ORIGINAL ARTICLE

Prevalence and determinants of antimicrobial resistance in pneumonia among adult patients in Hospital Shah Alam, Malaysia

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ABSTRACT

Introduction: Antimicrobial resistance (AMR) continues to threaten our healthcare system. Unnecessary antibiotic use contributes to the development of AMR infections in hospitalized pneumonia patients. This study was conducted to determine the prevalence of AMR and its associated factors in pneumonia among adult patients treated in-patient in a hospital.

Materials and Methods: A cross-sectional study was conducted using data extracted from the hospital's electronic medical records. Patients aged 18 years or older admitted to the hospital from 1st January 2018 to 31st December 31 2023, discharged with a diagnosis of pneumonia were included in the study population.

Results: A total of 300 eligible samples were selected using universal sampling. The analysis revealed a prevalence of AMR of 15.7% (95% CI: 11.5, 19.8). Multivariable analysis using multiple logistic regression showed that patients' age (OR = 1.03; 95% CI: 1.01, 1.05), Indian and other ethnicities (OR = 2.24; 95% CI: 1.05, 4.77), length of stay (OR = 1.05; 95% CI: 1.01, 1.08) and invasive procedures (OR = 3.65; 95% CI: 1.71, 7.82) were significantly associated with AMR.

Conclusion: The findings from our study highlighted a considerable burden of AMR among pneumonia patients in a Malaysian tertiary hospital. Thus, there is a need for targeted infection control strategies and antimicrobial stewardship, especially among high-risk groups. Strengthening surveillance and justified antibiotic use is crucial to fight the rising threat of AMR in Malaysia.

KEYWORDS:
Antimicrobial resistance, pneumonia, hospital, antibiotic, Malaysia

INTRODUCTION

Antimicrobial resistance (AMR) is defined as the capacity of microorganisms to resist the effects of antimicrobial agents that were previously effective in treating infections.[1] Globally, AMR was associated with an estimated 4.7 million deaths in 2021, with approximately one-quarter directly attributable to bacterial resistance.[2] The economic burden is also substantial with projected global capital losses from AMR-related mortality estimated at USD 300 billion to USD 1 trillion by 2050.[3] In Malaysia, surveillance data had demonstrated increasing antibiotic resistance among clinically important pathogens, including *Acinetobacter baumannii* and *Pseudomonas aeruginosa*, which are associated with serious infections such as pneumonia, sepsis and urinary tract infections.[4-5]

Pneumonia is a common infection requiring hospitalisation and is particularly relevant to AMR because of its substantial antibiotic exposure. Studies have reported high resistance rates among bacterial pathogens causing pneumonia with up to 100% resistance to certain antibiotics such as ampicillin.[6-7] The COVID-19 pandemic also further contributed to AMR through increased empirical antibiotic use for suspected bacterial infections.[8] AMR in pneumonia is therefore concerning because it can compromise treatment effectiveness and increase healthcare costs.[9]

However, AMR surveillance and research remain limited in many low- and middle-income countries, including Malaysia, where relatively few studies have examined AMR specifically among adult pneumonia patients.[10] This evidence gap is important in the context of Malaysia's healthcare system, whereby AMR has been recognised as an emerging threat. The Malaysia Health White Paper identifies the re-emergence of communicable diseases as being partly attributable to AMR.[11]

Therefore, the limited local evidence on AMR among adult pneumonia patients together with the increasing burden of AMR highlights the need for further investigation. Determining the prevalence and associated factors of AMR in this population may provide locally relevant evidence to improve antibiotic prescribing and strengthen antimicrobial stewardship while supporting national efforts to address AMR. Therefore, this study was conducted to determine the prevalence and associated factors of AMR in pneumonia among adult patients treated in-patient in a hospital.

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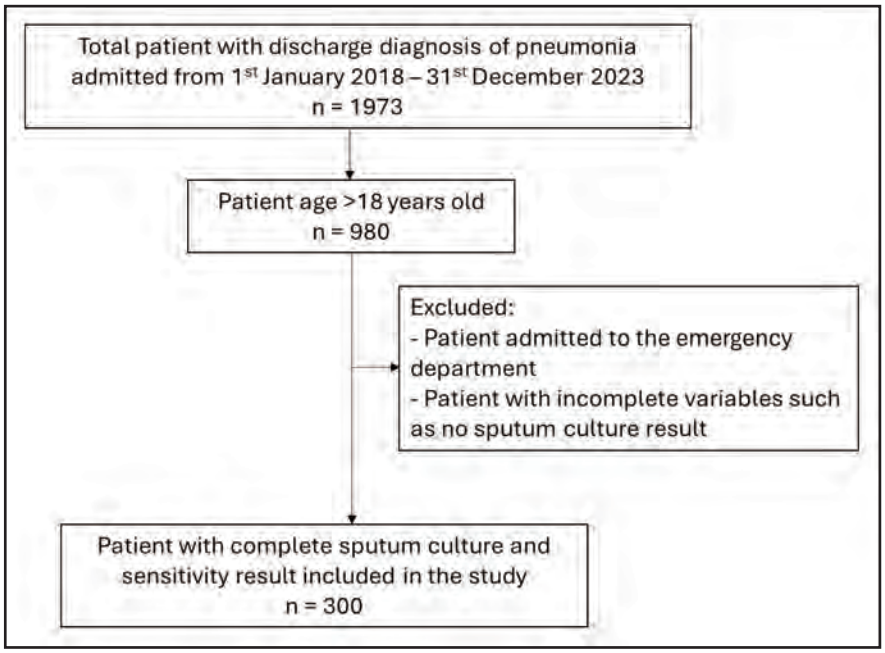

Fig. 1: Data extraction flowchart

MATERIALS AND METHODS

Study settings

Petaling district in Selangor provides an important setting for local investigation because of its rapid population growth, from approximately 360,000 in 1980 to 2.3 million in 2023.[12] Hospital Shah Alam is the only publicly funded tertiary hospital in this district and also receiving referrals from surrounding hospitals and health clinics. In 2022, the incidence of extended-spectrum beta-lactamase (ESBL) *Klebsiella pneumoniae* infection at Hospital Shah Alam was estimated at 0.22 per 100 admissions, approaching the Ministry of Health Malaysia indicator of ≤0.3 per 100 admissions.[13-14] Antimicrobial susceptibility testing in this hospital was conducted according to Clinical & Laboratory Standards Institute (CLSI) standards.

Study design

This cross-sectional study was conducted using data extracted from the Hospital Shah Alam's electronic medical records (EMR). The study was done between October 2024 and June 2025 involving secondary data analysis of patients admitted to the hospital between 1st January 2018 and 31st December 2023. The inclusion criteria consist of patients aged 18 years and above who were admitted within the specified timeframe and discharged with a diagnosis of pneumonia identified based on administrative ICD-10 discharge coding (ICD-10: J18.9). Patients discharged from the emergency department with a diagnosis of pneumonia for outpatient treatment and those without sputum culture results were excluded from the study.

Sample size calculation

The sample size was estimated using online sample size calculator based on the prevalence of AMR in pneumonia patients reported by Purba et. al.[7,15] Using a prevalence of 22%, an estimated population of 2000 patients, a 95% confidence interval level and 80% power, the required sample size was 234 samples. After adjusting for 20% missing data rate, the minimum required sample size was 292. Universal sampling method was used to select the sample for the study.

Statistical analysis

AMR status as the outcome in this study was operationally defined as positive (coded as 1) if the organism identified from the culture was resistant to at least one class of antibiotics, including the intermediate susceptibility. All univariate and multivariable analyses were conducted using SPSS version 29. To maintain confidentiality, patient identifiers were removed and only study identification numbers were used. The data extraction flowchart is described in Figure 1. Missing data were handled using multiple imputation. The prevalence and its 95% confidence interval (95% CI) were calculated using the formula:

$$\text{Prevalence} = \frac{\text{(No. of AMR positive sample)}}{\text{(Total adult pneumonia patient in the sample)}} \times 100\%$$

$$95\%\ \text{CI} = z \times \sqrt{\frac{p(1-p)}{n}}$$

For the determination of factors associated with AMR, data were analysed using simple logistic regression and Fisher's exact test. Subsequently, variables with a p-value<0.25 were included in the multivariable analysis using multiple logistic regression.[16] The crosstabulation of organisms isolated and antibiotic class resistance was presented by frequency and percentage.

Ethical approval

The study's ethical approval was obtained from the Malaysian Research Ethics Committee (MREC) with reference number: NMRR ID-25-00243-CVW. Exemption from the faculty ethics review was obtained from Universiti Teknologi MARA Faculty Ethics Review Committee (FERC) with reference number: 100 - FPR (PT.9/19) (FERC-EX-25-06).

Table I: Characteristics of study sample by AMR status

Characteristics	AMR (n = 47)	Non-AMR (n = 253)	Total (n = 300)
Age (years), mean (SD)	58.79 (17.061)	53.26 (18.270)	54.13 (18.17)
Gender, n (%)			
Male	22 (46.8)	118 (46.6)	140 (46.7)
Female	25 (53.2)	135 (53.4)	160 (53.3)
Ethnicity, n (%)			
Malay	26 (55.3)	184 (72.7)	210 (70.0)
Chinese	3 (6.4)	20 (7.9)	23 (7.7)
Indian & others	18 (38.3)	49 (19.4)	53 (22.3)
Citizenship, n (%)			
Malaysian	47 (100.0)	241 (95.3)	288 (96.0)
Non-Malaysian	0 (0.0)	12 (4.7)	12 (4.0)
Diabetes mellitus, n (%)			
Yes	17 (36.2)	103 (40.7)	120 (40.0)
No	30 (63.8)	150 (59.3)	180 (60.0)
Hypertension, n (%)			
Yes	29 (61.7)	127 (50.2)	156 (52.0)
No	18 (38.3)	126 (49.8)	144 (48.0)
Chronic Kidney Disease, n (%)			
Yes	5 (10.6)	31 (12.3)	36 (12.0)
No	42 (89.4)	222 (87.7)	264 (88.0)
Coronary Heart Disease, n (%)			
Yes	7 (14.9)	41 (16.2)	48 (16.0)
No	40 (85.1)	212 (83.8)	252 (84.0)
Smoking status, n (%)			
Yes	14 (29.8)	76 (30.0)	90 (30.0)
No	33 (70.2)	177 (70.0)	210 (70.0)
Length of stay (days), mean (SD)	17.53 (21.612)	7.65 (7.002)	9.20 (11.23)
ICU admission, n (%)			
Yes	23 (48.9)	51 (20.2)	74 (24.7)
No	24 (51.1)	202 (79.8)	226 (75.3)
Prior antibiotic use, n (%)			
Yes	9 (19.1)	24 (9.5)	33 (11.0)
No	38 (80.9)	229 (90.5)	267 (89.0)
Prior admission <30 days, n (%)			
Yes	8 (17.0)	27 (10.7)	35 (11.7)
No	39 (83.0)	226 (89.3)	265 (88.3)
Prior history of pneumonia, n (%)			
Yes	7 (14.9)	18 (7.1)	25 (8.3)
No	40 (85.1)	235 (92.9)	275 (91.7)
History of HAI, n (%)			
Yes	2 (4.3)	7 (2.8)	9 (3.0)
No	45 (95.7)	246 (97.2)	291 (97.0)
Invasive procedures, n (%)			
Yes	28 (59.6)	55 (21.7)	83 (27.7)
No	19 (40.4)	198 (78.3)	217 (72.3)

RESULTS

Out of 1,973 pneumonia admissions assessed, 980 met the age criteria and a total of 300 samples were found to be eligible for final analysis in the study (Figure 1). The characteristics of the samples are presented in Table I. The prevalence of AMR in pneumonia among patients in this study was 15.7% (95% CI: 11.5, 19.8). The mean age of patients was 54.13 years (SD: 18.17), with a slightly balanced proportion of males and females. Most patients in this study were of Malay ethnicity and Malaysian citizens.

Univariate analyses of the factors examined in this study identified a few statistically significant variables with p-value<0.25 (Table II). Variables included in the multivariable analysis were patients' age, ethnicity, presence of hypertension comorbidity, length of stay, ICU admission, prior antibiotic use, prior admission, prior history of pneumonia and invasive procedures. When multiple logistic regression analysis was used to build the prediction model, only patients' age, ethnicity, length of stay, and invasive procedures were found to be statistically significant at p-value<0.05 (Table III). The Receiver Operating Characteristic (ROC) curve shows acceptable prediction with Area Under Curve (AUC) of 0.771 (95% CI: 0.696, 0.845).

A total of 68 positive patient samples were identified, and among them, the majority of isolated organisms were K. pneumoniae (50.0%), followed by *P. aeruginosa* (23.5%) and *A. baumannii* (7.4%). Resistance to penicillin was highest in number in pneumonia cases with *K. pneumoniae* (47.8%), while resistance to penicillin combined with beta-lactamase inhibitors was highest in *P. aeruginosa* infections (37.5%). *A. baumannii* showed resistance rates of 20% to the carbapenem group, penicillin combined with beta-lactamase inhibitors and cephalosporins. The crosstabulation between antibiotic resistance class and the organism is presented in Table IV.

Table II: Univariate analysis of factors associated with AMR

Variables	Crude OR (95% CI)[a]	p-value
Age (years), mean ± SD	1.02 (0.99, 1.04)	0.057*
Gender, n (%)		
Male	1.01 (0.54, 1.88)	0.983
Female	ref	
Ethnicity, n (%)		
Malay	ref	
Chinese	1.06 (0.30, 3.82)	0.927
Indian & others	2.60 (1.32, 5.12)	0.006*
Citizenship, n (%)		
Malaysian	1.20 (1.14, 1.26)[b]	0.225
Non-Malaysian		
Diabetes mellitus, n (%)		
Yes	0.83 (0.43, 1.67)	0.560
No	ref	
Hypertension, n (%)		
Yes	1.60 (0.85, 3.02)	0.149*
No	ref	
Chronic Kidney Disease, n (%)		
Yes	0.85 (0.31, 2.32)	0.755
No	ref	
Coronary Heart Disease, n (%)		
Yes	0.91 (0.38, 2.16)	0.822
No	ref	
Smoking status, n (%)		
Yes	0.99 (0.50, 1.95)	0.972
No	ref	
Length of stay (days), mean ± SD	1.07 (1.04, 1.10)	<0.001*
ICU admission, n (%)		
Yes	3.80 (1.98, 7.27)	<0.001*
No	ref	
Prior antibiotic use, n (%)		
Yes	2.26 (0.98, 5.23)	0.057*
No	ref	
Prior admission <30 days, n (%)		
Yes	1.72 (0.73, 4.05)	0.217
No	ref	
Prior history of pneumonia, n (%)		
Yes	2.29 (0.90, 5.82)	0.083*
No	ref	
History of HAI, n (%)		
Yes	1.56 (0.31, 7.76)	0.586
No	ref	
Invasive procedures, n (%)		
Yes	5.31 (2.76, 10.21)	<0.001*
No	ref	

[a]Univariate analysis done using simple logistic regression unless specified otherwise. OR: Odds Ratio. CI: Confidence Interval.
[b]Analysed using Fisher's Exact Test.
*Variables significant at P-value<0.25 were included into the multivariable analysis.

Table III: Multivariable analysis

	Adjusted ORa (95% CI)	Wald (df)	p-value*
Age (years)	1.03 (1.01, 1.05)	6.79 (1)	0.009
Ethnicity			
Malay	ref		
Chinese	0.75 (0.18, 3.06)	0.16 (1)	0.688
Indian & others	2.24 (1.05, 4.77)	4.38 (1)	0.036
Length of stay (days)	1.05 (1.01, 1.08)	6.99 (1)	0.008
Invasive procedures	3.65 (1.71, 7.82)	11.15 (1)	<0.001

[a]Multivariable analysis done using multiple logistic regression. Backward Likelihood Ratio method was used. Multicollinearity checked where Variable Inflation Factor (VIF) for all factors were less than 2. Final model Hosmer-Lemeshow goodness-of-fit test was not significant (p-value: 0.96). Cox & Snell adjusted R2: 0.143. No influential outliers were detected. p-values for interactions between variables were not significant.
*Statistically significant at p-value<0.05.

Table IV: Crosstabulation of antibiotic class resistance and cultured organisms

Antibiotic Organism	Amino glycoside, n (%)	Sulpho namide*, n (%)	Carba penem, n (%)	Cepha losporin, n (%)	Cephal osporin +β-lactam ase inhibitor**, n (%)	Fluroq uinolone, n (%)	Fusi dane***, n (%)	Macro lide, n (%)	Peni cillin, n (%)	Peni cillin +β-lactam ase inhibitor****, n (%)	Total
K. pneumonia	3 (4.5)	3 (4.5)	1 (1.5)	8 (11.9)	2 (3)	5 (7.5)	0 (0)	0 (0)	32 (47.8)	13 (19.4)	67
A. baumannii	2 (10)	0 (0)	4 (20)	4 (20)	2 (10)	3 (15)	0 (0)	0 (0)	1 (5)	4 (20)	20
E. coli	1 (10)	1 (10)	0 (0)	2 (20)	1 (10)	1 (10)	0 (0)	0 (0)	2 (20)	2 (20)	10
Acinetobacter sp.	0 (0)	0 (0)	2 (25)	2 (25)	2 (25)	0 (0)	0 (0)	0 (0)	1 (12.5)	1 (12.5)	8
P. aeruginosa	1 (12.5)	0 (0)	1 (12.5)	2 (25)	0 (0)	0 (0)	0 (0)	0 (0)	1 (12.5)	3 (37.5)	8
S. aureus	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (25)	2 (25)	4 (50)	0 (0)	8
Enterobacter sp.	0 (0)	0 (0)	0 (0)	1 (33.3)	0 (0)	0 (0)	0 (0)	0 (0)	1 (33.3)	1 (33.3)	3

*Sulphonamide class: sulfamethoxazole/trimethoprim.
**Cephalosporin+β-lactamase inhibitor class: cefoperazone/sulbactam
***Fusidane class: fusidic acid
****Penicillin+β-lactamase inhibitor class: amoxicillin/clavulanic acid, ampicillin/sulbactam and piperacillin/tazobactam.

DISCUSSION

The prevalence of AMR found in this study was substantially higher compared to a study in the United States, which estimated AMR prevalence of 1.4%.[17] Fortunately, our results showed a lower burden compared to a study in Ethiopia, which revealed a staggering AMR prevalence of 50%.[6] This finding aligns with evidence in the literature indicating that the burden of AMR is related to the country's income level.[2,18-19]

Through the multivariable regression analysis, our study found that patients' age has a positive association with the AMR (OR=1.03; 95% CI: 1.01, 1.05). This result corroborates the findings of recent studies, indicating that older age groups have increased odds of AMR.[6,20] As patients' age increases, their comorbidities may significantly contribute to the development of AMR. Therefore, clinicians should consider patients' age when selecting an appropriate antibiotic treatment.

Interestingly, this study found that Indian and other ethnicities were significantly associated with AMR compared to Malay ethnicity (OR=2.24; 95% CI: 1.05, 4.77). A prior study by Haque et al. showed that ethnicity influences knowledge and beliefs about antibiotic prescriptions, while a study by Hassali et al. found that ethnicity was associated with the level of antibiotic practice.[21-22] Both studies suggested possible hypothesis that the association could also be attributed to differences in health beliefs and cultural perceptions among various ethnicities.

Additionally, the duration of patient admission was found to be statistically significant with the AMR (OR = 1.05; 95% CI: 1.01, 1.08). This finding is consistent with previous reports indicating that the length of patient stay is an essential predictor of AMR.[23-24] Besides AMR, the duration of patient stay also contributes to the overall cost of healthcare.[25] However, because total length of stay was evaluated cross-sectionally, prolonged stays could be both a cause and a consequence of AMR infection. Nevertheless, regularly evaluating whether continued hospitalization is needed is essential to avoid unnecessary admissions when appropriate.

Meanwhile, the presence of invasive procedures performed on the patient was found to be a significant predictor of AMR (OR=3.65; 95% CI: 1.71, 7.82). This result also corresponds with previous literature.[26-27] Patients who underwent invasive procedures such as mechanical ventilation, central line insertion and catheterization could be at higher risk of AMR. For example, procedures like mechanical ventilation can predispose patients to ventilator-associated pneumonia. Similarly, patient catheterisation carries a higher risk of catheter-related bloodstream infections (CRBSI), which may lead to the development of resistant infections.

This study also found that the majority of *K. pneumoniae*-positive sputum cultures are resistant to the Penicillin antibiotic class, similar to findings reported in the literature.[8,17,28] This could be due to the prevalent genetic mutations of *K. pneumoniae* bacteria, such as production of β-lactamases, plasmid-mediated resistance and low outer membrane permeability.[29-31] According to a recent report by the World Health Organization, there is an increase in the detection of hypervirulent *K. pneumoniae* bacteria in patients' clinical samples.[32] Meanwhile, a study in Nigeria found that 86.7% of *K. pneumoniae* isolates from their samples were multidrug-resistant organisms.[33] Conversely, a study in the United States reported that 37.7% of *S. pneumoniae* isolates were associated with AMR, with the greatest resistance observed against macrolide antibiotic class.[19]

However, this study was unable to show statistically significant results for a few factors, unlike what previous research had suggested. Intensive care unit admission, prior antibiotic use and prior history of pneumonia showed borderline significance in the univariate analysis but did not remain significant in the final multivariable analysis. Although the exact reason is unclear, this could be due to the relatively small sample size in this study compared to other studies in the literature. For example, a retrospective analysis study involving 2899 patients found that ICU admission was significantly associated with multi-drug resistant infection.[34]

Several limitations are acknowledged in this study. Firstly, being a single-centre study, the findings may have limited

generalisability to other hospitals. Secondly, selection bias is possible due to the exclusion of patients with incomplete data. Furthermore, the study does not differentiate between sporadic and outbreak cases of pneumonia, community or hospital acquired pneumonia and healthcare worker-related factors, such as prescribing patterns, are not considered due to limitations in the data source. Additionally, the cross-sectional nature of the study restricts the ability to establish causality between the study variables. Future longitudinal research should be considered to overcome this study's limitations.

CONCLUSION

This study revealed a high rate of AMR in hospitalised adult pneumonia cases. Implementing targeted infection control and antimicrobial stewardship is urgently essential to lessen AMR impact. Since developing new antibiotics is time-consuming and resource-intensive, improving local surveillance and promoting the proper use of current antibiotics are vital in tackling this escalating issue in Malaysia. Addressing this "silent" pandemic requires coordinated action throughout the healthcare system to maintain antibiotic effectiveness for future generations.

CONFLICT OF INTEREST

None declared.

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REFERENCES

1. U.S. Centers for Disease Control and Prevention. Antibiotic resistance threats in the United States 2019. [cited June 2025]. Available from: http://dx.doi.org/10.15620/cdc:82532.
2. GBD 2021 Antimicrobial Resistance Collaborators. Global burden of bacterial antimicrobial resistance 1990-2021: a systematic analysis with forecasts to 2050. Lancet 2024; 404(10459): 1199-226.
3. Pulingam T, Parumasivam T, Gazzali AM, Sulaiman AM, Chee JY, Lakshmanan M, et al. Antimicrobial resistance: prevalence, economic burden, mechanisms of resistance and strategies to overcome. Eur J Pharm Sci 2022; 170: 106103.
4. Ministry of Health Malaysia. National antibiotic resistance surveillance report 2023. [cited June 2025]. Available from: https://library.nih.gov.my/e-doc/imr/nsar-2023.pdf.
5. Thamlikitkul V, Rattanaumpawan P, Sirijatuphat R, Wangchinda W. Integrated one-day surveillance of antimicrobial use, antimicrobial consumption, antimicrobial resistance, healthcare-associated infection, and antimicrobial resistance burden among hospitalized patients in Thailand. J Infect 2020; 81(1): 98-106.
6. Mussema A, Beyene G, Gudina EK, Alelign D, Mohammed T, Bawore SG, et al. Bacterial etiology, antimicrobial resistance and factors associated with community acquired pneumonia among adult hospitalized patients in Southwest Ethiopia. Iran J Microbiol 2023; 15(4): 492-502.
7. Purba AKR, Ascobat P, Muchtar A, Wulandari L, Rosyid AN, Purwono PB, et al. Multidrug-resistant infections among hospitalized adults with community-acquired pneumonia in an Indonesian tertiary referral hospital. Infection and Drug Resistance. 2019; 12: 3663-75.
8. Li J, Wang J, Yang Y, Cai P, Cao J, Cai X, et al. Etiology and antimicrobial resistance of secondary bacterial infections in patients hospitalized with COVID-19 in Wuhan, China: a retrospective analysis. Antimicrob Resist Infect Control 2020; 9(1): 153.
9. Haseeb A, Faidah HS, Algethamy M, Alghamdi S, Alhazmi GA, Alshomrani AO, et al. Antimicrobial usage and resistance in Makkah region hospitals: a regional point prevalence survey of public hospitals. Int J Environ Res Public Health 2021; 19(1).
10. Ministry of Health Malaysia. Malaysian Action Plan on Antimicrobial Resistance (MyAP-AMR) 2022-2026 2022. [cited June 2025]. Available from: https://cdn.who.int/media/docs/default-source/antimicrobial-resistance/amr-spc-npm/nap-library/malaysia-amr-nap-2022-2026.pdf.
11. Ministry of Health Malaysia. Health white paper Malaysia 2023. [cited June 2025]. Available from: https://www.moh.gov.my/images/04-penerbitan/kertas-putih/Kertas_Putih_Kesihatan_ENG_compressed.pdf.
12. Department of Statistics Malaysia. Petaling Kawasanku Open DOSM 2024; (21/10/2024). [cited June 2025]. Available from: https://open.dosm.gov.my/dashboard/kawasanku/Selangor/district/Petaling.
13. Hospital Shah Alam. Laporan tahunan Hospital Shah Alam 2023 2024. [cited June 2025]. Available from: https://heyzine.com/flip-book/3b74ef80f4.html.
14. Ministry of Health Malaysia. Annual report infection prevention & control and antimicrobial resistance containment program 2023 2024. [cited June 2025]. Available from: https://myohar.moh.gov.my/reports-human-health/.
15. Arifin WN. Sample size calculator (web) 2026. [cited June 2025].Available from: http://wnarifin.github.io.
16. Hosmer D, Lemeshow S, Sturdivant R. Applied logistic regression: Wiley; 2013.
17. Ding H, Mang NS, Loomis J, Ortwine JK, Wei W, O'Connell EJ, et al. Incidence of drug-resistant pathogens in community-acquired pneumonia at a safety net hospital. Microbiol Spectr 2024; 12(8): e00792-24.
18. Lewnard JA, Charani E, Gleason A, Hsu LY, Khan WA, Karkey A, et al. Burden of bacterial antimicrobial resistance in low-income and middle-income countries avertible by existing interventions: an evidence review and modelling analysis. Lancet 2024; 403(10442): 2439-54.
19. Mohanty S, Cossrow N, Yu KC, Ye G, White M, Gupta V. Clinical and economic burden of invasive pneumococcal disease and noninvasive all-cause pneumonia in hospitalized US adults: a multicenter analysis from 2015 to 2020. Int J Infect Dis. 2024; 143: 107023.
20. Bourgi N, Olaby AA, Najdi A, Hatem G. Predictors of antibiogram performance and antibiotic resistance patterns in the northern Syrian region: a cross-sectional investigation. Explor Res Clin Soc Pharm 2024; 13: 100416.
21. Haque M, Rahman NAA, McKimm J, Binti Abdullah SL, Islam MZ, Zulkifli Z, et al. A cross-sectional study evaluating the knowledge and beliefs about, and the use of antibiotics amongst Malaysian university students. Expert Rev Anti Infect Ther 2019; 17(4): 275-84.
22. Hassali MA, Arief M, Saleem F, Khan MU, Ahmad A, Mariam W, et al. Assessment of attitudes and practices of young Malaysian adults about antibiotics use: a cross-sectional study. Pharm Pract (Granada) 2017; 15(2): 929.

23. Dark P, Hossain A, McAuley DF, Brealey D, Carlson G, Clayton JC, et al. Biomarker-guided antibiotic duration for hospitalized patients with suspected sepsis: the ADAPT-sepsis randomized clinical trial. JAMA 2025; 333(8): 682-93.
24. Hellyer TP, Mantle T, McMullan R, Dark P. How to optimise duration of antibiotic treatment in patients with sepsis? BMJ. 2020; 371: m4357.
25. Ar MNA, Binti Wan Puteh SE, Ibrahim R, Rahman MM, Abdul Karim Z, Bin Ali FZ, et al. Antimicrobial resistance in Malaysia: a cross-sectional study analysing trends and economic impacts. BMJ Open 2025; 15(2): e091687.
26. Abukhalil AD, Barakat SA, Mansour A, Al-Shami N, Naseef H. ESKAPE pathogens: antimicrobial resistance patterns, risk factors, and outcomes a retrospective cross-sectional study of hospitalized patients in Palestine. Infect Drug Resist 2024; 17: 3813-23.
27. Timsit JF, Esaied W, Neuville M, Bouadma L, Mourvllier B. Update on ventilator-associated pneumonia. F1000Res 2017; 6: 2061.
28. Chee HP, Ong YC. Antimicrobial Resistance Patterns among patients in a district hospital in Perak, Malaysia from year 2013 to 2015. Pak J Med Health Sci 2017; 11(3): 1179-81.
29. Bush K, Bradford PA. β-lactams and β-lactamase Inhibitors: an overview. Cold Spring Harb Perspect Med 2016; 6(8).
30. Domenech-Sanchez A, Martinez-Martinez L, Hernandez-Alles S, del Carmen Conejo M, Pascual A, Tomas JM, et al. Role of Klebsiella pneumoniae OmpK35 porin in antimicrobial resistance. Antimicrob Agents Chemother 2003; 47(10): 3332-5.
31. Pitout JD, Laupland KB. Extended-spectrum beta-lactamase-producing Enterobacteriaceae: an emerging public-health concern. Lancet Infect Dis 2008; 8(3): 159-66.
32. World Health Organization. Antimicrobial resistance, hypervirulent Klebsiella pneumoniae - global situation 2024. [cited June 2025]. Available from: https://www.who.int/emergencies/disease-outbreak-news/item/2024-DON527.
33. Chukwu EE, Awoderu OB, Enwuru CA, Afocha EE, Lawal RG, Ahmed RA, et al. High prevalence of resistance to third-generation cephalosporins detected among clinical isolates from sentinel healthcare facilities in Lagos, Nigeria. Antimicrob Resist Infect Control 2022; 11(1): 134.
34. Marghoob B, Khosravi-Khezri M. The relationship between positive cultures with multidrug-resistant microorganisms and mortality in a general intensive care unit. Avicenna J Clin Microbiol Infect 2022; 9(2): 70-6.