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Bacterial Profiles and Their Associations with SOFA Scores and Procalcitonin Levels in Patients with Culture-Positive Pneumonia: A Retrospective Study in an Internal Medicine High Care Unit

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ABSTRACT

Background: Pneumonia is a leading cause of morbidity and mortality in hospitalized patients. Identifying the bacterial etiology is crucial for effective management. The Sequential Organ Failure Assessment (SOFA) score is a valuable tool in evaluating the severity of organ dysfunction in these patients. Elevated levels of procalcitonin can indicate bacterial infection and assist in guiding antibiotic therapy.

Purpose: This study aims to explore the relationship between the bacterial profile of sputum cultures, SOFA scores, and procalcitonin levels in hospitalized pneumonia patients.

Methods: This research used a retrospective design with a total sampling of 68 pneumonia patients who were hospitalized in internal medicine High Care Unit from January to June 2024. Data was obtained by Electronic Medical Record.

Results: The results showed that the highest number of sputum culture results were gram-negative bacteria (80.88%), which was dominated by Acinetobacter Baumannii (25%), followed by Klebsiella P. (17.6%), E. Coli (13.2%), and Pseudomonas aeruginosa (13.2%). On the examination of antibiotic sensitivity, it was found that Sulfamethoxazole-trimethoprime has a high sensitivity (76.5%) for Acinetobacter Baumanii, and Amikacin high sensitivity (100%) for Klebsiella P, and E.Coli. The correlation between the bacterial profile and the SOFA score was not significant p= 0.942, while the correlation between the bacterial profile and procalcitonin levels showed a significant relationship with p= 0.001.

Conclusion: Procalcitonin levels are significantly associated with bacterial pneumonia but cannot specifically identify the type of bacteria.

Keywords **:** Bacterial Pneumonia, Procalcitonin, SOFA Score, Sputum Culture

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BACKGROUND

Pneumonia is an inflammation that occurs in the lung perenchyma caused by an infectious agent (Assefa et al., 2022). The bacteria that cause infection in each place, both in the community and in treatment wards, vary greatly (Melo et al., 2024). Differences in the characteristics of pneumonia bacteria influence the therapy given, if the identification of bacteria is not appropriate, it will potentially worsen the patient's condition (Bramantono et al., 2021).

Pneumonia causes high rates of morbidity and mortality in hospital treatment rooms. This occurs if pneumonia is not treated immediately and will develop into sepsis, thus worsening the clinical condition and worsening the patient's prognosis (Mizgerd, 2018). The mortality rate that occurs in outpatients is 2%, inpatients is 5-20% and in intensive care >50% (Purwitasari et al., 2017). The death rate that occurs due to pneumonia increases with increasing age, nutrition, symptoms and comorbid diseases (Park et al., 2022). The death rate that occurs due to pneumonia is increasing every year, making it a world health problem (Jiang et al., 2018).

The prevalence of death rates for pneumonia patients varies from place to place. Based on data from the Indonesian Ministry of Health's (2018), 4% of the Indonesian population is diagnosed with pneumonia, and it is the 9th leading cause of death (Purwitasari et al., 2017). Microorganisms that cause pneumonia will enter the lung tissue through the upper respiratory tract, enter the bronchioles and alveoli and then cause a severe inflammatory reaction and produce edema fluid which is rich in protein in the alveoli and interstitial tissue (Irawan et al., 2019).

Pneumococcal bacteria can spread through the pores of kohn from alveoli to alveoli throughout the lobe segments. Red hepatization occurs through the penetration of erythrocytes and some leukocytes from the pulmonary capillaries. The alveoli and septa become filled with edema fluid containing erythrocytes and fibrin and relatively few leukocytes, causing the alveolar capillaries to dilate, thereby reducing the surface area of the alveoli for the exchange of oxygen and carbon dioxide (Tasaka et al., 2022).

Quick and accurate treatment needs to be carried out so that this process does not continue and become sepsis which worsens the patient's condition (Gebre et al., 2021). Carrying out initial screening for the bacterial profile that causes infection is important to reduce patient morbidity and mortality rates during hospitalization (Yulia et al., 2020). Microbiological examination procedures require relatively varying amounts of time depending on the type of sample being examined (Truant, 2016). Apart from that, the collection procedure, location and number of samples greatly influence the results of the culture examination (Carroll et al., 2019).

Antibiotic therapy given while waiting for the results of microbiological culture examination has the potential to experience inappropriate/irrational use of antibiotics so that it has no effect on the patient's condition (Yulia et al., 2020). So other data is needed to support the rationale for antibiotic therapy given apart from microbiological results, namely clinical and laboratory parameters. Clinical and laboratory identification of worsening patient conditions can be measured using the Sequential Organ Failure Assessment (SOFA) value, which is a score to assess the degree of organ damage caused by infection/sepsis (Iskandar & Siska, 2020).

Apart from that, to determine the level of spread of infection, you can look at the patient's Procalcitonin levels (Sungurlu & Balk, 2018). Supporting data such as SOFA scores and procalcitonin levels need to be measured to support the rationalization of therapy given to pneumonia patients (Yu et al., 2019). The high level of infection in pneumonia patients has the potential to cause organ damage which will worsen the patient's condition (Raess et al., 2021). Patients whose procalcitonin values are known to be high can be confirmed as having an infection, but empirically it is not known for certain which bacteria are causing the infection (Tripon et al., 2021).

Research by Yu et al (2019) shows that procalcitonin levels in patients with infections have a significant relationship with SOFA, the higher the procalcitonin level, the higher the SOFA score. This can be a reason to start antibiotic therapy. In line with previous phenomena and theories, a combination of SOFA scores and procalcitonin levels can be a consideration for providing early antibiotic therapy. Providing appropriate antibiotics can reduce infection rates by reducing patient procalcitonin levels (Sungurlu & Balk, 2018). Apart from that, the risk of organ damage will also decrease and patients will gradually improve, thereby reducing the risk of morbidity and mortality (Saeed et al., 2019).

However, the problem related to the type of antibiotic given in the inpatient room is the mismatch between the antibiotic and the type of bacteria that causes infection due to procedurally waiting for the results of the patient's sputum culture. As a solution, it is necessary to identify the mapping of the type of bacteria that causes infection in an inpatient room so that it can become a reference for starting the right type of antibiotic. In addition to the bacterial type profile, the patient's clinical condition and procalcitonin levels need to be identified to consider appropriate antibiotic administration.

Based on the theory and phenomena previously explained where the relationship between the bacterial profile resulting from microbiological culture examination and the SOFA score and blood procalcitonin levels in pneumonia patients cannot yet be explained, the researchers will identify the relationship between the bacterial profile and the SOFA score and procalcitonin levels in pneumonia patients, Since the prompt administration of definitive antibiotic therapy is essential, sputum culture results are crucial for patients with pneumonia; however, as this test is time-consuming, parameters are needed to predict the bacterial type.

This study aims to demonstrate the association of parameters such as procalcitonin, SOFA scores, and the Pneumonia Severity Index (PSI) with the prediction of the bacterial type. in addition to the results of the sputum culture will be used as a mapping of the bacteria present at the research location

METHODS

Design and Setting

This was a retrospective, single-center observational study conducted in the Internal Medicine High Care Unit of Dr. Soetomo General Academic Hospital, Surabaya, Indonesia. Medical records of patients hospitalized with pneumonia between January and June 2024 were reviewed.

Participants and Sampling

Sampling technique with total sampling method. Fit of the entire population sample that meets the inclusion and exclusion criteria. A total of 68 patients were in the present study. Eligible criteria were patients pneumonia with PSI score >70, sputum culture results, procalcitonin values, and SOFA scores. Exclusion criteria were that sputum culture results did not come out or no bacterial cultures were found, and there were no procalcitonin results.

Sputum specimens were processed for bacterial culture according to the standard operating procedures of the Clinical Microbiology Laboratory of Dr. Soetomo General Academic Hospital, Surabaya, Indonesia. Before microbiological culture, the adequacy of expectorated sputum specimens was assessed microscopically based on the presence of squamous epithelial cells (SEC) and polymorphonuclear neutrophils (PMNs). According to the institutional laboratory standard operating procedure, an acceptable sputum specimen was defined as having fewer than 10 squamous epithelial cells per low-power field using a 10× objective and more than 10 PMNs per squamous epithelial cell (PMN-to-SEC ratio >10:1).

These criteria were used to minimize the inclusion of specimens predominantly contaminated by oropharyngeal material. The use of SEC and PMN assessment is consistent with established approaches for evaluating the adequacy of expectorated sputum for bacterial culture. Murray and Washington demonstrated that specimens containing fewer than 10 SEC per low-power field more closely resembled lower respiratory tract specimens, whereas specimens with more than 10 SEC were more frequently associated with oropharyngeal flora. Martin et al. subsequently demonstrated the value of evaluating PMNs and SEC together when determining the suitability of expectorated sputum for bacteriological examination (Murray & Washington, 1975; Martin et al., 1978).

The institutional criteria were therefore described as microscopic sputum adequacy criteria rather than being designated as a complete Bartlett score or as a formal Murray–Washington grading system, because the institutional standard operating procedure uses its own specific acceptance criteria. Bacterial identification was based on the microbiological culture results documented in the medical record. Antimicrobial susceptibility testing was performed using the broth microdilution method with the BD Phoenix Automated Microbiology System according to the manufacturer's standard procedures and applicable Clinical and Laboratory Standards Institute recommendations.

Instruments and Data Collection

Data were collected through the Electronic Medical Record (EMR) in the main computer of the internal Medicine High Care Unit. There were 5 variables from the EMR in addition of demographic data, including: 1) PSI score data obtained from assessments, diagnoses, or Integrated Patient Progress Notes by medical doctors. 2) Bacterial growth was found by microbiological examination. 3) SOFA score was found from assessments and diagnoses by medical doctors. 4) Procalcitonin data is obtained through the clinical pathology column which contains a history of laboratory results. 5) Length of stay patients in High Care Unit, obtained from patient registration, medical resumes and Integrated Patient Progress Notes.

The Pneumonia Severity Index contains scores of demographic data, physical examination, and laboratory/radiological results. The results are divided into 5 risk classes (Fine

et al., 1997). Sequential Organ Failure Assessment (SOFA) consists of the Respiration, by calculating PaO2/FiO2. The nervous system, using by the GCS scale, and cardiovascular, using MAP and the amount of vasopressor needed. Kidneys by calculating creatinine or the amount of urine excreted. Liver, by calculating the amount of bilirubin. Coagulation, by counting the number of platelets/thrombocytes (Vincent et al., 1998).

Data Analysis

We used SPSS (Statistical Package for Social Sciences, SPSS, inc., Chicao, IL, USA) for windows 25.0 program for the statistical analysis. We used Kolmogorov-Smirnov to evaluate the distribution and homogeneity of variables. Chi-Square test for significance of the relationship between bacterial profile to SOFA score and Procalcitonin level. The Receiving Operating Curve (ROC) test was carried out to determined the cut-off point for gram-negative bacteria on the SOFA score, procalcitonin, and PSI score.

Ethical Considerations

This research was approved by ethical test from the Helath Research Ethics Committee of Dr. Soetomo General Academic Hospital Surabaya, East Java, Indonesia. (protocol no: 1605/LOE/301.4.2/III/2024).

RESULTS

Table 1. Baseline characteristics of the patients

	patients		p
	n	%	
Age (Years)	52.87±17.434		
Gender			
Male	34	50	
Female	34	50	
Comorbidities			
Kidney Disease	29	42.65%	
Gastrology-Hepatology Disease	4	5.88%	
Diabetes Mellitus	12	17.65%	
Hematology-Oncology Disease	9	13.24%	
Cerebrovascular disease	5	7.35%	
SLE	6	8.82%	
No Comorbidities	3	4.41	
PSI (mean±SD)	119,32±29.84		0.098
SOFA (mean±SD)	6.57±3.15		0.023
PCT (mean±SD)	12.13±22.03		0.001
LOS (min-max) (mean±SD)	(0-19) (5.32±4.345)		0.001

PSI: Pneumonity Severity Index, PCT: Procalcitonin, SOFA: Sequential Organ Failure Assessment, LOS: Length OF Stay

There were 68 respondents who met the inclusion criteria with equal gender, 34 (50%) men and 34 (50%) women. The average patient age was 52.87 with a standard deviation of 17.434. The most common comorbidities among respondents were kidney disease 29 (42.65%), followed by diabetes mellitus 12 (17.65%) and hemato-oncology disease 9 (13.24%), only 3 respondents did not have comorbid diseases. The results of the data normality test showed the p-value of PSI (p=0.098), SOFA (p=0.023), procalcitonin (p=0.001), and LOS

(0.001). The average value and standard deviation of each variable include: PSI (119.32 ± 29.84), SOFA (6.57 ± 3.15), procalcitonin (12.13 ± 22.03), LOS (5.32 ± 4.345). The shortest LOS of respondents was less than 1 day and the longest was 19 days of hospitalized.

Table 2. Distribution profile of microorganisms based of SOFA score

Microorganisms		SOFA Category											
		0-6		7-9		10-12		13-14		15		Σ	
		f(x)	%	f(x)	%	f(x)	%	f(x)	%	f(x)	%	f(x)	%
Gram negative bacteria	*Acinetobacter baumanii*	12	70.6	3	17.6	2	11.8	0	0	0	0	17	25
	Citrobacter	0	0	1	50	1	50	0	0	0	0	2	2.9
	Stenotrophomonas	0	0	1	50	1	50	0	0	0	0	2	2.9
	Cronobacter sakazaki	1	100	0	0	0	0	0	0	0	0	1	1.5
	Enterobacter cloacae	1	50	1	50	0	0	0	0	0	0	2	2.9
	Escherichia coli	4	44.4	0	0	3	33.3	1	11.1	1	11.1	9	13.2
	Klebsiella pneumoniae	5	41.7	5	41.7	2	16.7	0	0	0	0	12	17.6
	Ochrobactrum species	0	0	1	100	0	0	0	0	0	0	1	1.5
	Pseudomonas aeruginosa	5	55.6	3	33.3	1	11.1	0	0	0	0	9	13.2
Gram positive bacteria	*Staphylococcus aureus*	1	50	1	50	0	0	0	0	0	0	2	2.9
	Staphylococcus coagulase negative	1	50	0	0	1	50	0	0	0	0	2	2.9
	Staphylococcus haemolyticus	1	100	0	0	0	0	0	0	0	0	1	1.5
	Corynebacterium striatum	2	100	0	0	0	0	0	0	0	0	2	2.9
	Streptococcus viridans	4	66.7	2	33.3	0	0	0	0	0	0	6	8.8
	∑	37	54.4	18	26.5	11	16.2	1	1.5	1	1.5	68	100

Contingency Coefficient (c) : 0.594
P Value : 0.942

The respondents' sputum results were dominated by gram-negative bacteria, with the most common type of bacteria being Acinetobacter baumannii 17 (25%), followed by Klebsiella pneumoniae 12 (17.6%), Escherichia Coli 9 (13.2%), and Pseudomonas aeruginosa 9 (13.2%). The relationship between the bacterial profile and the SOFA score is explained in table 2. It shows that the Acinetobacter Baumanii bacteria of most of the 12 respondents (70.6%) were in the SOFA score category (0-6). The highest SOFA score is 15 caused by E.Coli bacteria. Mean±SD of SOFA scores (6.57±3.15). Most of the respondents 37 (54.4%) were in the Score category (SOFA 0-6), the results of the Chi-Square statistical test showed a p value of p=0.942, this value was >0.05 which means the bacterial profile showed no relationship to the SOFA score in pneumonia patients, with a contingency coefficient = 0.594.

Table 3. Distribution profile of microorganisms based of Procalcitonin level

Microorganisms		Procalcitonin Category									
		Local Infection		Systemic Infection		Severe		Septic Shock		Σ	
		f(x)	%	f(x)	%	f(x)	%	f(x)	%	f(x)	%
Gram negative bacteria	*Acinetobacter baumanii*	0	0	2	11.8	14	82.4	1	5.9	17	25
	Citrobacter	0	0	0	0	1	50	1	50	2	2.9

	Stenotrophomonas	0	0	0	0	2	100	0	0	2	2.9
	Cronobacter sakazaki	0	0	0	0	0	0	1	100	1	1.5
	Enterobacter cloacae	0	0	0	0	2	100	0	0	2	2.9
	Escherichia coli	0	0	1	11.1	5	55.6	3	33.3	9	13.2
	Klebsiella pneumoniae	0	0	0	0	8	66.7	4	33.3	12	17.6
	Ochrobactrum species	0	0	0	0	1	100	0	0	1	1.5
	Pseudomonas aeruginosa	0	0	0	0	5	55.6	4	44.4	9	13.2
Gram positive bacteria	*Staphylococcus aureus*	0	0	0	0	2	100	0	0	2	2.9
	Staphylococcus coagulase negative	0	0	0	0	1	50	1	50	2	2.9
	Staphylococcus haemolyticus	1	100	0	0	0	0	0	0	1	1.5
	Corynebacterium striatum	0	0	0	0	1	50	1	50	2	2.9
	Streptococcus viridans	0	0	0	0	5	83.3	1	16.7	6	8.8
	∑	1	1.5	3	4.4	47	69.1	17	25	68	100
Contingency Coefficient (c) : 0.747											
	P Value :									0.001	

The procalcitonin values of respondents in this study were divided into 4 categories, namely: local infection 1 (1.5%), systemic infection 3 (4.4%), severe 47 (69.1%), and septic shock 17 (25%). Most of the Acinetobacter baumannii bacteria were in the severe category 14 (82.4%), followed by Klebsiella pneumoniae 8 (66.7%), E.Coli 5 (55.6%) and Pseudomonas aeruginosa 5 (55.6%). The Chi Square test results show pValue results, p=0.001, this value is <0.05, which means the relationship between the bacterial profile and procalcitonin shows a significant relationship, with contingency coefficient = 0.747.

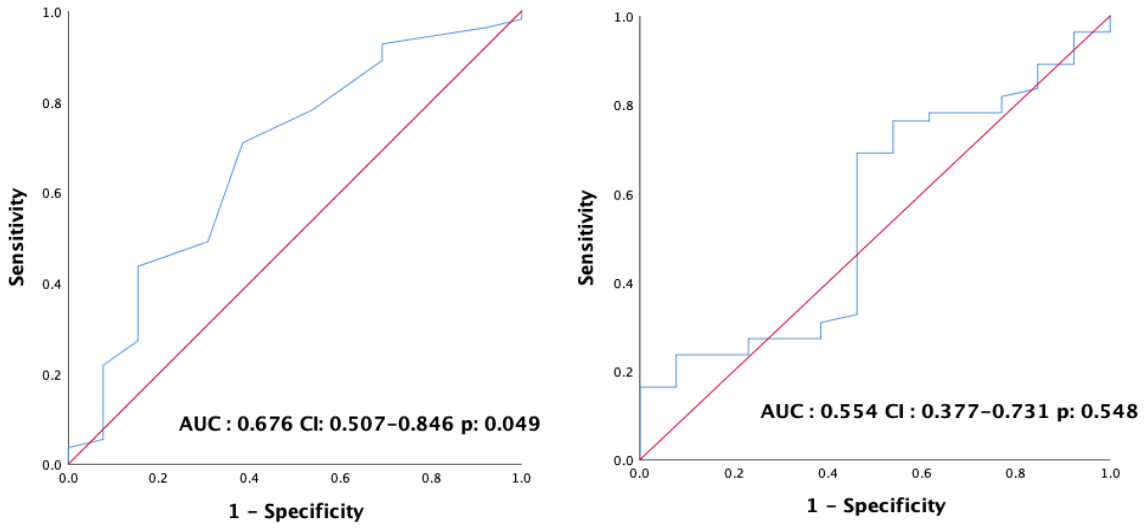
Table 4. Antibiotic sensitivity profile

Microorganisms	**Sensitivity (%)**								
	AMK	**SAM**	**CRO**	**CHL**	**CIP**	**IPM**	**LVX**	**MEM**	**SXT**
Acinetobacter baumanii	64,7	52.9	11.8	0	52,9	52.9	58.8	52.9	76.5
Klebsiella pneumonia	100	50	58.3	75	8,3	66.7	50	75	66.7
Escherichia coli	100	0	11.1	66.7	0	77.8	11.1	88.9	66.7
Pseudomonas aeruginosa	77.8	0	0	0	77.8	88.9	88.9	100	0

AMK: Amikacin, SAM: Ampicilin Sulbact, CRO: Ceftriaxone, CHL: Chlorampenicol, CIP: Ciprofloxacin, IPM: Imipenem, LVX: Levofloxacin, MEM: Meropenem, SXT: Trimethoprime-Sulfamethoxazole.

Based on the results of sputum culture, it shows that the 4 most abundant bacteria are Acinetobacter baumannii, Klebsiella pneumoniae, E. Coli, and Pseudomonas. Antimicrobial susceptibility testing was carried out via the broth microdilution method using a BD Phoenix Automated Microbiology system according to the manufacturer's standard protocols (Phoenix-100; Becton Dickson Indonesia), susceptibility testing was carried out against 9 types of antimicrobials based on CLSI standards (Weinstein et al., 2019) including : Amikacin (AMK), Ampicilin Sulbactam (SAM), Ceftriaxone (CRO), Chlorampenicol (CHL), Ciprofloxacin (CIP), Imipenem (IPM), Levofloxacin (LVX), Meropenem (MEM), and Trimethoprim-Sulfamethoxazole (SXT). Acinetobacter baumannii bacteria have the highest sensitivity to Trimethoprime-Sulfomethoxazole bacteria 76.5%, while Klebsiella pneumonia and E.Coli bacteria have the highest sensitivity to the antibiotic Amikacin 100%, Pseudomonas aeruginosa is sensitive 100% to the antibiotic Meropenem.

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(a) **(b)**

Note: AUC:Under Curve, CI: Confidence Interval.

Figure 1. Receiver Operating Characteristic curve analysis of : (a) SOFA score for predicting gram negative bacteria, (b) Procalcitonin for predicting gram negative bacteria.

To predict the type of pneumonia bacteria based on the SOFA score and procalcitonin levels, the Reveiver Operating Characteristics (ROC) test is carried out. The results of the ROC test show the cut point for sensitivity and specificity of the possible type of infecting bacteria. Most of the bacteria in this study were gram-negative bacteria, so the ROC test was carried out to determine the sensitivity and specificity points of each SOFA and Procalcitonin score in predicting the results of sputum culture for gram-negative bacteria. Figure 1 (a) shows that the SOFA score curve for gram-negative bacteria obtained an Area Under Curve value (AUC=0.676), with a Confident Interval (0.507-0.846), with a significant level of p : 0.049. The results of the ROC test obtained a cut point of meeting sensitivity and specificity of 0.491 and 0.692 respectively, both cut points are equivalent to a SOFA value of 6.5 or with a rounded SOFA score of >6. So it can be concluded that if the SOFA value is >6 then it is likely that the sputum culture results are gram-negative bacteria. The Positive Predictive Value (PPV) (Table 4) of gram-negative bacteria regarding the possibility of a SOFA value >6 is 49.1%, with a Negative Predictive Value (NPV) of 69.2%. Odds Ratio (OR) is: 2.17. then the risk of possible gram-negative bacterial culture results with a SOFA value >6 is 2.17 times. Figure 1 (b) shows that the procalcitonin level against gram-negative bacteria obtained an AUC value = 0.554 with the lowest Confident Interval value of 0.377 and the highest 0.731, a significant level of pValue = 0.548, the cut point obtained from meeting sensitivity = 0.545 and specificity = 0.538, the cut point for both equivalent to a procalcitonin value ≥1.815. The Positive Predictive Value (PPV) of procalcitonin levels ≥1,815 against gram-negative bacteria is 54.5%, with a Negative Predictive Value (NPV) of 53.8%. The Odds Ratio (OR) value = 1.4, so the potential possibility of a gram-negative culture result with a procalcitonin value ≥1.815 is 1.4 times with the lowest value being 0.416 and the highest being 4.7 (Table 5).

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Table 5. Predictive value of variables on gram negative bacterial

Microorganisms	f (%)	SOFA		PCT		PSI		Mortality	
		≤6	>6	<1.8	≥1.8	≤114	>114	Survive	Death
		f (%)	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)
Gram Negative Bacteria	13	9 (69.2)	4 (30.8)	7 (53.8)	6 (46.2)	7 (53.8)	6 (46.2)	9 (69.2)	4 (30.8)
Gram Positive Bacteria	55	28 (50.9)	27 (49.1)	25 (45.5)	30 (54.5)	28 (50.9)	27 (49.1)	30 (54.5)	25 (45.5)
Total	68 (100)	37 (54.4)	31 (45.6)	32 (47.1)	36 (52.9)	35 (51.5)	33 (48.5)	39 (57.4)	29 (42.6)
p(Value)		0.233		0.586		0.849		0.927	
Contingency Coefficient		0.145		0.066		0.023		0.116	
OR(CI,min-max)		2.17(0.59-7.89)		1.4(0.41-4.7)		1.12(0.33-3.78)		1.875(0.51-6.82)	

Note: OR: Odds Ratio, CI: Confident Interval, PCT: Procalcitonin, PSI: Pneumonia Severity Index, PPV: Positive Predictive Value, NPV : Negative Predictive Value

DISCUSSION

The quality of expectorated sputum is an important consideration when interpreting bacterial culture results in patients with pneumonia because expectorated specimens may contain variable amounts of oropharyngeal contamination. Microscopic assessment of squamous epithelial cells and polymorphonuclear neutrophils provides a practical approach to evaluating whether a specimen is sufficiently representative of lower respiratory tract secretions. Murray and Washington reported that specimens containing fewer than 10 squamous epithelial cells per low-power field more closely resembled lower respiratory tract specimens, whereas specimens with higher numbers of squamous epithelial cells were more frequently associated with oropharyngeal flora. Martin et al. further demonstrated that assessment using both polymorphonuclear cells and squamous epithelial cells can improve the evaluation of sputum suitability for bacterial culture (Murray & Washington, 1975; Martin et al., 1978).

The higher the SOFA score, the higher the picture of organ damage and the possibility of mortality that will occur (Iskandar & Siska, 2020). Pneumonia sufferers with comorbidities show higher mortality, the morbidity of comorbid diseases will increase and will even show a faster progression of worsening conditions (Fauziyah et al., 2021). Patients who have comorbid diseases and experience respiratory tract infections will show an acceleration in the severity of their comorbid diseases (Saeed et al., 2019). SOFA scores will be higher than subjects who do not have comorbid diseases (Güleç et al., 2023). Patients with CKD show a higher SOFA score, so that the SOFA score can relatively be used to predict the prognosis of patients who will be admitted to intensive care (Goswami et al., 2018). Age is a factor that can increase the SOFA score, the higher the age, the higher a person's SOFA score, this is due to the vulnerability to organ degeneration in the elderly (Baek et al., 2020). The higher the SOFA score, the higher the picture of organ damage and mortality that will occur (Iskandar & Siska, 2020). Elderly pneumonia sufferers should receive special attention, because they have the potential to experience an increase in SOFA scores. Especially sufferers with comorbid chronic kidney disease, have a higher chance of experiencing organ damage and risk of death. Elderly patients

with pneumonia who have comorbid kidney disease must undergo more special intervention, especially to maintain the function of their organs, providing extra nutrition or administering the appropriate type and dose of antibiotics is a concern. The cleanliness of the environment, staff and families/companions of sufferers must be further improved. It is an input for hospital policy makers to consider the SOFA score as an indication for ICU admission, because research shows the possibility of worsening the patient's condition and prognostic mortality along with a high SOFA score. The relationship between the bacterial profile and the SOFA score shows a value higher than the established significance threshold; therefore, the research hypothesis was rejected. This occurs because there is no correlative relationship between the type of bacteria and organ damage, because all the bacteria found cause infection but there is no specific type of bacteria that causes damage to organ function in certain categories. Most bacteria, whatever the type, are in the SOFA score range of 0-6, this does not show a significant relationship between the type of bacteria in damaging organ function, all bacteria can cause infection but do not necessarily have the potential to progressively damage organ function. The SOFA score does not refer to a specific type of bacteria, but can be used as an indicator of organ damage that occurs due to bacterial infection (Wiguna et al., 2020). A meta-analysis study from Tang et al (2023) shows that SOFA does not correlate with the type of bacteria, however, it correlates with the stage of infection that occurs so that the SOFA score cannot be used as a predictor of the type of bacteria but as an indicator of the extent of the infection.

The use of the SOFA score in predicting antibiotic resistance that occurred was carried out by Wei et al (2024) who showed that the SOFA score had a positive correlation in predicting antibiotic resistance of the Carbapenem Resistant Acinetobacter Baumanii (CRAB) type. Other research uses the SOFA score as an indicator of the effectiveness of administering antibiotics to bacteria with ESBL class antibiotic resistance (Gatti et al., 2024). Research from Chen et al (2022) shows that the most common bacteria found was Acinetobacter baumannii and showed an average SOFA value of 7, with the highest mortality occurring at an average SOFA value of 9, while Pseudomonas aeruginosa bacteria with a higher frequency. relatively smaller, but showed deaths with an average SOFA value of 9 as many as total deaths, with fewer than half of the patients receiving definitive antibiotic therapy. Research conducted conducted by Asai et al (2022) proves that a SOFA score ≥2 has the potential for antibiotic resistance, organ damage that occurs, and is an indicator of the weakness of antibiotics in fighting bacterial infections that occur.

The SOFA score does not specifically prove a relationship with the bacterial type profile, but the SOFA score is used to predict various possibilities that occur, namely: the level of infection that occurs, the potential for antibiotic resistance that occurs, the effectiveness of the antibiotics given, and the mortality prognosis. This research shows that the most common bacteria is Acinetobacter baumannii with the highest SOFA value in the SOFA category 0-6, this bacteria has the highest sensitivity to Trimethoprim-Sulfamethoxazole (SXT) antibiotics. Although the SOFA score cannot be used to determine the type of bacteria, clinically it can be used as an indicator of the level of infection that occurs, as well as the effectiveness of empirical antibiotics given while waiting for definitive antibiotics based on culture results. Apart from assessing the effectiveness of the antibiotics given, the SOFA score is also used as a reference

to assess the potential for antibiotic resistance to occur. When treating pneumonia patients in the High Care Unit, it is important to check SOFA values serially to evaluate the effectiveness of the antibiotics being given.

Procalcitonin is a biomarker for infections in hospitalized patients, especially pneumonia (Maves & Enwezor, 2022). In addition, this biomarker is used to assess the effectiveness of antibiotics given to patients with symptoms of infection (Florence et al., 2019). Based on this, procalcitonin is the main biomarker that must be monitored in infectious patients with empirical antibiotic therapy. Infections that are not resolved will develop into sepsis, which is a condition that occurs due to activation of the body's immune system in response to infection and causes organ dysfunction. Bacterial culture results take a relatively long time and sometimes even give negative results. In sepsis patients, bacterial cultures successfully identify the causative pathogen in a small proportion to nearly half of all cases. Efforts to strengthen the diagnosis of sepsis use inflammatory markers, namely procalcitonin. Procalcitonin is a precursor of the hormone calcitonin produced by C cells of the thyroid gland which is useful for calcium metabolism. Primary pro-inflammatory cytokines, such as IL-1 and TNF-α, can induce the release of IL-6 and IL-8 cytokines, which can trigger the production of acute phase proteins such as procalcitonin and CRP. Procalcitonin is induced by TNF-α, IL-2, and IL-6, where these cytokines are released during incubation of infection. Levels can be detected in the blood circulation within 2-6 hours, with a peak concentration of 12-48 hours and a half-life of 20-35 hours (Wibowo et al., 2019).

False negative results or low procalcitonin values can be found if the examination is carried out early in the course of infection, therefore the examination must be repeated 6-12 hours later, however, if all microbiological culture results are negative and the source of infection cannot be explained within 24 am with persistent procalcitonin results low, then antibiotics can be stopped and other diagnoses must be considered (Dharaniyadewi et al., 2017). Research by Ozer Simsek (2021) shows that there is no significant difference between infections caused by Acinetobacter baumannii or not, in terms of increasing procalcitonin levels. Another study showed that infection with Acinetobacter baumannii caused a significant increase in procalcitonin levels at a cut-off value of just under seven-tenths, with a sensitivity of slightly more than half and a specificity of slightly less than half (Keskin et al., 2023). This study indicates that patients with high procalcitonin levels are at an increased risk of nosocomial infections caused by *Acinetobacter* spp. Procalcitonin cannot be used as a reference for converting the type of bacteria that causes infection, however, research by Koizumi et al (2021) shows procalcitonin levels in gram-negative bacteria compared to gram-positive bacteria, this is similar to the current study which proves that the top 4 bacteria found were gram negative bacteria. Another study used the procalcitonin value as a marker to predict potential resistance to Carbapenem antibiotics (Chen et al., 2022), Klebsiella pneumoniae infection sufferers who have risk factors: age ≥65 years, respiratory failure, high SOFA value, procalcitonin value ≥ 5ng/mL, treated >3 days, there will be the potential for resistance to Carbapenem antibiotics.

Research from Rathore et al (2020) used procalcitonin as a predictor of bacterial types, where in patients with acute exacerbations of chronic obstructive pulmonary disease on

ventilators in the intensive care unit who showed an increase in procalcitonin, Pseudomonas aeruginosa bacteria were found. This type of bacteria is one of the most frequently found bacteria and is the most threatening bacteria in patients on ventilators in the ICU treatment room (Souza et al., 2021), this bacteria is a nosocomial bacteria that causes antibiotic resistance so that it has the potential to cause worsening In patients in intensive care (Alhussain et al., 2021), procalcitonin is a biomarker used to evaluate the effectiveness of antibiotics given, the use of carbapenem drugs is still the main therapy in fighting this bacteria. Similar to this research, in this study the antimicrobial carbapenem class, namely meropenem, had 100% sensitivity to Pseudomonas aeruginosa bacteria.

A study by Xu et al (2022) showed that infection with Escherichia coli bacteria showed a 3-fold increase in procalcitonin values compared to other bacteria. Escherichia coli bacterial infections in the respiratory tract are rare, but this bacterial infection is closely related to previous nosocomial infections in hospitals/nursing rooms, so deaths that occur from this bacteria can be attributed to nosocomial bacteri (Schneer et al., 2020). In this study, it showed that Escherichia coli caused the highest number of subjects treated for >7 days, with the number of deaths caused by this bacteria being 5 people (17.2%) out of 29 deaths. This is in line with research from Effendi et al (2022) which states that procalcitonin is very weak in predicting mortality that occurs in patients with gram-negative infections, especially Escherichia coli. There is no significant relationship between procalcitonin levels and Escherichia coli bacteria, however procalcitonin is more significant in predicting sepsis than C-Reactive Protein (Patil & Patil, 2020). Procalcitonin is the most sensitive parameter compared to white blood cells and C-reactive protein to determine the cause of infections that occur in children, tract infections in children are mostly caused by gram-negative bacteria, namely Escherichia coli (Li et al., 2021).

Procalcitonin cannot determine the type of bacteria that causes infections of the respiratory tract. However, under certain conditions, the procalcitonin value for certain patient conditions can be taken into consideration to predict certain bacteria. For example, a patient with an acute exacerbation of chronic lung disease who was placed on a ventilator during ICU care, then found an increase in procalcitonin levels, was suspected to be caused by the bacteria Pseudomonas aeruginosa. Klebsiella pneumonia bacteria in elderly patients ≥65 years old with respiratory failure and an increase in procalcitonin >5ng/mL can be suspected of being resistant to carbapenem antibiotics. Procalcitonin with a cut point ≥0.69 shows a sensitivity in causing nosocomial infections by Acinetobacter of 55.9%. Increased procalcitonin levels in children indicate sensitivity to the cause of infection to gram-negative bacteria, the most common being Escherichia coli. Based on the theory and facts from this research, procalcitonin cannot specifically determine the bacteria that infect pneumonia patients, therefore, increasing procalcitonin levels must be supported by certain data on the patient to determine the type of bacteria. The most common bacteria found in this study was Acinetobacter baumannii, with an average procalcitonin level value of 12.12 with an interquartile value of 9.98, so it is possible that sufferers fall into the severe sepsis procalcitonin value category. So the recommended antibiotic choice is Sulfamethoxazole-Trimethoprime, Amikacin or Meropenem. It is

important to always evaluate procalcitonin serially to evaluate the effectiveness of the antibiotics given before definitive antibiotic results come out.

The PSI score is a score used to assess the possibility of a respiratory infection occurring in a patient. This score is not a definite diagnosis for pneumonia patients because sometimes patients show a high score but the culture results show that no bacteria were found in the sputum. In a clinical setting, this value is used as a reference to determine follow-up treatment, whether hospitalization is required or not (Tripon et al., 2021). This PSI score cannot determine the type of bacteria but can be used as a measuring tool to assess the potential risk of antibiotic resistance (Rider & Frazee, 2018). In addition, the PSI score has a positive correlation with the prognosis of patient death (Baek et al., 2020). Research by Yudhawati and Yuniawati (2021), shows a positive relationship between PSI scores and interleukin-6 in hospitalized pneumonia patients, but the relationship between the two does not explain the type of bacteria that infects the respiratory tract. There are many microorganisms that cause pneumonia, but infections caused by bacteria usually produce high procalcitonin values (Li et al., 2021).

Most of the bacteria in this study showed PSI score categories in the medium and high range. Statistical tests do not show a significant relationship between the type of bacteria and the PSI score, this means that the PSI score cannot specifically determine the type of sputum bacteria in pneumonia patients, and vice versa, the type of bacteria does not always cause the exact degree of PSI score in pneumonia patients. This statement is similar to the results of research by Rajarajan and Chellappa (2017), that the PSI score cannot determine the type of bacteria but can assess the outcome or prognosis of pneumonia patients. The PSI score does not stand alone in determining the type of infecting bacteria, it is supported by patient criteria such as SOFA value, Procalcitonin, respiratory failure condition, age, and history of therapy that has been given (Rider & Frazee, 2018). Research conducted by Wijit et al (2023) produced a measuring tool that is used to predict the type of Pseudomonas bacteria that infects the respiratory tract of intensive care inpatients: if age ≥60 years then assess the presence of bronchiectasis, respiratory disease (atelectasis, pulmonary fibrosis, and bleeding). in the lungs), a history of administering immunocompromised drugs, and feeding via a feeding tube before entering the hospital. If the value is ≥2, it indicates a high risk of infection with Pseudomonas aeruginosa.

Researchers believe that the PSI score is not the only diagnostic tool to determine the type of bacteria that infects the respiratory tract, however, in this study the PSI score was positively correlated with gram-negative bacteria. PSI can be used as a follow-up tool in determining patient hospitalization, apart from that, this score can be used as a tool to predict patient mortality rates and the risk of antibiotic resistance that occurs, based on research results and supporting theories, it is necessary to carry out serial checks of PSI scores as a reference in determine patient hospitalization, risk of antibiotic resistance, and risk of mortality rates. Research by Assefa et al (2022) explains that the specific type of bacteria does not indicate a risk of death, but the bacteria indicate a risk of resistance to the antibiotics given. Meanwhile, research by Lakbar et al (2021) found bacteria that have a high risk of antibiotic resistance in the ICU, including: Staphylococcus aureus, Enterobacteriaceae, Pseudomonas aeruginosa, and Acinetobacter baumannii, these bacteria have a mortality rate in the ICU of 30%. Other

research shows that gram-negative bacteria, namely Pseudomonas and Klebsiella pneumoniae, show a mortality rate of 14-30% of deaths with pneumonia in India (Eshwara et al., 2020). Deaths that occur due to bacteria are resistant to certain types of antibiotics (Costa et al., 2022). The type of bacteria that most often causes death in the intensive care unit (ICU) is Pseudomonas aeruginosa (Wijit et al., 2023), the cause of death occurs due to resistance to previously administered antibiotics.

Research by Guo et al (2019) created parameters to predict the death of pneumonia patients within 90 days of hospitalization which consisted of several variables, namely: multibular infiltration in the lungs, lymphocyte count, bacterial co-infection, active smoking, history of quitting smoking, and age ≥60 years. . Each has a score and Odds Ratio to predict the possibility of mortality occurring. The Odds Ratio for the bacterial co-infection variable is 3.71, which means there is a 3.71 chance of mortality in pneumonia patients if co-infected bacteria are found. In this study, the most bacteria found was Acinetobacter baumannii 60 subjects, followed by Klebsiella pneumonia 50 subjects. Bacteria that have been found to have the potential to cause antibiotic resistance include Staphylococcus aureus and Pseudomonas aerugionasa which are bacteria that cause Methicillin Resistance, Enterobacteriaceae bacteria that cause extended-spectrum ß-lactamase, and Acinetobacter baumannii, Stenotrophomonas maltophilia, Chryseobacterium, and Elizabethkingia meningoseptica that cause MDR or even Extensively drug-resistant (XDR) (Jean et al., 2020). Research conducted by Feng et al (2019) shows that the most negative bacteria that cause pneumonia deaths in China are: Acinetobacter baumannii and Pseudomonas aeruginosa with a death rate of 14.5% caused by age >70 years, admission to the ICU, blood lymphocytes <0.8 x109/L, drug resistance of gram-negative bacteria, and increased Blood Urea Nitrogen (BUN).

In this study, the bacteria most commonly found in subjects who died were Acinetobacter baumannii and Klebsiella pneumoniae, 6 subjects each out of 29 total deaths, Acinetobacter baumannii showed resistance to MDRO and Carbapenem class antibiotics, while Klebsiella pneumonia caused resistance to Carbapenem and ESBL class antibiotics. The death rate is triggered by antibiotic resistance, so appropriate antibiotics need to be given. In this study, the two bacteria showed the highest sensitivity to antibiotics in the Sulfamethoxazole-Trimthoprime (SXT) and Amikacin (AMK) groups, so to prevent the high mortality rate of pneumonia patients, both antibiotics were used. This is an initial option that can be considered.

Limitations

This study has several limitations. First, it was retrospective and single-center, and the sample was selected: culture-negative patients, patients without a PCT measurement, and patients with PSI ≤70 were excluded. This introduces selection bias, and the results apply only to culture-positive patients with PSI >70 and a measured PCT in this unit; they should not be generalized to all hospitalized patients with pneumonia. Second, the sample was small (68 patients, 13 with Gram-positive isolates), the species-level analyses involved 14 organism categories with many zero or very small cells, and estimates were imprecise. Monte Carlo exact tests address the validity of the p-values but not the lack of statistical power. Third, analyses were unadjusted: renal disease (42.6%), age, other comorbidities, and prior antibiotic exposure may confound the relationships among SOFA, PCT, and organism type, and could not be

modeled with this sample size. Finally, the timing of SOFA, PCT, and sputum collection relative to admission and antibiotic treatment may have varied in routine care, and sputum culture may not distinguish infection from colonization despite adequacy screening.

Implications for Nursing Practice

Sputum culture with susceptibility testing remains necessary to identify the causative organism. SOFA and PCT should be interpreted as indicators of severity and of the presence of infection, not as tools to select antibiotics by bacterial type. In clinical and nursing practice, obtaining good-quality sputum specimens and documenting their timing relative to antibiotic administration improve the interpretability of culture results, and the local bacterial profile and susceptibility patterns reported here can contribute to the unit's antibiogram review. Larger multicenter prospective studies with standardized timing of measurements, inclusion of culture-negative patients, and multivariable analysis are needed to determine whether SOFA, PCT, or other markers have any role in predicting bacterial type.

CONCLUSION

In this retrospective study of 68 hospitalized patients with culture-positive pneumonia and PSI >70, Gram-negative bacteria predominated (80.9%), mainly *A. baumannii*, *K. pneumoniae*, *E. coli*, and *P. aeruginosa*. Bacterial profile was not associated with SOFA category, and the association with PCT category was borderline and not evident at the Gram-group level. Exploratory ROC analyses showed limited discrimination for SOFA (AUC 0.676) and none for PCT (AUC 0.554). Neither SOFA nor PCT can therefore be used to identify bacterial type in this population, and sputum culture remains necessary. The findings are limited to this selected sample and require confirmation in larger prospective studies.

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All authors contributed equally to the conception, data collection, analysis, and writing of this manuscript.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

DECLARATION OF AI USE

During manuscript preparation, the authors used Claude (Anthropic) to improve grammar and language clarity. The authors reviewed and edited the output and remain responsible for the content and integrity of the article.

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