x-ray was also positive in 35 patients (28 True positives).

Chest Ultrasound was found to have a higher sensitivity of 0.96 (95% CI 0.85 – 0.99) compared to x-ray which had a sensitivity of 0.57 (95% CI 0.42 – 0.70). Also a higher specificity was found in Chest Ultrasound compared to chest x-ray, 0.95 (95% CI 0.84-0.99) vs 0.85 (95% CI 0.71-0.93). Therefore, proving that chest ultrasound was not only sensitive but was highly specific and had a greater positive and negative predictive value when compared to chest x-ray.

Figure 4.1

	Pneumonia		Totals
	Absent	Present	
USG Positive	2	49	51
USG Negative	44	2	46
Totals	46	51	97
	Estimated Value	95% Confidence Interval	
		Lower Limit	Upper Limit
Prevalence	0.526	0.422	0.627
Sensitivity	0.961	0.854	0.993
Specificity	0.957	0.84	0.992
For any particular positive test result, the probability that it is:			
Postive (PPV)	0.961	0.854	0.993
For any particular negative test result, the probability that it is:			
Negative (NPV)	0.957	0.84	0.992

Figure 4.2

	Pneumonia		Totals
	Absent	Present	
CXR Positive	7	28	35
CXR Negative	41	21	62
Totals	48	49	97
	Estimated Value	95% Confidence Interval	
		Lower Limit	Upper Limit
Prevalence	0.505	0.402	0.607
Sensitivity	0.571	0.423	0.709
Specificity	0.854	0.716	0.935
For any particular positive test result, the probability that it is:			
PPV	0.8	0.625	0.909
For any particular negative test result, the probability that it is:			
Negative (NPV)	0.661	0.529	0.774

**Cohen's kappa coefficient** was calculated to measure the inter-rater agreement between the results of chest ultrasound and chest xray with that of final diagnosis. As per Landis and Koch, who characterized values < 0 as indicating no agreement and 0–0.20 as slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1 as almost perfect agreement. Chest ultrasound was found to have a perfect agreement with the final diagnosis i.e k=0.91 compared to a moderate agreement between chest x-ray and the final diagnosis i.e k=0.42 . Therefore proving that chest

ultrasound was superior in diagnosing pneumonia when compared to chest x-ray.

**t-Test: Two-Sample Assuming Unequal Variances**

	Chest Ultrasound	Chest X-Ray
Mean	0.5257732	0.360824742
Variance	0.25193299	0.233032646
Observations	97	97
Hypothesized Mean Difference	0	
df	192	
t Stat	2.33280605	
P(T<=t) one-tail	0.0103471	
t Critical one-tail	1.65282859	
P(T<=t) two-tail	0.02069419	
t Critical two-tail	1.97239645	

An unpaired student's t-test was performed to determine if the difference between the sets of data of chest ultrasound and chest x-ray was statistically significant. A 'p' value was calculated and was only considered to be statistically significant if less than 0.05. The two tailed p value was 0.020 and by conventional criteria, this difference was found to be statistically significant.

**McNemar's test**

Difference (Unsigned)	0.1632
Two-Tail	0.003719
One-Tail	0.00186

Further, A McNemar's test was performed to see if there is a statistical significant difference between Chest ultrasound and Chest x-ray. The difference was found to be statistically significant.

**Conclusion**

We conclude that chest ultrasound is more sensitive and specific the chest x-ray in diagnosing patients with pneumonia. Chest ultrasound is easily available, less expensive, faster and gives off no radiation when compared to chest x-ray. We recommend that with adequate training chest ultrasound should be preferred over chest x-ray for patients in a critical care setting.

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