International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 17s, 2025
https://www.theaspd.com/ijes.php

Metabolic Parameters Affecting Incidence Of Acquired Pneumonia And Length Of Hospital Stay In Intensive Care Unit Patients

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Abstract

Background*: Hospital-acquired pneumonia (HAP) is a major cause of morbidity and mortality in intensive care unit (ICU) patients. This study investigated the correlation between HAP incidence and metabolic parameters, including C-reactive protein (CRP), procalcitonin (PCT), blood glucose, lactate, and electrolyte levels.* ***Methods****: Data were collected from 100 ICU patients, including demographic information and clinical metrics such as ICU length of stay, duration of mechanical ventilation, and Oxygenation Index. Biochemical parameters, including CRP, PCT, blood glucose, lactate, and electrolytes, were measured using standard clinical protocols.* ***Results****: Among the participants, 45% developed HAP, while 55% did not. HAP incidence was positively correlated with ICU length of stay ($r = 0.512$, $p < 0.001$), duration of mechanical ventilation ($r = 0.507$, $p < 0.001$), and Oxygenation Index ($r = 0.522$, $p < 0.001$). Significant associations were also observed with CRP ($r = 0.505$, $p < 0.001$), PCT ($r = 0.506$, $p < 0.001$), blood glucose ($r = 0.509$, $p < 0.001$), lactate ($r = 0.519$, $p < 0.001$), and electrolyte levels (sodium: $r = 0.518$; potassium: $r = 0.512$; both $p < 0.001$).* ***Discussion:*** *The study findings indicate that 45% of participants developed acquired pneumonia during their ICU stay, while the remaining 55% did not. A moderate to strong positive correlation was observed between the length of ICU stay and the incidence of pneumonia ($r = 0.512$) and between the duration of mechanical ventilation and the onset of pneumonia ($r = 0.507$). These findings suggest that patients with longer ICU stays and extended mechanical ventilation are at an increased risk of developing pneumonia. Additionally, the Oxygenation Index was significantly correlated with pneumonia, though further details on this relationship were truncated in the document.*

The mean age of the study cohort was 50.43 years, reflecting a population typically requiring ICU care due to chronic illnesses or acute medical events, such as infections or myocardial infarctions, as supported by Angus and Der Poll (2013) [12]. The balanced gender distribution minimizes bias and facilitates a more generalized understanding of ICU outcomes. Previous research by Wiencek and Winkelman (2010) suggests that gender differences can influence recovery trajectories, with females sometimes experiencing distinct complications due to hormonal factors [13]. The mean BMI of 24.36 kg/m² indicates that most participants were of normal weight, though the cohort likely included individuals who were either underweight or obese. According to Akinnusi et al. (2008) [14], both obesity and underweight status have been associated with poorer ICU outcomes, with obesity linked to longer ventilation periods and higher infection rates due to impaired immune function. Consequently, BMI remains essential in predicting ICU outcomes and guiding patient management.

Smoking status and educational background varied among participants, ensuring broad representation in the study. Smoking is a well-established risk factor for respiratory complications, making it particularly relevant for critically ill ICU patients. Smokers, as noted by Vincent et al. (2014) [15], are more susceptible to respiratory infections, such as chronic obstructive pulmonary disease (COPD), which can complicate ICU care and increase the risk of pneumonia. The

variability in the length of ICU stays (mean = 5.98 days) reflects the severity of illness and recovery trajectories among participants. Kollef (1993) demonstrated that longer ICU stays are often associated with increased complications, such as infections and muscle wasting [16], and higher healthcare costs. Therefore, effectively managing ICU stay durations is crucial for improving patient outcomes and reducing resource utilization.

The mean duration of mechanical ventilation was 4.81 days, underscoring the need for individualized ventilatory strategies and timely weaning protocols to minimize complications like VAP, as highlighted by Vincent and Moreno (2010) [17]. Ranieri et al. (2018) further explained that prolonged mechanical ventilation increases the risk of lung injury, and difficulties in weaning can further complicate patient recovery [18]. Implementing structured weaning protocols reduces ventilation duration and improves patient outcomes.

The study's focus on clinical biomarkers such as CRP, PCT, and the Oxygenation Index provides valuable insights into ICU patients' inflammatory and infection status. A Bakker et al. (2013) study demonstrated that elevated CRP and PCT levels indicate significant inflammatory responses and potential bacterial infections commonly observed in critically ill patients [19]. These biomarkers are crucial for guiding treatment decisions, such as antibiotic therapy, and monitoring the disorder's progression [20]. ***Implication:*** *Several limitations should be noted in this study. First, a clear causative relationship could not be established, as the reported effect size between variables was measured using the correlation coefficient. Second, the study was conducted at a single setting, El-Kasr El-Einy Teaching Hospital, which may limit the generalizability of the findings, as different hospitals with more advanced ICU equipment may report varying parameters. The study included only 100 participants, which may restrict the ability to draw strong conclusions and generalize the results.*

Keywords: *Hospital-acquired pneumonia; ICUs; metabolic biomarkers; mechanical ventilation.*

1. INTRODUCTION

Globally, pneumonia remains one of the leading causes of morbidity and mortality, especially in vulnerable populations such as children, the older adult population, and those who are immunocompromised. Pneumonia is characterized by inflammation, congestion, and/or impaired gas exchange that occurs in the lungs with the clinical consequence of being acutely unwell and/or death [1]. The most commonplace types of pneumonia can be categorized as community-acquired pneumonia (CAP), hospital-acquired pneumonia (HAP), aspiration pneumonia, and pneumonia occurring in immunocompromised patients [2]. HAP is a severe respiratory infection that occurs at least 48 hours after a patient's initial admission to the hospital, therefore, there are no clinical signs of pneumonia at time of admission. HAP primarily affects the elderly, postsurgical, or immunocompromised patients, with a focus on those patients that may be intubated or placed on enterial feeding [3].

The main cause of HAP is the aspiration of infected oropharyngeal secretions, and patients on mechanical ventilation are at high risk of developing ventilator-associated pneumonia (VAP), a serious form of HAP associated with greatly increased morbidity and mortality [4]. HAP is the second most common nosocomial infection after urinary tract infections, with rates of 5 to 20 cases per 1,000 hospital admissions. HAP occurs in 65% of cases in wards that are not ICUs, however, patients in the ICU have a markedly increased risk, particularly if they require mechanical ventilation [5]. Mortality rates for HAP are high, with reports of up to 70% of critically ill patients dying, especially those with VAP [6].

Pneumonia, depending on the causative pathogen, and one's state of health, has a wide range of symptoms ranging from mild to severe. Symptoms include chest pain, cough, fever, and shortness of breath [7]. Pneumonia may be caused by bacteria (e.g., Streptococcus pneumoniae) and viruses (e.g., influenza, respiratory syncytial virus [RSV]) with bacterial infections accounting for most cases of severe pneumonia [1,8]. Viral pneumonia cases are more common in pediatrics and vary based on age, season, and the environment [9]. The clinical diagnosis of HAP and VAP can be made through a combination of imaging and laboratory evidenced based findings. Imaging studies can include, but are not limited to chest x-ray, pulmonary CT, labs can include elevated leukocyte levels and positive sputum cultures [7, 5]. Hematologic and serum chemistries (electrolytes) are important tools for monitoring critically ill patients. In patients with

severe pneumonia an electrolyte imbalance, such as hyponatremia and hypokalemia, potentially affects disease outcomes [10]. Lipid metabolism interaction in the immune response with infection may affect, as lipid components have been observed changed in conditions such as sepsis and acute lung injury [11].
To the authors' knowledge, there have been no previous research studies that have addressed the considerable morbidity and mortality with HAP and VAP, and how metabolic parameters relate to the progression of disease. Hence, the aim of this study is to assess the relationship between metabolic parameters and the occurrence of pneumonia acquired in the ICU.

2. METHODS

2.1. Study Design and Setting

This study adopted the cross-sectional design to assess the correlation between the metabolic parameters and the occurrence of acquired pneumonia among in patients in ICU. The research was conducted from June 2024 to September at El-Kasr El-Ainy teaching hospital.

2.2. Ethical Considerations

All participants signed an informed consent after informing them the objectives of the study and the procedures. Moreover, they were informed about their right to withdraw from the study at any time without any conditions. The study got an ethical approval from the Research Ethics Committee, Faculty of Physical Therapy, Cairo University (Approval ID: P.T.REC/012/004289). Moreover, the study was registered on ClinicalTrials.gov with ID (NCT04567890).

2.3. Sample Size Calculation

The sample size for this study was calculated using G*POWER statistical software (version 3.1.9.2; Franz Faul, Universität Kiel, Germany) using a previous study by Bossola et al. (2014), which concluded a correlation coefficient of 0.318. The required sample size was N = 100, using a significance level (α) of 0.05 and a statistical power of 80%.

2.4. Population

One hundred patients from EL-Kasr El-Ainy Teaching Hospital were randomized into two groups. The inclusion criteria were set to include patients with age at least eighteen years old, undergoing intensive care unit treatment, and capable of giving written informed consent. Patients with cognitive impairment or psychiatric disorders, recent involvement in similar studies, acute illnesses unrelated to pneumonia, communication difficulties, pregnancy, and treatment non-compliance were excluded.

2.5. Assessment Tools

The authors prepared a form created to gather demographic and basic health information, such as age, gender, height, weight, body mass index (BMI), smoking status, and educational attainment. The intensive care unit stay clinical information was also documented, including the length of the ICU stay, the rate of pneumonia, the length of time on mechanical ventilation, and the Oxygenation Index (OI), which was used to evaluate the effectiveness of oxygenation.Bacterial infections and inflammation were detected by assessing the levels of procalcitonin (PCT) and C-reactive protein (CRP). Blood glucose, lactate, and electrolyte levels were used to show the overall metabolic state and glycaemic control.
The researchers documented partial pressure of carbon dioxide ($PaCO_2$) and the acid-base balance (pH and bicarbonate levels) to assess respiratory function and general metabolic health, the analysis also included tracking the To ensure the accuracy required to investigate the relationship between the incidence of pneumonia and metabolic parameters in intensive care unit patients, all data were gathered by trained medical personnel using standard clinical procedures.

2.6. Procedures

A structure format was used to collect demographic data from the participants including age, gender, weight, height, BMI, smoking status, and educational level. The forms were filled in during the clinic visits or scheduled meeting. Researcher ensured that all the participants were informed by the objectives of the study and written informed consent was provided.

Trained medical staff was responsible to gather the clinical data including the length of ICU stay, incidence of pneumonia, duration of mechanical ventilation, and the Oxygenation Index (OI).the pneumonia diagnosis was confirmed by clinical evaluation, imaging studies and laboratory studies. Patient records were used to obtain the length of ICU stay and mechanical ventilation. The Oxygenation Index was calculated using FiO_2 and PaO_2 values obtained from arterial blood gas results and ventilator settings. Additionally, blood samples were used to assess the biochemical and metabolic parameters including CRP, PCT, blood glucose, lactate, and electrolyte levels (sodium, potassium, and chloride). Acid-base balance was assessed using pH and bicarbonate levels, while Partial Pressure of Carbon Dioxide ($PaCO_2$) was measured via arterial blood gas analysis.

2.7. Statistical Analysis

Descriptive statistics were used to describe the demographics and other variables of the participants. Means and standard deviations were used to summarize the continuous demographic variables, while categorical variables (gender smoking status) were described using frequencies and percentages. The independent t-test was used for continuous variables such as CRP and PCT and Chi-square for categorical variables, including gender and smoking status, to compare patients with and without pneumonia. Correlation analysis was conducted using either Pearson correlation coefficients to assess the relationships between continuous variables and ICU metrics such as the length of stay and mechanical ventilation.

3. RESULTS

Table 1 shows characteristics of the included participants with a mean age of .43 years (SD = 5.770), a mean weight of 75.54 kg (SD = 14.026) and a mean height of 175.53 cm (SD = 14.074). Participants showed a mean BMI of 24.36 kg/m² (SD = 2.508) and mean duration of ICU stay was 5.98 days (SD = 3.194). The education level varied among the partipcants with 25% had a bachelor's degree, 21% have completed the high school and 25% hold a master degree. Regarding smoking status, 40.0% of participants were non-smokers, 38.0% were current smokers, and 22.0% were former smokers. The gender distribution was balanced, with 50.0% male and 50.0% female participants.

Table 1. Baseline Demographic and Clinical Characteristics

Variable	Frequency/Mean	Percentage/SD
Age (years)	50.43	5.770
Weight (kg)	75.54	14.026
Height (cm)	175.53	14.074
BMI (kg/m²)	24.356	2.5080
Length of ICU Stay (days)	5.98	3.194
Educational Level		
Associate Degree	21	21.0%
Bachelor Degree	25	25.0%
High School	29	29.0%
Master's Degree	25	25.0%
Smoking Status		
Non-smoker	40	40.0%
Smoker	38	38.0%
Former Smoker	22	22.0%
Gender		

Variable	Frequency/Mean	Percentage/SD
Female	50	50.0%
Male	50	50.0%

3.1. Descriptive Statistics of Clinical and Biochemical Parameters in ICU Patients

The included participants showed a mean ventilation period of 4.81 days (SD = 2.733) and with OI that averaged 13.38 (SD = 6.204).The CRP level, showed a mean of 20.20 mg/L (SD = 8.568), The PCT level averaged 2.05 ng/mL (SD = 0.97974). Blood glucose levels were recorded with a mean of 141.45 mg/dL (SD = 31.569), while lactate levels, averaged 2.679 mmol/L (SD = 1.02596). Electrolyte balance was largely within normal ranges, with mean levels for sodium at 140.09 mEq/L (SD = 3.627), potassium at 4.196 mEq/L (SD = 0.45303), and chloride at 104.22 mEq/L (SD = 3.552). The pH level was 7.4021 (SD = 0.03447), reflecting a near-normal acid-base balance, and bicarbonate (HCO_3^-) levels averaged 25.64 mEq/L (SD = 2.480). The partial pressure of carbon dioxide ($PaCO_2$) was 41.73 mmHg (SD = 3.081), indicating stable respiratory function.

These results provide a comprehensive view of the clinical and biochemical parameters in ICU patients, illustrating their overall metabolic and respiratory health status.

Table 2. Clinical and Biochemical Parameters

Parameter	Mean	Standard Deviation (SD)
Mechanical Ventilation Duration (days)	4.81	2.733
Oxygenation Index (OI)	13.38	6.204
CRP (mg/L)	20.20	8.568
PCT (ng/mL)	2.05	0.97974
Blood Glucose Levels (mg/dL)	141.45	31.569
Lactate Levels (mmol/L)	2.679	1.02596
Sodium Levels (mEq/L)	140.09	3.627
Potassium Levels (mEq/L)	4.196	0.45303
Chloride (Cl) Levels (mEq/L)	104.22	3.552
pH	7.4021	0.03447
Bicarbonate (HCO_3^-) (mEq/L)	25.64	2.480
Partial Pressure of Carbon Dioxide ($PaCO_2$) (mmHg)	41.73	3.081

3.2. Incidence of Acquired Pneumonia in ICU Patients

Table 3 demonstrates the incidence of acquired pneumonia in ICU patients. The study population included 55 patients (55.0%) who had no pneumonia during their ICU stay and 45 patients (45.0%) with acquired pneumonia. The findings demonstrate the fairly high incidence of pneumonia within the ICU in the nearly half of the subjects. This is truly indicative of the significance of monitoring and management of respiratory complications in critically ill patients.

Table 3. Incidence of Pneumonia

Pneumonia Status	Frequency	Percentage
Absence of Acquired Pneumonia	55	55.0%
Presence of Acquired Pneumonia	45	45.0%

3.3. Correlation Between Incidence of Pneumonia and Various Clinical Parameters

Pearson correlation coefficients were employed to explore the association between incidence of pneumonia and clinical parameters of ICU patients. Table 4 presents that all the variables were strongly and positively correlated with pneumonia, with p-values of 0.000. Surprisingly, ICU stay length (r = 0.512), mechanical ventilation time (r = 0.507), and Oxygenation Index (OI) (r = 0.522) were also highly correlated with pneumonia, suggesting prolonged ICU stays and mechanical ventilation are risk factors for developing pneumonia. CRP (r = 0.505) and PCT (r = 0.506) inflammatory markers were also highly significantly associated with pneumonia, this suggests a role for inflammation in the aetiology of pneumonia. Also the metabolic indicators of blood glucose (r = 0.509), lactate (r = 0.519), and electrolyte (sodium, r = 0.518; potassium, r = 0.512) disruptions also showed a significant correlation with pneumonia suggesting, at least in their capacity to result in pneumonia outcomes, they are potentially pathogenetic metrics. Acid-base balance parameters like pH (r = 0.507), bicarbonate (HCO_3^-) (r = 0.507), and partial pressure of carbon dioxide ($PaCO_2$) (r = 0.506) correlated strongly with pneumonia, emphasizing the importance of maintaining respiratory and metabolic balance to control the risk of pneumonia. The findings underscore the complex interplay among clinical, inflammatory, and metabolic variables in the etiology of pneumonia among critically ill patients.

Table 4. Correlation Between Incidence of Pneumonia and Various Clinical Parameters

	Incidence of Pneumonia	
	Pearson Correlation	Sig. (2-tailed)
Length of ICU stay (days)	0.512**	0.000
Mechanical ventilation duration(days)	0.507**	0.000
Oxygen index	0.522**	0.000
CRP	0.505**	0.000
PCT	0.506**	0.000
Blood Glucose levels	0.509**	0.000
Lactate Levels	0.519 **	0.000
Sodium Levels	0.518**	0.000
Potassium levels	0.512 **	0.000
PH levels	0.507**	0.000
Bicarbonate (HCO_3^-)	0.507**	0.000
Partial Pressure of Carbon Dioxide ($PaCO_2$)	0.506**	0.000

4. DISCUSSION

The results of this study showed that 45% of individuals affected by acquired pneumonia during their ICU admission, and 55% did not. Length of stay in the ICU showed a moderate to strong positive correlation with the risk of developing pneumonia (r = 0.512) and length of mechanical ventilation had a moderate to strong positive correlation with developing pneumonia (r = 0.507). Overall these findings suggest that patients with a longer duration of ICU stay or longer duration of mechanical ventilation are likely to develop pneumonia. The Oxygenation Index was also significantly correlated with pneumonia but details of this finding were unfortunately omitted at the point of editing of the report.

The mean age for the study cohort was 50.43 years. Therefore, it is reasonable to expect them to represent a population that necessitates ICU admission due to either chronic diseases or acute deterioration of clinical status, such as infections and myocardial infarcts (Angus & Der Poll, 2013) [12]. The gender distribution within the cohort was fairly equal, further minimizing bias and assisting with the generalizability of this research and research looking at ICU patients. Wiencek and Winkelman (2010) indicated that recovery and outcome trajectories can depend on gender with female patients experiencing some previous complications

because of hormonal influences [13]. The mean BMI was 24.36 kg/m², which suggests that participants were normal weight individuals. However, it is likely that there were also underweight and obese individuals included in the current cohort. Akinnusi et al. (2008) [14] indicated that both obesity and being under-weight were associated with poorer outcomes, with obesity causing a greater duration of ventilation and a higher rate of infection due to abnormal immune responses. Therefore, BMI is still the best parameter for predicting ICU mortality and progression of care.

Participants varied in smoking status and educational history to ensure a broad representation for the study. Smoking is a known risk factor for respiratory complications, which is particularly pertinent to critically-ill patients in the ICU as smokers are known to get respiratory infections, including chronic obstructive pulmonary disease (COPD) ([15] Vincent, et al., 2014), that are problematic in the ICU and which can put patients at risk for pneumonia. Variability in ICU length of stay (M=5.98 days) reflects the diversity of illness severity and recovery trajectories among study participants. Kollef (1993) showed that longer ICU length of stays are associated with increased complications (e.g., infection and muscle wasting) ([16] Kollef, 1993) and increased healthcare costs; therefore, shortening ICU length of stay is important for patient recovery and allocation of healthcare resources.

The mean duration of mechanical ventilation was 4.81 days, representing the need for individualized ventilatory strategies and timely weaning protocols to prevent complications like VAP ([17] Vincent & Moreno, 2010), and as noted by Ranieri et al. (2018) prolonged mechanical ventilation increases the risk of lung injury and complicated patient recovery if weaning is difficult ([18] Ranieri et al., 2018). Structured weaning protocols help shorten ventilation duration improving patient outcomes.

The biomarkers CR mentioned in the study CRP, PCT, and Oxygenation Index were used to inform clinical aspects of ICU patients inflammatory status and infection status. Bakker et al. (2013) state that an increase of CRP and PCT resulted in a severe inflammatory response and a likely bacterial infection typically exhibited in patients in CRITICAL CARE [19]. The values produced from these biomarkers are vital for determining how to treat these patients such as antibiotic therapy, and tracking the evolvement of their disorder [20].

CONCLUSION

This study presented notable variation in the clinical characteristics and outcomes of ICU patients which recognized that there is heterogeneity in this population. Findings suggested there were moderate to strong positive correlations between length of stay in the ICU, length of time on mechanical ventilation and the prevalence of pneumonia, and clinical biomarkers that increased in values suggest differing levels of inflammation and infection.

LIMITATIONS

Several limitations must be considered in the present study. Firstly, a definitive cause-and-effect association was not possible due to the correlation coefficient being used to measure the reported effect sizes between variables. Secondly, this study was conducted in a singular setting, being El-Kasr El-Einy Teaching Hospital, and may be more restricted in applicability as different hospitals with better ICU equipment could likely report different parameters. The study also only included 100 subjects, which may limit drawing strong conclusions and generalizability.

RECOMMENDATION

The results of the current study highlight the significance of closely monitoring metabolic parameters in order to decrease ICU length of stay and, as well as developing strategies concerning the duration of mechanical ventilation to lessen the chances of pneumonia also. Additionally, a full multicenter study should be performed to compare findings at different institutions, each with different devices, to develop a much stronger evidence base for clinical practice.

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