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Correlation Between Lung Ultrasound (LUS) And Thorax X-rays in Patients with Pneumonia in The Intensive Care Unit of Prof. Dr. I.G.N.G Ngoerah Hospital

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ABSTRACT

Pneumonia is based on symptoms such as tachypnea, fever, rhonchi, and opacity/consolidation on a thoracic X-ray or CT scan of the thorax. Lung ultrasound (LUS) has been reported to be highly effective in diagnosing pneumonia and pneumothorax. LUS can be an excellent imaging modality and complement chest radiography and physical examination in diagnosing and surveillance pneumonia cases. Lung ultrasound examination has advantages mainly because the ionization exposure to the patient is minimal. This study was proposed to find the correlation between lung ultrasound (LUS) and thorax X-ray for pneumonia in patients in the ICU. This type of research is a prospective analytic observational with a cross-sectional study. The samples were all adult patients with clinical pneumonia symptoms in the Intensive Care Unit of Prof. Dr. I.G.N.G. Ngoerah Denpasar Central General Hospital from May to July 2023, aged 20-60 years with B.M.I. < 40 kg/m2. The sampling method was consecutive sampling. Statistical data analysis using the Statistical Package for the Social Sciences (SPSS) version 26 for Windows program. Data analysis was carried out in three stages: Descriptive analysis, Spearman correlation coefficient analysis, and diagnostic analysis with the help of Stata 17. The number of subjects obtained was 56 respondents. The mean age ± SD was 52.79 ± 17.11 years, 30 subjects were male (53.6%), and 26 were female (46.4%). Body mass index was obtained with an expected average of 23.17 ± 3.58 kg / m2. The correlation analysis results were obtained (r=0.772; p<0,001). The diagnostic test results got sensitivity 98% (CI95% 89.1%-99.9%), specificity 85.7% (CI95% 42.1%-99.6%), positive predictive value 98% (CI95% 89.1%-99.9%), negative predictive value 85.7% (CI 95% 42.1%-99.6%), positive likely hood ratio 6.86 (CI 95% 1.12-42.1), negative likely hood ratio 0.023 (CI 95% 0.003-0.17), accuracy 88% (CI 95% 76%-94.8%). This study concluded a strong positive correlation between lung ultrasound (LUS) and thorax X-ray in pneumonia patients in the intensive therapy room of Prof. Dr. I.G.N.G. Ngoerah Hospital Denpasar.

Keywords: Pneumonia; lung ultrasound (LUS); thorax x-ray; intensive care unit diagnostic.

INTRODUCTION

The incidence of pneumonia in the Intensive Care Unit (ICU) is quite high, necessitating rapid and accurate diagnosis. The standard diagnostic tool for pneumonia is a CT scan of the thorax; however, this is often difficult to perform on ICU patients due to their inability to mobilize. Advances in technology have made portable ultrasound devices, which are highly mobile, a recommended tool for diagnosing pneumonia. However, lung ultrasound (LUS) has limitations, particularly in visualizing areas obscured by bone structures.

According to the WHO in 2022, the incidence of pneumonia in adults over 18 years in intensive care is 23%-27%, with a mortality rate of up to 15% [1]. In Brazil, the incidence of ICU-acquired pneumonia ranges from 6-52%, with an average of 3.3 – 13.6 cases per 1000 patients and a mortality rate of 25.8% [2]. In Mexico, 20.7%-40% of ICU patients were found to have pneumonia, with an incidence rate of 18.6 per 1000 patients per day [3].

According to Riskesdas 2018, the prevalence of pneumonia increased to 2.0% [4]. Pneumonia is among the top ten inpatient diseases in hospitals, with a higher proportion of cases in males compared to females. The Indonesian Society of Respirologists (2020) states that pneumonia has a high crude fatality rate (CFR) of around 7.6%. Data from the 2018 Basic Health Research (Riskesdas) indicated that the prevalence of pneumonia in the elderly reached 15.5% [5].

Pneumonia diagnosis is based on symptoms such as tachypnea, fever, rhonchi, and opacity/consolidation on chest X-ray or CT scan. While the CT scan is the gold standard for pneumonia diagnosis, it has limitations such as high cost and higher radiation exposure compared to chest X-rays, and it is not flexible [6]. This makes chest X-rays the preferred diagnostic tool, despite limitations in patient positioning for posteroanterior and lateral projections, especially in critically ill patients, and high inter-radiologist variability in interpretation [7].

Chest X-rays also have delays in image acquisition and processing, significant observer variability, and cannot cover 40% of the lung area obscured by the heart, mediastinum, and subdiaphragmatic structures [8]. Patients who cannot mobilize and have a pneumonia incidence rate of 36% require immediate and easy diagnostic tests for optimal therapy [9,10].

In the past decade, LUS has been reported to be highly effective in diagnosing pneumonia and pneumothorax [11]. Ultrasound examination is a simple diagnostic tool that avoids radiation exposure. LUS can overcome the limitations of chest X-rays and CT scans [12]. LUS is easy to perform, inexpensive, non-invasive, and can be done at the patient's bedside. It has high accuracy in diagnosing lung abnormalities [13]. Pneumonia ultrasound images have four characteristics: B-profile, A/B-profile, C-profile, and A non-V-PLAPS Profile, each with its predictive value for diagnosing pneumonia [14,15].

Xin et al. demonstrated that lung ultrasound could be an excellent imaging modality, complementing chest radiography and physical examination in diagnosing and monitoring pneumonia cases [16]. Lung ultrasound has advantages, particularly minimal ionization exposure. This meta-analysis showed that lung ultrasound has high sensitivity and specificity, at 0.93 and 0.96 respectively. The higher the sensitivity and specificity of a diagnostic test, the more effective and accurate it is in diagnosing a disease [17].

The diagnostic value of chest X-rays for pneumonia is 72.3% sensitivity and 97.1% specificity. The positive predictive value (PPV) is 97.9%, while the negative predictive value (NPV) is 65.4%. This suggests that the negative predictive value and sensitivity of chest X-rays excluding pneumonia are relatively low [18]. Pallares' study found that lung ultrasound is more sensitive and has a better NPV than chest X-rays in excluding pneumonia (100% vs. 72.3% and 100% vs. 65.4%, respectively). Meanwhile, its specificity (85.7%) and PPV (92.9%) are comparable to chest X-rays [19].

A meta-analysis by Qian-Jing Hu et al., including 9 primary studies with a total of 1080 patients, showed high sensitivity, specificity, and positive and negative likelihood ratios, highlighting the superiority of LUS as a diagnostic tool for pneumonia compared to the gold standards, chest X-rays and CT scans [20]. The Receiver Operator Characteristic (ROC) curve also showed excellent results. Limitations of this study include the small sample size in some primary studies, the involvement of pediatric and neonatal subjects (who have different thoracic anatomy from adults), and the use of chest X-rays as the gold standard for pneumonia diagnosis in some studies [11,17,20].

This study aims to find the correlation between lung ultrasound (LUS) and chest X-rays for pneumonia in ICU patients. The high incidence of pneumonia in the ICU and the long wait time for sputum culture results necessitate the use of LUS, which is easy and highly flexible, to help improve diagnostic value.

METHOD

This study is a prospective observational analytic study with a cross-sectional design aimed at finding the correlation between lung ultrasound (LUS) and chest X-rays for pneumonia in the ICU, as well as obtaining the diagnostic test values for the use of both tools. The study was conducted in the Intensive Care Unit (ICU) of RSUP Prof. Dr. IGNG Ngoerah Denpasar, starting in May 2023 until the sample size was met. The research sample was drawn from the accessible population using consecutive sampling techniques.

Inclusion criteria: 1. Patients in the ICU with a diagnosis of pneumonia, presenting with two or more of the following symptoms: increased cough, changes in sputum/purulent characteristics, body temperature >38.5°C / history of fever, physical examination revealing signs of consolidation, bronchial breath sounds, and rhonchi, leukocytes >10,000/µl or <4,500/µl; 2. Patients aged 20-60 years; 3. BMI < 40 kg/m^2. Exclusion criteria: Diagnosis of pulmonary edema, pleural effusion, asthma, lung tumors, pulmonary embolism, or acute exacerbation of COPD.

All accessible populations that meet the inclusion criteria and do not meet the exclusion criteria are referred to as the eligible sample. The eligible sample will undergo a lung ultrasound (LUS) examination and be classified according to pneumonia characteristics. Patients suspected of having pneumonia will undergo both chest X-rays and lung ultrasound on the same day. The chest X-rays will be interpreted by the chief resident of radiology, while the lung ultrasound will be performed by the researcher.

Lung ultrasound will be conducted by setting the ultrasound machine to Lung mode, then using a curved probe to examine six areas of the lung (upper and lower anterior, upper and lower lateral, and upper and lower posterior) to look for signs of consolidation. Classification will be done according to operational definitions.

All research results will be recorded and analyzed using the Statistical Package for the Social Sciences (SPSS) version 26 for Windows. Data analysis will be carried out in three stages: Descriptive Analysis, Spearman correlation coefficient analysis, and diagnostic analysis with the help of Stata 17.

RESULTS

This study included 56 subjects who met the inclusion and exclusion criteria. The characteristics of the study data are presented in Table 1. The average age was 52.79 ± 17.11 years, with 30 males (53.6%) and 26 females (46.4%). The average Body Mass Index (BMI) was 23.17 ± 3.58 kg/m^2. The most common underlying condition was a history of trauma, present in 20 subjects (37.5%). Pneumonia confirmation from chest X-ray results was found in 48 subjects (85.7%), while ultrasound confirmation was found in 49 subjects (87.5%).

TABLE 1: Patient Data Characteristics.

Variable	Mean±SB	Percentage n=56 (%)
Age (years) (kg/m2)	52.79±17.11*	
Gender		
Man		30 (53.6)
Woman		26 (46.4)
Body mass index (kg/m2)	23.17±3.58*	
Basic disease		
Trauma		20 (37.5)
Strokes		11 (19.6)
Cancer		8 (14.3)
Metabolic syndrome		5 (8.9)
Lung infection		3 (5.4)
Sepsis		3 (5.4)
Digestive surgery		2 (3.6)
Tetanus		1 (1.8)
Malaria		1 (1.8)
Postoperative spondylosis		1 (1.8)
Guillaine Barre Syndrome		1 (1.8)
Confirmation of pneumonia from Thorax X-ray		48 (85.7)
Confirmation of pneumonia from LUTS		49 (87.5)

*Results of the Shapiro-Wilk test showed normal distribution p>0.05; SB: Standard Deviation.

The correlation analysis using the Spearman Rho test between chest X-ray and LUS results is shown in Table 2. The analysis showed a strong positive correlation with a correlation coefficient (r) of 0.772 and a p-value < 0.001 (Table 2). This indicates a significant strong relationship between chest X-ray and LUS results. The % agreement obtained was 96.4%, indicating a very high concordance between LUS and chest X-ray results, suggesting that LUS can be used as an alternative for diagnosing pneumonia.

TABLE 2: Correlation Test of Lung Ultrasound (LUS) with Chest X-ray.

Variable		Chest x-ray		% Agreement	Correlation (r)	p-value
		+	-			
Lung Ultrasound (LUS)	≥ 3	48 (97.9%)	1 (2.1%)	96.4%	0.722	<0.001*
	<3	1 (14.3%)	6 (85.7%			

Significant if p<0.05; correlation analysis using Spearman Rho test

The diagnostic test to determine the accuracy of LUS based on chest X-ray is presented in Table 3. The results showed a sensitivity of 98% (CI 95% 89.1%-99.9%), specificity of 85.7% (CI 95% 42.1%-99.6%), positive predictive value (PPV) of 98% (CI 95% 89.1%-99.9%), negative predictive value (NPV) of 85.7% (CI 95% 42.1%-99.6%), positive likelihood ratio of 6.86 (CI 95% 1.12-42.1), negative likelihood ratio of 0.023 (CI 95% 0.003-0.17), and accuracy of 88% (CI 95% 76%-94.8%).

TABLE 3: Accuracy of Lung Ultrasound (LUS) for Pneumonia.

Lung Ultrasound (LUS) Value (IK95%)	
Sensitivity	98 % (89.1%-99.9%)
Specificity	85.7 % (42.1%-99.6%)
Positive predictive value	98 % (89.1%-99.9%)
Negative predictive value	85.7 % (42.1%-99.6%)
Likelihood Ratio (+)	6.86 (1.12-42.1)
Likelihood Ratio (-)	0.023 (0.003-0.17)
Accuracy	88 % (76%-94.8%)

DISCUSSION

The average age was 52.79 ± 17.11 years. This finding is consistent with the study conducted by Valentino in the Intensive Care Unit at RSUD Arifin Achmad, Riau Province, which reported an average age of 53.56 ± 18.23 years (Valentino et al., 2020). Similarly, Pramono et al. (2021) found an average age of 54.34 ± 19.65 years in patients at RSUD Prof. Dr. Margono Soekarjo Purwokerto [21]. Data from Ylimartimo indicated that the median age in ICU was 57 years (range 45-70) [22]. Older age (>65 years) is associated with a longer stay in the ICU compared to younger age, and a higher incidence of hospital-acquired pneumonia (HAP) due to a weakened immune system [23]. Aydemir's study found the average age of HAP patients to be 70 ± 14.46 years, with a majority being male (73%) [24]. These findings differ from those of Widyati et al. and Aydemir & Hoşgün, which focused on older patients using lung ultrasound, leading to higher average ages.

As age increases, organ function declines, immune response weakens, and recovery slows. Additionally, although ICU admission reasons and consciousness levels may be similar between older and younger patients, older adults have less effective swallowing and coughing reflexes, leading to the accumulation of secretions in the lower respiratory tract and the risk of nosocomial pneumonia due to oropharyngeal bacterial colonization [25].

The study found that the majority of cases involved males (53.6%), similar to findings by Pramono et al. (2021) [21], Valentino et al. (2020) [26], Widyati et al. (2021) [23], and Ylimartimo et al. (2022) [22]. The most common reason for ICU admission among males was accidents. The most frequent underlying condition was trauma, present in 20 subjects (37.5%).

Males are more likely to be affected than females because their airways are smaller. Additionally, estrogen increases pulmonary surfactant levels in women, reducing airway resistance and increasing airflow, providing protection against lung diseases. The size of airways varies, with males having smaller airways than females. Different protective mechanisms also exist in men and women, with females having lower airway resistance and better lung conductivity, facilitating easier breathing and lung disease prevention [25].

Pneumonia can be caused by intrinsic factors (host-related) and extrinsic factors (external to the patient), such as surgery duration, elective or emergency nature of the surgery, use of a ventilator for ≥ 48 hours, and length of hospital stay before HAP. Cases of craniotomy for hematoma evacuation (EDH, SDH, ICH, SAH, and IVH) due to severe brain injury generally have worse outcomes than other causes. Jovanovic found a VAP incidence of 47% in trauma patients, and Kesinger reported a HAP incidence of 30% in post-trauma head injury patients [27,28].

Pneumonia pathogens can vary and include monobacterial and multibacterial infections. Studies from South Korea identified Staphylococcus aureus (45.7%) as a common pathogen, while Acinetobacter spp. (44.4%) was common in India. Similar data from Indonesia showed Acinetobacter spp. (38.7%) and Klebsiella pneumonia (25%) as the most frequent pathogens causing pneumonia in ICUs [26].

Trauma stimulates the sympathetic nervous system, releasing catecholamines that suppress the immune system, making patients susceptible to infection. Other factors predisposing brain injury patients to HAP include a full stomach at the time of trauma, leading to aspiration, and other concurrent injuries (e.g., abdominal or musculoskeletal trauma), hindering patient mobility and extending the hospital stay [27].

Lopez-de-Andrez et al. found higher postoperative pneumonia incidence in non-diabetic compared to diabetic patients. Chronic systemic diseases like type 2 diabetes, heart disease, and CKD reduce immune response, increasing infection risk. In patients with pre-existing lung disease or trauma, decreased immune response and damaged lung tissue facilitate bacterial infiltration and infection [29].

The average BMI was 23.17 ± 3.58 kg/m^2. This result aligns with Aydemir and Hoşgün (2022) [24], who reported an average BMI of 22.41 ± 4.55. BMI influences pneumonia occurrence, with obesity increasing pneumonia incidence by 3.44 times (CI 95% 0.7-14.5), and a BMI < 18 increasing pneumonia risk by 2.45 times (CI 1.98-4.56) [25,30].

Pneumonia confirmation via chest X-ray was found in 48 subjects (85.7%), while ultrasound confirmed pneumonia in 49 subjects (87.5%). According to the WHO, typical pneumonia features include consolidation and infiltrates >2.5 mm in diameter or pleural infiltration (pleural effusion). Pneumonia with infiltrates and pleural effusion is easily identified on chest X-rays; in studies, infiltrates were found in 71% of 137 subjects, while lung ultrasound detected them in 83% [20].

The study showed a strong positive correlation ($r=0.772$; $p<0.001$) between lung ultrasound and chest X-ray. Lung ultrasound has high diagnostic accuracy for pneumonia. Stadler et al. reported that lung ultrasound when performed by less trained doctors, could detect lung consolidation as well as chest X-ray [31]. Amatya et al. found lung ultrasound more sensitive (98.4%) for consolidations >1 cm compared to chest X-ray (87.1%) [15].

Lung ultrasound uses ultrasound waves above 20,000 Hz. Electrical waves generated by a generator are converted into acoustic energy by a transducer, which is then transmitted to the examined object. Some waves are reflected while others penetrate the tissue. Different tissue densities produce varied reflections based on impedance. Acoustic impedance is the resistance encountered by ultrasound waves passing through tissue [32].

During thoracic ultrasound, acoustic waves travel from superficial to deep tissues, with different impedance levels creating varying echogenicity. Echogenicity is the tissue's ability to reflect ultrasound waves. Structures with high echogenicity appear white, while those with low echogenicity appear black. Structures are classified as hyper-echoic (white on screen), hypo-echoic (gray on screen), and anechoic (black on screen) [33].

In pneumonia, inflamed lungs with fluid-filled alveoli change impedance as air is replaced by fluid, eliminating parallel A-line patterns and creating B-line patterns. Continued hepatisation leads to lung deaeration, visualized on thoracic ultrasound as liver-like parenchyma. Unlike atelectasis, real-time movement of air in bronchi and alveoli and Doppler-detected blood flow are still present in pneumonia [34].

The sensitivity of lung ultrasound for pneumonia diagnosis was 98% (CI 95% 89.1%-99.9%), specificity 85.7% (CI 95% 42.1%-99.6%), PPV 98% (CI 95% 89.1%-99.9%), NPV 85.7% (CI 95% 42.1%-99.6%), positive likelihood ratio 6.86 (CI 95% 1.12-42.1), negative likelihood ratio 0.023 (CI 95% 0.003-0.17), and accuracy 88% (CI 95% 76%-94.8%). The % agreement was 96.4%, indicating high concordance between lung ultrasound and chest X-ray, making lung ultrasound a viable alternative for pneumonia diagnosis. This result is consistent with Touw et al. (2015), who found high LUS accuracy compared to CT Scan for pleural effusion (sensitivity 94%, specificity 97%), alveolar consolidation (sensitivity 90%, specificity 98%), interstitial syndrome (sensitivity 93%, specificity 93%), complete pneumothorax (sensitivity 100%, specificity 95%), and occult pneumothorax (sensitivity 95%, specificity 100%) [35].

LUS sensitivity for pneumonia diagnosis using BLUE protocol ultrasound findings (PLAPS, AB profile, C profile, B' profile, or Local B lines) was 82% (CI 95% 78-89%), specificity 98% (CI 95% 97-99%), PPV 96% (CI 95% 88-98%), and NPV 94% (CI 95% 92-96) [34].

This study's results can serve as an additional reference for diagnosing pneumonia using lung ultrasonography (LUS) and explaining disease risks to suspected pneumonia patients, allowing for prophylactic antibiotic treatment. Further research with larger sample sizes and from various regions in Indonesia and worldwide is needed to establish diagnostic thresholds for lung ultrasonography. A limitation of this study is patients with thick fat folds > 5 cm, it is difficult to obtain good results in observations.

CONCLUSION

There is a strong positive correlation ($r=0.772$; $p<0.001$) and very high agreement (96.4%) between lung ultrasound (LUS) and chest X-rays in diagnosing pneumonia in patients in the intensive care unit at RSUP Prof. Dr. IGNG Ngoerah Denpasar. Thus, lung ultrasound (LUS) can be used as a substitute for chest X-rays in diagnosing pneumonia.

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