ANALYSIS OF BACTERIAL CHARACTERISTICS AND ANTIBIOTIC RESISTANCE PATTERNS IN THE TREATMENT OF HOSPITAL-ACQUIRED PNEUMONIA AT CAN THO GENERAL HOSPITAL

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ARTICLE INFO

Received: 15/01/2025
Revised: 27/3/2025
Published: 28/3/2025

KEYWORDS

Acinetobacter baumannii
Antibiotic resistance
Hospital-acquired pneumonia
Intensive care unit
Klebsiella pneumoniae

ABSTRACT

Hospital-acquired pneumonia is a severe disease that increases treatment duration, costs, and mortality risk. This study analyzed bacterial characteristics and antibiotic resistance patterns in hospital-acquired pneumonia cases treated at the Intensive Care Unit and Poison Control Department of Can Tho General Hospital. A cross-sectional descriptive study was conducted on 181 specimens isolated from patients treated at the Intensive Care Unit between January 2022 and December 2023. The male-to-female ratio was 2.1:1, with 77.3% of patients aged over 60 years, 21.0% between 40–60 years, and 1.7% under 40 years. The most common pathogenic bacteria were *A. baumannii* (32%) and *K. pneumoniae* (45.9%). The *A. baumannii* strain was highly sensitive to Ertapenem (100%) but resistant to most other antibiotics. Meanwhile, *K. pneumoniae* showed moderate sensitivity to Amikacin (59.0%) but high resistance to other antibiotics. Ertapenem is recommended for treating hospital-acquired pneumonia caused by *A. baumannii*, while Amikacin, combined with other antibiotics, is suggested for treating hospital-acquired pneumonia caused by *K. pneumoniae*. These findings emphasize the need for antibiotic susceptibility testing to optimize treatment strategies and reduce resistance development.

ĐẶC ĐIỂM VÀ SỰ ĐỀ KHÁNG KHÁNG SINH CỦA VI KHUẨN Ở BỆNH NHÂN VIÊM PHỔI BỆNH VIỆN TẠI BỆNH VIỆN ĐA KHOA THÀNH PHỐ CẦN THƠ

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THÔNG TIN BÀI BÁO

Ngày nhận bài: 15/01/2025
Ngày hoàn thiện: 27/3/2025
Ngày đăng: 28/3/2025

TỪ KHÓA

Acinetobacter baumannii
Kháng kháng sinh
Viêm phổi bệnh viện
Phòng điều trị tích cực
Klebsiella pneumoniae

TÓM TẮT

Viêm phổi bệnh viện là một bệnh lý nghiêm trọng, làm tăng thời gian điều trị, chi phí và nguy cơ tử vong. Nghiên cứu này phân tích đặc điểm vi khuẩn và tình trạng kháng kháng sinh trong điều trị viêm phổi bệnh viện tại Khoa Hồi sức tích cực - Chống độc, Bệnh viện Đa khoa thành phố Cần Thơ. Nghiên cứu mô tả cắt ngang được thực hiện trên 181 mẫu bệnh phẩm phân lập từ bệnh nhân điều trị tại khoa Khoa Hồi sức tích cực từ tháng 01/2022 đến tháng 12/2023. Tỷ lệ nam/nữ là 2,1:1, trong đó 77,3% bệnh nhân trên 60 tuổi, 21,0% từ 40–60 tuổi và 1,7% dưới 40 tuổi. Các vi khuẩn gây bệnh phổ biến nhất là *A. baumannii* (32%) và *K. pneumoniae* (45,9%). Chủng *A. baumannii* nhạy cảm cao với Ertapenem (100%) nhưng kháng hầu hết các kháng sinh khác. Trong khi đó, *K. pneumoniae* có độ nhạy vừa phải với Amikacin (59,0%) nhưng kháng cao với các kháng sinh còn lại. Ertapenem được khuyến nghị sử dụng để điều trị viêm phổi bệnh viện do *A. baumannii*, trong khi Amikacin, kết hợp với các kháng sinh khác, phù hợp để điều trị Viêm phổi bệnh viện do *K. pneumoniae*. Kết quả nghiên cứu nhấn mạnh tầm quan trọng của việc xét nghiệm kháng sinh đồ nhằm tối ưu hóa phác đồ điều trị và giảm nguy cơ kháng thuốc.

DOI: https://doi.org/10.34238/tnu-jst.11905

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1. Introduction

Hospital-acquired infections (HAIs) are a persistent challenge for healthcare systems worldwide, with significant implications for patient outcomes and resource allocation. In Europe, HAIs contribute to approximately 37,000 deaths annually, while the United States reports up to 99,000 cases per year [1]. Among these, hospital-acquired pneumonia (HAP) is a particularly severe condition, associated with prolonged hospital stays averaging 13.1 days [2], increased treatment costs reaching 32 million VND per patient [3], [4], and alarmingly high mortality rates ranging from 26% to 72% [3], [4].

The rise of multidrug-resistant (MDR) pathogens, driven by the widespread and sometimes inappropriate use of antibiotics, has made HAP increasingly difficult to treat. Common pathogens associated with HAP include *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, and *Acinetobacter baumannii*. These bacteria often exhibit resistance to multiple antibiotic classes, including penicillins, cephalosporins, carbapenems, quinolones, and aminoglycosides [5], [6]. While drugs like piperacillin/tazobactam, imipenem, and amikacin remain effective against certain strains, resistance rates vary significantly across regions and studies, reflecting local antibiotic usage patterns and healthcare practices [7], [8].

The emergence of Extended-Spectrum Beta-Lactamase (ESBL)-producing organisms has become a significant concern, with prevalence rates reported to exceed 50% in multiple epidemiological studies [5], [6]. Additionally, carbapenem-resistant *A. baumannii* has been identified as a critical pathogen in HAP due to its high resistance rates and limited treatment options [6]. These trends underscore the urgent need for robust surveillance and targeted antimicrobial stewardship programs to guide effective therapy.

This study aims to characterize the antibiotic resistance profiles of pathogens causing HAP in patients admitted to the Intensive Care Unit of Can Tho General Hospital. By elucidating resistance patterns, the findings will support evidence-based interventions to improve diagnostic accuracy, optimize treatment regimens, and ultimately enhance patient outcomes while reducing the burden on healthcare systems.

2. Materials and methods

2.1. Research subjects

The study focused on bacterial strains isolated from respiratory specimens of patients diagnosed with HAP in the Intensive Care Unit (ICU) of Can Tho General Hospital between January 2022 and December 2023. Inclusion criteria encompassed bacterial isolates obtained from respiratory specimens, including sputum, pus, bronchoalveolar lavage fluid, or tracheal aspirates, of HAP-diagnosed patients receiving treatment in the ICU during the specified period. For patients with multiple specimens yielding bacterial isolates, only one type of specimen per patient was included in the study. Additionally, only patients who provided informed consent were enrolled.

The study excluded bacterial isolates from patients with a history of community-acquired pneumonia, those with a treatment duration of less than three days, and patients intubated at other healthcare facilities before admission. Patients with underlying conditions such as cancer, pulmonary tuberculosis, or HIV infection, as well as pregnant women, were also excluded.

2.2. Research methodology

The study was designed as a cross-sectional descriptive study with analytical components. A total of 181 bacterial strains were isolated from respiratory specimens of patients who underwent antibiotic susceptibility testing at the laboratory of Can Tho General Hospital between February 2022 and July 2023. The research focused on several aspects, including the general characteristics of patients, such as age and gender, as well as the types of respiratory specimens from which the bacteria were isolated. The study also aimed to identify and characterize certain bacterial species and assess the levels of antibiotic resistance in commonly encountered bacteria.

2.3. Data analysis

Data collection and analysis involved identifying the general characteristics of the study samples and determining the frequency and proportion of bacterial isolates. The antibiotic resistance rates of these isolates were then calculated and analyzed using Excel and SPSS software.

3. Result and Discussion

3.1. General characteristics of the study sample

Table 1 presents the characteristics of the study subjects. Regarding the general characteristics of patients, the male-to-female ratio was approximately 2.1:1, with 123 males (68.0%) and 58 females (32.0%). The distribution of HAP cases across age groups revealed that the majority of cases occurred in patients aged 60 years and older (77.3%), followed by those aged 40–60 years (21.0%), and the lowest incidence was observed in patients under 40 years of age (1.7%).

For the characteristics of the specimens, sputum was the predominant sample type, accounting for 93.4% (n = 169), while bronchial aspirates and endotracheal aspirates contributed to 4.4% (n = 8) and 2.2% (n = 4) of the samples, respectively. These findings highlight the predominance of sputum as the primary sample source and the higher prevalence of HAP among older patients (Table 1).

Table 1. *Characteristics of the study subjects*

Characteristics		n	%
General characteristics			
Gender	Male	123	68.0
	Female	58	32.0
Age groups	< 40 years	3	1.7
	40–60 years	38	21.0
	≥ 60 years	140	77.3
Specimen characteristics			
Type of specimen	Sputum	169	93.4
	Bronchial aspirates	8	4.4
	Endotracheal aspirates	4	2.2

3.2. Identification of bacterial isolates

The bacterial isolates obtained from respiratory specimens of patients diagnosed with HAP predominantly consisted of Gram-negative bacteria, which accounted for 91.6% (n = 166) of the total isolates, while Gram-positive bacteria represented 8.3% (n = 15). Among the Gram-negative species, *K. pneumoniae* was the most frequently identified pathogen, comprising 45.9% (n = 83) of the total isolates. *A. baumannii* was the second most common species, accounting for 32.0% (n = 58). Other notable Gram-negative bacteria included *E. coli* (7.7%, n = 14) and *P. aeruginosa* (5.0%, n = 9).

Table 2. *Identification of Bacterial Isolates*

Characteristics		n	%
Bacteria	*Acinetobacter baumannii*	58	32.0
	Escherichia coli	14	7.7
	Klebsiella pneumoniae	83	45.9
	Pseudomonas aeruginosa	9	5.0
	Other species	17	9.4
Gram staining	Gram-negative	166	91.6
	Gram-positive	15	8.3

A small proportion of isolates were identified as other bacterial species, comprising 9.4% (n = 17). In terms of Gram-positive bacteria, their overall representation was limited, contributing to a smaller fraction of the isolates. These results highlight the predominance of Gram-negative bacteria as the primary causative agents in hospital-acquired pneumonia, particularly *K. pneumoniae* and *A. baumannii* as the leading pathogens (Table 2).

3.2. Antibiotic resistance profile

The antibiotic susceptibility testing of *A. baumannii* isolates revealed significant resistance patterns. Notably, *A. baumannii* exhibited complete susceptibility to ertapenem (100%) and moderate intermediate resistance rates to gentamicin (46.6%), amikacin (39.7%), and trimethoprim/sulfamethoxazole (37.9%). However, high resistance levels were observed across most antibiotics, with ciprofloxacin, clindamycin, levofloxacin, and vancomycin demonstrating resistance rates exceeding 90%. The resistance to piperacillin/tazobactam and ticarcillin/clavulanic acid was also substantial, at 81.0% and 63.8%, respectively. The susceptibility to amikacin and gentamicin was moderate, with resistance rates of 27.6% and 25.9%, respectively. The overall findings emphasize the alarming resistance of *A. baumannii* to nearly all tested antibiotics, except for ertapenem, which remains effective (Table 3).

Table 3. *Antibiotic resistance levels of Acinetobacter baumannii*

Antibiotic	Susceptible n (%)	Intermediate n (%)	Resistant n (%)
Ampicillin	0 (0)	5 (8.6)	53 (91.4)
Amikacin	19 (32.8)	23 (39.7)	16 (27.6)
Ciprofloxacin	1 (1.7)	0 (0)	57 (98.3)
Clindamycin	1 (1.7)	0 (0)	57 (98.3)
Colistin	8 (13.8)	8 (13.8)	42 (72.4)
Erythromycin	11 (19.0)	11 (19.0)	36 (62.1)
Ertapenem	58 (100)	0 (0)	0 (0)
Gentamicin	16 (27.6)	27 (46.6)	15 (25.9)
Levofloxacin	0 (0)	2 (3.4)	56 (96.6)
Linezolid	1 (1.7)	2 (3.4)	55 (94.8)
Trimethoprim/Sulfamethoxazole	6 (10.3)	22 (37.9)	30 (51.7)
Ticarcillin/Clavulanic Acid	20 (34.5)	1 (1.7)	37 (63.8)
Piperacillin/Tazobactam	7 (12.1)	4 (6.9)	47 (81.0)
Vancomycin	1 (1.7)	1 (1.7)	56 (96.6)

The susceptibility testing of *K. pneumoniae* isolates demonstrated moderate sensitivity to Amikacin (59.0%) and low sensitivity to ticarcillin/clavulanic acid (33.7%). Intermediate resistance rates were generally low, with the highest values observed for amikacin (15.7%), gentamicin (15.7%), and levofloxacin (16.9%). Resistance rates were notably high across most tested antibiotics, with the exception of amikacin, which exhibited a relatively low resistance rate of 25.3%. These findings indicate significant challenges in managing *K. pneumoniae* infections due to its high resistance to most antibiotics (Table 4).

Table 4. *Antibiotic resistance levels of Klebsiella pneumoniae*

Antibiotic	Susceptible n (%)	Intermediate n (%)	Resistant n (%)
Ampicillin	0 (0)	0 (0)	83 (100)
Amikacin	49 (59.0)	13 (15.7)	21 (25.3)
Ciprofloxacin	10 (12.0)	4 (4.8)	69 (83.1)
Clindamycin	11 (13.3)	3 (3.6)	69 (83.1)
Colistin	10 (12.0)	3 (3.6)	70 (84.3)
Erythromycin	8 (9.6)	1 (1.2)	74 (89.2)
Ertapenem	12 (14.5)	0 (0)	71 (85.5)
Gentamicin	7 (8.4)	13 (15.7)	63 (75.9)

Antibiotic	Susceptible n (%)	Intermediate n (%)	Resistant n (%)
Levofloxacin	18 (21.7)	14 (16.9)	51 (61.4)
Linezolid	13 (15.7)	4 (4.8)	66 (79.5)
Trimethoprim/Sulfamethoxazole	8 (9.6)	2 (2.4)	73 (88.0)
Ticarcillin/Clavulanic Acid	28 (33.7)	1 (1.2)	54 (65.1)
Piperacillin/Tazobactam	18 (21.7)	8 (9.6)	57 (68.7)
Vancomycin	11 (13.3)	2 (2.4)	70 (84.3)

The distribution of colistin resistance across demographic and sample characteristics is summarized in Table 5. Gender analysis showed no statistically significant difference in Colistin susceptibility or resistance for either pathogen. For *A. baumannii*, 62.5% of susceptible isolates were from male patients compared to 70.0% of resistant isolates. Among female patients, susceptibility accounted for 37.5%, while resistance was at 30.0% (p = 0.694). For *K. pneumoniae*, susceptible isolates were predominantly from male patients (90.0%), whereas resistance was more evenly distributed between males (64.4%) and females (35.6%, p = 0.155).

Age group analysis indicated that all resistant *A. baumannii* isolates were from patients aged ≥ 40 years, with the majority in the ≥ 60 years group (78.0%, p = 1). In contrast, susceptible *K. pneumoniae* isolates were distributed more evenly across age groups, with the highest proportion from patients aged ≥ 60 years (50.0%, p = 0.074).

Sample type analysis revealed that sputum samples constituted the majority of isolates for both pathogens, regardless of susceptibility or resistance status. For *A. baumannii*, 92.0% of resistant isolates and 87.5% of susceptible isolates were from sputum (p = 0.296). Similarly, for *K. pneumoniae*, all susceptible isolates and 91.8% of resistant isolates were from sputum (p = 1).

Table 5. *Distribution of colistin resistance by patient and sample characteristics*

Characteristic		*Acinetobacter baumannii*			*Klebsiella pneumoniae*		
		Susceptible n (%)	Resistant n (%)	p-value	Susceptible n (%)	Resistant n (%)	p-value
Gender	Male	5 (62.5)	35 (70.0)	0.694	9 (90.0)	47 (64.4)	0.155
	Female	3 (37.5)	15 (30.0)		1 (10.0)	26 (35.6)	
Age Groups	< 40 years	0 (0)	0 (0)	1.000	1 (10.0)	2 (2.7)	0.074
	40–60 years	1 (12.5)	11 (22.0)		4 (40.0)	12 (16.4)	
	≥ 60 years	7 (87.5)	39 (78.0)		5 (50.0)	59 (80.8)	
Sample type	Sputum	7 (87.5)	46 (92.0)	0.296	10 (100)	67 (91.8)	1
	Bronchial aspirate	0 (0)	3 (6.0)		0 (0)	4 (5.5)	
	Endotracheal aspirate	1 (12.5)	1 (2.0)		0 (0)	2 (2.7)	

3.3. Characteristics of some isolated bacteria

The results of this study indicate that Gram-negative bacteria are the primary causative agents of HAP, accounting for 91.6% of cases. Among them, *A. baumannii* (32.0%) and *K. pneumoniae* (45.9%) were the most prevalent. Similar findings were observed in studies by Nguyen [9] and Werarak et al. [12], where *A. baumannii* and *K. pneumoniae* were identified as key pathogens.

According to Luong and Nguyen [3], the most common pathogens for HAP were *A. baumannii* (32.65%), *S. aureus* (14.29%), and *K. pneumoniae* (12.24%). Another study by Pham [13] revealed a higher prevalence of *A. baumannii* (68.2%), *K. pneumoniae* (22.7%), and *E. faecium* (9.1%). These findings indicate that *A. baumannii* is the dominant pathogen, with variations in prevalence across different studies, which may reflect regional differences in the bacterial strains involved.

The variation in results across studies emphasizes the importance of ongoing surveillance to understand regional epidemiological trends and antibiotic resistance patterns. These differences underline the urgency of research on the epidemiology and antibiotic resistance of bacterial strains to inform effective prevention and treatment strategies for hospital-acquired pneumonia.

In terms of antibiotic resistance, *E. coli* strains exhibited high resistance to many antibiotics in the penicillin and cephalosporin groups, except for piperacillin/tazobactam, which remained effective (70.8%). However, a significant minority (19.4%) of *E. coli* strains were still resistant to piperacillin/tazobactam, in contrast only 5.75% resistance [5]. On the other hand, *E. coli* showed very high sensitivity to the carbapenem, quinolone, and aminoglycoside groups, particularly imipenem (83.3%), ertapenem (83.3%), and amikacin (92.8%). Yet, a small proportion of *E. coli* strains exhibited resistance to these drugs, with amikacin showing a 2.7% resistance rate, imipenem 7.2%, and ertapenem 16.7%. These discrepancies, particularly regarding imipenem and ertapenem resistance, may be attributed to differences in sample sizes, research timing, and an increasing trend in *E. coli* resistance.

Amikacin, being an injectable antibiotic, remains highly effective against most *E. coli* strains, making it an excellent treatment option. However, due to the higher resistance rates of ertapenem and piperacillin/tazobactam, their use should be carefully considered.

Furthermore, our research found that 51.2% of the isolated *E. coli* strains produced ESBL, a result consistent with Nghiem et al. (51.49%) [5], Que (54.5%) [6], and Vo et al. (51.2%) [8]. Conversely, the study by Hoang et al. [7] reported a lower prevalence of 34.8%, which may be due to variations in sample sizes, research timing, and regional differences in antibiotic usage practices. These findings highlight the need for continuous monitoring of ESBL-producing strains and their clinical impact on the treatment of hospital-acquired infections.

3.4. Antibiotic resistance of common pathogens

A. baumannii demonstrates high resistance to most antibiotics used in this study, with resistance rates ranging from 51.7% to 98.3%. However, it shows relatively low resistance to amikacin (27.6%) and gentamicin (25.9%), and is fully susceptible to ertapenem (0%), with a 100% sensitivity rate to this antibiotic. The intermediate resistance of *A. baumannii* is moderately high for amikacin (39.7%), gentamicin (46.6%), and trimethoprim/sulfamethoxazole (37.9%).

In comparison, Nguyen and Pham [9] also showed high resistance of *A. baumannii* to most antibiotics, but there was a reversal in resistance to ertapenem (100%) and colistin (0%). This discrepancy may stem from a year of colistin use, during which *A. baumannii* mutated, developing strains with higher resistance to this antibiotic. However, resistance to Ertapenem appears to have disappeared, likely due to its complete resistance leading to a shift in clinical practice towards alternative antibiotics, thereby reducing selective pressure and eventually eliminating ertapenem from circulation.

K. pneumoniae remains sensitive to Amikacin (59.0%) and ticarcillin/clavulanic acid (33.7%), but shows low intermediate resistance to these antibiotics. The highest intermediate resistance is observed to amikacin (15.7%), gentamicin (15.7%), and levofloxacin (16.9%), while high resistance is noted to most antibiotics except for amikacin, which has relatively low resistance (25.3%).

Similar findings were reported in Nguyen and Pham [9], where *K. pneumoniae* remained sensitive to amikacin (52%) but showed high resistance to most other antibiotics used. This study also found that ertapenem exhibited a relatively high sensitivity rate (44%).

From these results, it is evident that *K. pneumoniae* has developed strains capable of resisting ertapenem. However, amikacin remains a viable treatment option for *K. pneumoniae*-induced HAP. Combining amikacin with other antibiotics is advisable to enhance efficacy, minimize the development of resistance, and reduce mortality rates in patients.

4. Conclusion

A. baumannii and *K. pneumoniae* are among the most prevalent bacterial pathogens associated with HAP, a severe and potentially life-threatening infection. Given their antimicrobial resistance profiles, ertapenem is recommended for the treatment of *A. baumannii* infections, whereas amikacin, in combination with other antibiotics, is advised for managing *K. pneumoniae* infections. Furthermore, comprehensive bacterial screening and antibiotic susceptibility testing are crucial to optimizing antimicrobial therapy, ensuring the selection of the most effective antibiotic regimen tailored to the patient's clinical condition.

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