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Factors associated with multidrug-resistant organism (MDRO) mortality: an analysis from the national surveillance of multidrug-resistant organism, 2018-2022

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Abstract

Introduction Antimicrobial resistance is a global issue, with the World Health Organization identifying it as one of the greatest threats to public health, with an estimated 4.95 million deaths linked to bacterial AMR in 2019. Our study aimed to determine the prevalence of mortality among multidrug-resistant organism (MDRO)-infected patients in state hospitals and major specialist hospitals and to identify risk factors that could be associated with mortality outcomes.

Methods This is a cross-sectional study performed at 28 hospitals under the Ministry of Health, Malaysia, involved in the National Surveillance of Multidrug-Resistant Organism, which surveys 6 MDROs (*Acinetobacter baumanii*, extended-spectrum beta-lactamase (ESBL)-producing *Escherichia coli*, extended-spectrum beta-lactamase (ESBL)-producing *Klebsiella pneumoniae*, carbapenem-resistant *Entrobacterales (CRE)*, methicillin-resistant *Staphylococcus aureus (MRSA)* and vancomycin-resistant *Enterococcus (VRE)*).

Results In terms of mortality, 9.6% ($n=951$) of the patients died overall, whereas 90.4% ($n=8931$) of the patients survived. Healthcare-acquired infection (HCAI) poses a high risk of mortality, with an adjusted odds ratio (aOR) of 2.91 (95% CI: 2.15–3.94). The presence of sterile specimens was significantly associated with increased mortality risk (aOR: 2.33, 95% CI: 2.02–2.68). Gram-negative bacteria had a greater mortality risk (aOR 1.63 95% CI: 1.37–1.93), whereas *Acinetobacter baumanii* had the highest prevalence of 30.7% (3033) among the 6 MDRO organisms isolated. Patients in medical-based departments had a greater mortality risk (aOR: 1.47, 95% CI: 1.22–1.75).

Conclusion HCAIs, Gram-negative bacteria, sterile specimens, medical-based departments and state hospitals have been shown to be associated with increased mortality risk in patients with MDRO infections. Improved surveillance and reporting mechanisms are necessary to better understand the burden of MDRO infections and guide research funding allocation.

Keywords Healthcare-acquired infections, Antimicrobial resistance, Bacteraemia, Hospital mortality

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Introduction

Antimicrobial resistance is a global issue, with the World Health Organization identifying it as one of the greatest threats to public health [1]. An estimated 4.95 million deaths were linked to bacterial AMR in 2019, of which 1.27 million were directly related to the disease [2, 3]. In 2019, more than 1.5 million deaths were caused by resistance-related lower respiratory infections, making it the most burdensome infectious condition [3]. The improper use of antibiotics results in the development and preferential survival of microorganisms that are resistant to these drugs [4]. Studies have revealed that a tremendous clinical and economic burden is caused by multidrug-resistant organism (MDRO) bacteraemia compared with antibiotic-susceptible and noninfected bacteraemia, suggesting that substantial investment and efforts by related government agencies and medical staff are needed [5, 6].

According to the Key Health Indicator Report 2023 by the Ministry of Health, Malaysia, the mortality rate of bacterial agents resistant to antibiotics (MDROs) in Malaysia is 0.03 per 100 000 people [7]. A report published by the Institute for Health Metrics and Evaluation (IHME) in 2019 reported that Malaysia had 3,500 deaths caused by antimicrobial resistance (AMR) and an additional 14,000 deaths associated with AMR. The number of AMR deaths in Malaysia is greater than the number of deaths from digestive diseases, diabetes and kidney diseases, transport injuries, chronic respiratory diseases, and neurological disorders [8].

MDRO infections have been shown to increase the risk of hospital mortality by 1.5-4.0 times and can lead to longer stays in the hospital, higher costs, and increased morbidity [9, 10]. Bloodstream infections (BSIs) caused by MDROs are associated with high morbidity and mortality [9, 11]. Healthcare-associated infections (HCAIs) are a serious threat to healthcare safety [12]. Patients with healthcare-associated infections are more likely to develop BSIs caused by MDROs and have higher mortality rates [9, 13]. Other factors that increase the risk of MDRO acquisition include long-term institutionalization, older age, functional dependency, the presence of invasive devices, recent procedures, and recent antibiotic use [14, 15]. Preventing infections is crucial for reducing the burden of MDROs in healthcare settings [16].

Many studies have focused on a single tertiary hospital with a smaller sample size and may not be fully representative of other hospitals [17, 18]. Other studies focused only on single MDROs, such as *Acinetobacter baumannii* [19, 20]. Thus, this study aimed to determine the prevalence of commonly isolated MDROs in state hospitals and major specialist hospitals and to determine the risk factors that could be associated with mortality outcomes among MDRO-infected patients.

Materials and methods

Study design and settings

This cross-sectional study was performed at 28 hospitals under the Ministry of Health, Malaysia, which are involved in the National Surveillance of Multidrug Resistant Organism. The hospitals involved in the surveillance were from 14 state hospitals and 14 major hospitals. The data were collected from 2018 to 2022.

Study sample and data collection

The data were collected from the National Surveillance of Multidrug Resistant Organism by the Infection Control Unit, Ministry of Health, Malaysia. This surveillance includes all inpatients in the hospital except for cases from emergency or outpatient services, cases previously identified at other healthcare facilities, patients who were admitted with the same MDRO within a year, and cases from a screening culture. The infection control nurse (ICN)/infection control personnel (ICP) collected data on MDRO and MRSA strains isolated from blood cultures daily from the laboratory. The MDROs that were monitored included *Acinetobacter baumanii*, extended-spectrum beta-lactamase (ESBL)-producing *Escherichia coli*, extended-spectrum beta-lactamase (ESBL)-*producing Klebsiella pneumoniae*, carbapenem-resistant *Entrobacterales (CRE)*, methicillin-resistant *Staphylococcus aureus (MRSA)* and vancomycin-resistant *Enterococcus (VRE).*

The sample size was calculated via the single proportion formula in OpenEpi software version 3.0, which is based on a previous study reporting an MDRO mortality rate of 37.3% [17]. The minimum required sample size was determined to be 360, with a precision of 5% and a 95% confidence interval. The selection of the study population is described in Fig. 1.

Definition of variables, inclusion criteria, and exclusion criteria

The definition of MDRO cases according to the Multidrug Organism Surveillance Manual of 2018 is as follows: the organism must fulfill all three criteria: isolation of the MDRO from any site of the body, the case must be an inpatient, and the case must be "Newly identified." "Newly identified" includes MDROs identified for the first time during current hospital admission and cases identified at the hospital site but acquired 'new infection' with different MDROs [21]. If more than one type of MDRO is isolated from the same patient, it should be counted separately. There are six types of MDROs collected for this purpose: methicillin-resistant *Staphylococcus aureus* (MRSA), extended-spectrum beta-lactamase (ESBL)-producing *Klebsiella pneumoniae*, extended-spectrum beta-lactamase (ESBL)-producing *Escherichia coli*, multidrug-resistant *Acinetobacter baumanii*,

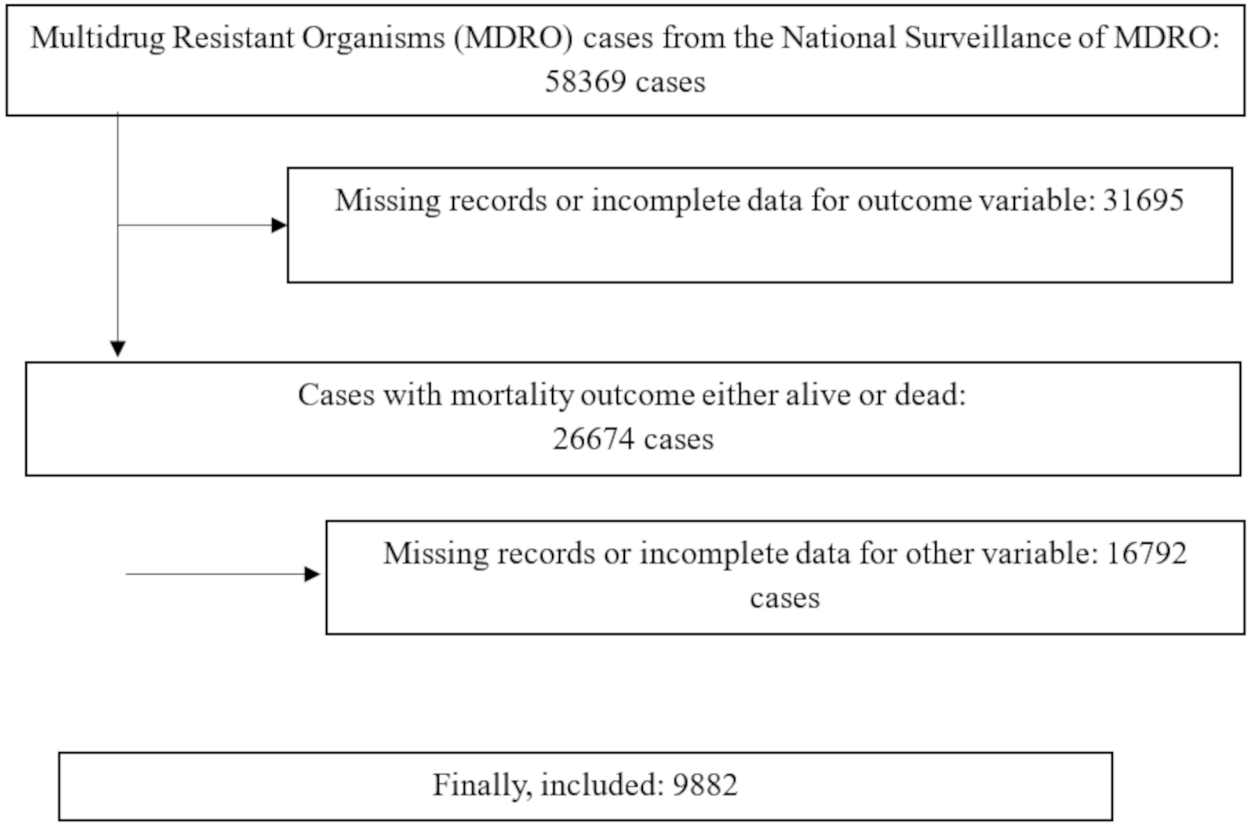

Fig. 1 Selection of the study population

carbapenem-resistant *Enterobacteriaceae* (CRE), and vancomycin-resistant *Enterococcus* (VRE). The exclusion criteria were as follows: cases from the emergency department, clinic, or other outpatient services; cases previously identified at other acute care facilities/hospitals; cases readmitted with the same MDRO within one year; screening culture; and incomplete or missing data.

The variables included in this study were year, department, previous encounter with healthcare facility, history of surgical intervention within 1 month, history of surgical implant within 1 year, type of specimen, isolated organism, isolation status, type of infection, healthcare-acquired infection (HCAI) status, antibiotics [1] and [2], hospitals, and category. The outcome of the study was mortality, which was further defined as "living" or "dead". The definitions of the variables are as per Table 1.

Statistical analysis

All the data was retrieved via an Excel spreadsheet. SPSS® version 26.0 (IBM, New York, USA) for Windows® was used for the data analysis, descriptive analysis (percentages and frequencies), and categorical analysis. The level of significance was set at $p < 0.05$. The chi-square test was used to compare all variables that were categorical data mortality-related MDROs. Simple logistic regression and multivariate regression were used to analyze the risk factors for mortality via backward and forward methods based on goodness-of-fit principles. The Hosmer–Lemeshow test was used to assess the model.

Results and analysis

A total of 9882 patients with MDROs from 2018 to 2022 were included in this study according to the eligibility criteria. The mortality outcome among MDRO-infected patients was 9.6% ($n = 951$), whereas 90.4% ($n = 8931$) of patients survived. The majority of MDRO cases occurred in 2021 (47.9%, $n = 4732$), followed by 2022 (36.2%, $n = 3577$). The most common departments involved were medical departments (34.5%, $n = 3411$), followed by anesthesia departments (28.2%, 2789) and surgical departments (10.3%, $n = 1018$). A total of 65.7% ($n = 6489$) of patients had no previous encounter with a healthcare facility, and 85.2% ($n = 8423$) of patients had no history of surgical intervention within the past month before admission. Blood samples were the most common type of sample (40.8%, 4029), followed by tracheal samples (27.5%, $n = 2719$). The antibiotics most prescribed for the past 3 months among MDRO patients were

Table 1 Operational definitions of the variables

Variable	Operative Definition
Year	This variable is further divided into pre covid era (2018–2019) and post covid era (2020–2022)
Department	This variable was categorized into (21) i. Surgical-based department (Orthopedic, O&G, Surgical, Urology) ii.Medical-based Department (Anesthesia, Medical, Nephrology, Oncology, Pediatric) iii. Others
Previous Encounter with Healthcare Facility	This variable is categorized as "Yes" or "No" (21)
History of Surgical Intervention Within 1 Month	This variable is categorized as "Yes" or "No" (21)
History Of Surgical Implant Within 1 Year	This variable is categorized as "Yes" or "No" (21)
Type Of Specimen	This variable is categorized into (21) i. Sterile site (blood, Cerebrospinal fluid (CSF), pleural fluid, peritoneal fluid) ii. Nonsterile site (Bronchoalveolar Lavage (BAL), Rectal, Sputum, Tissue, Tracheal Aspirate, Urine) iii. Others
Isolated Organism	This variable is categorized as (22) i. Gram Negative Bacteria • *Acinetobacter baumanii* • Extended-spectrum beta lactamases (ESBL) producing *Escherichia coli*, • Extended-spectrum beta lactamases (ESBL) producing *Klebsiella pneumoniae*, • Carbapenem-resistant *Entrobacterales (*CRE*)* ii. Gram Positive Bacteria • Methicillin-resistant *Staphylococcus aureus (*MRSA*)* • Vancomycin-resistant *Enterococcus (*VRE*)* iii. Others
Type Of Infection	This variable is divided into (21) i. Bloodstream Infection (BSI) and ii. "Non-Bloodstream Infection" such as • Hospital Acquired Pneumonia (HAP) (non-VAP) • Intra-Abdominal • Surgical Site Infection (SSI) • Skin and Soft Tissue Infection (SSTI) • Urinary Tract Infection (UTI) • Others
Healthcare Acquired Infection (HCAI) Status	This variable is divided into (21) i. Healthcare Acquired Infection (HCAI) and • Hospital Acquired (HA)-MDRO, other MOH Facility • HA-MDRO, Own Facility • Healthcare Acquired Infection (HCAI), non MOH Facility • HCAI, other MOH Facility • HCAI, Own Facility ii. Non-Healthcare Acquired Infection (HCAI) • Community-Associated MRSA • Not Healthcare Associated MDRO
Antibiotic 1	Antibiotics that were prescribed within the last three months among patients with MDROs. This variable is divided into beta-lactam or non beta lactam antibiotic (23) i. beta lactam antibiotic • beta lactamase • aminoglycosides • carbapenems • cephalosporin • penicillin ii. non beta lactam antibiotic • colistin • fluoroquinolones • glycopeptides • Others

Table 1 (continued)

Variable	Operative Definition
Antibiotic 2	Antibiotics that were prescribed within the last three months among patients with MDROs. This variable is divided into beta-lactam or non beta lactam antibiotic (23) i. beta lactam antibiotic • beta lactamase • aminoglycosides • carbapenems • cephalosporin • penicillin ii. non beta lactam antibiotic • colistin • fluoroquinolones • glycopeptides • Others
Mortality Outcome	This variable was categorized as outcome of patient either "Dead" or "Alive" (21)
Hospitals Category	This variable is categorized as "State Hospital" or "Major Hospital" (21)

beta-lactamases, carbapenems and cephalosporins. There were 2 types of isolation statuses: infection or colonizer. Initially, there were a total of 58,369 MDRO cases where 17,407 of the cases are colonizers, but due to incomplete and missing data for other variables, these cases were then discarded. The characteristics of the MDRO cases are shown in Table 2.

The most common isolated organism in state and major specialist hospitals was *Acinetobacter baumanii* (30.7%; $n = 3033$). The distributions of MDROs by type in the state and major hospitals are shown in Table 3.

Acinetobacter baumanii (36.8%, 350) is the most common isolated organism among MDRO patients and contributes to the highest mortality among MDRO patients. Table 4 presents the results of MDRO mortality among the isolated organisms.

Table 5 presents the results of the chi-square analysis used to identify associations between the independent variables and mortality outcomes among MDRO patients. Chi-square analysis revealed significant associations between the year, department, previous encounter with healthcare facilities, history of surgical intervention, history of surgical implantation within 1 year, type of specimen, isolated organism, type of infection, HCAI status, antibiotic, and hospital category and mortality outcomes among MDRO patients.

Table 6 presents the results of simple logistic regression and multiple logistic regression analyses of mortality outcomes and their independent variables. The simple logistic regression analysis revealed that all 13 variables were significant at $p < 0.05$. After controlling for the selected variables in the multiple logistic regression analyses, four [4] independent variables were associated with a greater risk of mortality. HCAI seemed to be the most significant predictor of the mortality outcome of a patient (adjusted odds ratio (aOR): 2.91, 95% CI: 2.15–3.94). This was followed by sterile specimens (aOR 2.33 95% CI: 2.02–2.68), Gram-negative organisms (aOR: 1.63, 95% CI: 1.37–1.93), medical-based departments (aOR 1.47 95% CI: 1.22–1.75), and state hospitals (adjusted OR 1.22 95% CI: 1.05–1.42). There was no multicollinearity among these independent variables. Hosmer and Lemeshow goodness-of-fit tests demonstrated that our dataset fit well with the logistic model. This model was able to correctly predict 90.4% of mortality outcomes among MDRO cases and explained 9.9% of the variation in the outcome variable.

Discussion

To our knowledge, this is the largest study in Malaysia that analysed 6 MDROs that were monitored under National MDRO surveillance, which involves 28 hospitals. This study sheds light on the state of Malaysia concerning MDROs.

The mortality outcome among all MDRO-infected patients was 9.6% ($n = 951$). Our analysis revealed that Gram-negative bacteria (*Acinetobacter baumanii*, extended-spectrum beta lactamases (ESBL) producing *Escherichia coli*, extended-spectrum beta lactamases (ESBL) producing *Klebsiella pneumoniae*, and carbapenem-resistant *Entrobacterales* (CRE)) were associated with a greater risk of mortality among patients with MDRO infections ($p < 0.05$). In our study, *Acinetobacter baumanii* (36.8%, 350) had the highest mortality among MDRO-infected patients. The presence of *A. baumannii* bacteria is the greatest concern and has been repeatedly highlighted in other studies [19, 22, 23]. Recent research has also indicated that infection with *A. baumannii* is a contributing factor to mortality in the ICU [17]. The prevalence of commonly isolated MDROs among state hospitals and major specialist hospitals is *A. baumannii*. Other researchers reported the same findings for their hospital settings [19, 22]. *A. baumannii* is an opportunistic bacterial pathogen primarily associated with

Table 2 Descriptive analysis of MDRO case characteristics

Variables	MDRO-infected patients	
	n	%
Isolated Organism		
• *Acinetobacter baumanii*	3033	30.7
• ESBL - *Klebsiella pneumoniae*	1946	19.7
• MRSA	1526	15.4
• CRE	1252	12.7
• ESBL - *E. Coli*	1132	11.5
• Others	945	9.6
• VRE	48	0.5
Mortality outcome		
• Alive	8931	90.4
• Dead	951	9.6
Year		
• 2018	632	6.4
• 2019	931	9.4
• 2020	10	0.1
• 2021	4732	47.9
• 2022	3577	36.2
Department		
• Medical	3411	34.5
• Anaesthesia	2789	28.2
• Surgical	1018	10.3
• Orthopaedic	771	7.8
• Others	688	7.0
• Paediatric	679	6.9
• Urology	108	1.1
• Nephrology	201	2.0
• Obstetrics and Gynaecology (O&G)	158	1.6
• Oncology	59	0.6
Previous encounter to healthcare facility		
• No	6489	65.7
• Yes	3393	34.3
History of Surgical Intervention within 1 month		
• No	8423	85.2
• Yes	1459	14.8
History of Surgical Implant Within 1 Year		
• No	9612	97.3
• Yes	270	2.7
Type Of Specimen		
• Blood	4029	40.8
• Tracheal aspirate	2719	27.5
• Urine	783	7.9
• Tissue	654	6.6
• Sputum	398	4.0
• Wound	323	3.3
• Bronchoalveolar Lavage (BAL)	112	1.1
• Cerebro Spinal Fluid (CSF)	48	0.5
• Peritoneal Dialysis (PD) fluid	49	0.5
• Rectal swab	36	0.4
• Others	731	7.4
Isolate Status		
• Infection	9882	100
• Colonizers	0	0
Type of Infection		

Table 2 (continued)

Variables	MDRO-infected patients	
	n	%
• Bloodstream Infection (BSI)	3960	40.1
• Hospital-Acquired Pneumonia (HAP) non-Ventilator Acquired Pneumonia (VAP)	3199	32.4
• Others	883	8.9
• UTI (Urinary Tract Infection)	782	7.9
• SSTI (Skin and Soft Tissue Infection)	519	5.3
• Surgical Site Infection (SSI)	432	4.4
• Intraabdominal	107	1.1
Healthcare Associated Infection (HCAI) status		
• HCAI, own facility	7800	78.9
• Not Healthcare Associated MDRO	1223	12.4
• Hospital Acquired Multidrug Resistant Organism (HA-MDRO), Own Facility	530	5.4
• HCAI, other MOH Facility	160	1.6
• Community MDRO	93	0.9
• HCAI, non MOH Facility	70	0.7
• HA-MDRO, other MOH Facility	6	0.1
Antibiotic 1		
• B-lactamase	2475	25.0
• carbapenems	2057	20.8
• penicillin	989	10.0
• glycopeptides	552	5.6
• colistin	444	4.5
• Others	285	2.9
• aminoglycosides	115	1.2
• fluoroquinolones	49	0.5
Antibiotic 2		
• carbapenems	2441	24.7
• cephalosporins	2147	21.7
• B-lactamase	2035	20.6
• Others	876	8.9
• penicillin	844	8.5
• glycopeptides	754	7.6
• colistin	491	5.0
• aminoglycosides	226	2.3
• fluoroquinolones	68	0.7
Zone		
• Northern	582	33.0
• Central	404	22.9
• Southern	404	22.9
• Eastern	354	20.1
• East Malaysia	19	1.1
Hospital category		
• State Hospital	6415	64.9
• Major Specialist Hospital	3467	35.1

ESBL-*Klebsiella pneumoniae*: Extended spectrum beta-lactamase-*Klebsiella;* MRSA: Methicillin-Resistant *Staphylococcus aureus*; ESBL-E. Coli: Extended-spectrum beta-lactamase *Escherichia coli*, CRE: carbapenem-resistant *Enterobacterales*, VRE: vancomycin-resistant *Enterococcus*

hospital-acquired infections [22]. The lack of adequate infection control measures and overuse of antimicrobial drugs have contributed to the increase in multidrug-resistant *A. baumannii* [20].

Mortality is significantly greater in healthcare-acquired infections (HCAIs) ($p < 0.05$) than in non-HCAIs. Studies have shown that MDRO infections are associated with increased mortality in HAIs in which an MDRO is involved (HAI-MDRO), which is 1.7 times greater (HR, 1.7; 95% confidence interval [CI], 1.25–2.32) than in infections caused by susceptible microorganisms [9]. In the National Surveillance of Antibiotic Report of 2022, HCAI had the highest prevalence in state hospitals (5.07%), followed by major specialist hospitals (5.06%)

Table 3 Distributions of MDROs by state and major specialist hospital type

Variable	State Hospital (*n*,%)	Major Specialist Hospital (*n*,%)
Isolated Organism		
• *Acinetobacter baumanii*	1714 (26.7)	1319 (38)
• ESBL - *Klebsiella pneumoniae*	1347 (21.0)	599 (17.3)
• MRSA	1072 (16.7)	454 (13.1)
• ESBL - E. Coli	843 (13.1)	289 (8.3)
• CRE	802 (12.5)	450 (13.0)
• VRE	40 (0.6)	80 (0.2)
• Others	597 (9.3)	348 (10.0)

ESBL-*Klebsiella pneumoniae*: Extended Spectrum Beta-Lactamase-*Klebsiella pneumoniae*; MRSA: Methicillin-Resistant *Staphylococcus aureus;* ESBL-*E. Coli*: Extended-spectrum beta-lactamase *Escherichia coli*, *CRE*: carbapenem-resistant *Enterobacterales*, *VRE*: vancomycin-resistant *Enterococcus*

Table 4 Bivariate analysis of MDRO mortality among isolated organisms

Isolated Organism	Outcome after 1 month	
	Alive (n,%)	Dead (n,%)
Acinetobacter baumanii	2683 (30.0%)	350 (36.8%)
CRE	1091 (12.2%)	161 (16.9%)
ESBL - E. Coli	1061 (11.9%)	71 (7.5%)
ESBL - *Klebsiella pneumoniae*	1768 (19.8%)	178 (18.7%)
MRSA	1368 (15.3%)	158 (16.6%)
VRE	44 (0.5%)	4 (0.4%)
Others	916 (10.3%)	29 (3.0%)
Total	8931 (100%)	951 (100%)

ESBL-*Klebsiella pneumoniae*: Extended-spectrum beta-Lactamase-*Klebsiella pneumoniae;* MRSA: Methicillin-Resistant *Staphylococcus aureus*; ESBL-E. Coli: Extended-spectrum beta-lactamase *Escherichia coli*, CRE: carbapenem-resistant *Enterobacterales*, VRE: vancomycin-resistant *Enterococcus*

and university hospitals (3.08%) [24]. In healthcare settings, especially critical care, compliance with hand hygiene is crucial to prevent the transmission of infection from healthcare personnel to patients or vice versa. The national surveillance of hand hygiene compliance has improved over the years, with rates ranging from 79.6% in 2016 to 87.2% in 2020. However, the trend of HCAI from 2018 until 2021 has plateaued within the range of 4–5 per 100 admissions [25].

In our study, sterile samples were significantly associated with increased mortality risk ($p < 0.05$) among MDRO-infected patients, where blood represented 40.8% ($n = 4029$) of the samples collected and was a sterile specimen. This might be due to bloodstream infections (BSIs), which are commonly found in 40.1% ($n = 3960$) of MDROs. According to the chi-square analysis, the BSI was significantly associated with MDRO mortality ($p < 0.05$). According to a report by the Ministry of Health, Malaysia, in the Point Prevalence Survey HCAI findings, BSI was one of the most common types of HCAI [24]. Few studies have revealed that risk factors for mortality in patients with BSI caused by MDROs include an ICU stay, where patients admitted to the intensive care unit (ICU) have a higher risk of mortality due to BSI caused by MDROs [9, 26, 27]. Patients with severe clinical conditions are at increased risk of death [26].

The analysis revealed that MDRO patients who were admitted to medical-based departments had a greater risk of mortality ($p < 0.05$). This might also be influenced by the fact that, in this study, medical departments and anesthesia departments had a greater number of patients with MDRO infection than did nonmedical-based departments, such as surgical, orthopedic or O&G departments. A previous study revealed that ICU patients had a greater risk of MDRO mortality than surgical wards did [9].

In our study, patients with MDRO infections who were admitted during the post-COVID-19 period (2020–2022) were at lower risk for mortality outcomes than were patients who were admitted before the pandemic (2020–2022) ($p < 0.05$). However, this is the opposite, as the presence of MDRO infection is strongly associated with increased mortality in individuals with COVID-19. In a recent study, patients with MDRO infections had a fourfold greater risk of death than did those without MDRO infections, where MDRO infections can precipitate the deterioration of patient health, resulting in sepsis and multiple organ failure, ultimately leading to mortality [18].

For the hospital categories, state hospitals had a greater mortality risk than major hospitals did ($p < 0.05$). One study revealed that the overall in-hospital mortality rate for patients admitted to tertiary care hospitals was greater than that for patients admitted to secondary care hospitals (median in-hospital death rates of 3.7% vs. 2.9%, respectively, $p = 0.05$) [28]. A study in Brazil revealed that MDRO infection increased hospital mortality [29].

In our study, patients with a history of surgical intervention within the past month and patients who had a history of surgical implantation within 1 year had a lower mortality outcome ($p < 0.05$). This finding is similar to that of a previous study showing that there was an association between a history of previous surgery and MDRO mortality, and the number of deaths recorded was 13.4% lower ($n = 76$) in groups with a previous history of surgery than in those with no previous history of surgery (24.4%, $n = 106$) [9]. However, other studies have consistently shown that patients who have undergone surgery are more likely to develop MDRO infections than are those who have not undergone surgery [14, 15, 17, 30].

Limitations

Owing to the retrospective design of this study, there were incomplete data or missing data during the retrieval of information. The final diagnoses were incomplete; this

Table 5 Bivariate analysis of independent variables associated with MDRO mortality

Variable	*N* (9882)	Outcome		X^2 (df)*	*p* Value
		Dead (*n*, %)	Alive (*n*, %)		
Year					
Post Covid (2020–2022)	8319	725 (8.7%)	7594(91.3%)	49.92(1)	< 0.001
Pre Covid (2018–2019)	1563	226 (14.5%)	1337 (85.5%)		
Department					
Medical	7139	777 (10.9%)	6362(71.2%)	46.97(1)	< 0.001
Non-Medical	2743	174(6.3%)	2569(93.7%)		
Previous Encounter to Healthcare Facilty					
Yes	3393	291 (8.6%)	3102 (91.4%)	6.51 (1)	0.011
No	6489	660 (10.2%)	5829 (89.8%)		
History of Surgical Intervention Within 1 Month					
Yes	1459	76 (5.2%)	1383 (94.8%	38.35 (1)	< 0.001
No	8423	875 (10.4%)	7548 (89.6%)		
History of Surgical Implant Within 1 Year					
Yes	270	6 (2.2%)	264 (97.8%)	17.48(1)	< 0.001
No	9612	945 (9.8%)	8667 (90.2%)		
Type of Specimen					
Sterile	4126	591 (14.3%)	3535 (85.7%)	179.93 (1)	< 0.001
Non-Sterile	5756	360 (6.3%)	5396 (93.7%)		
Isolated Organism					
Gram Negative	7363	760 (10.3%)	6603(89.7%)	16.20 (1)	< 0.001
Non-Gram Negative	2519	191(7.6)	2328(92.4%)		
Isolate Status					
Infection	9882	951	8931	-	-
Type of Infection					
Bloodstream Infection (BSI)	3960	570 (14.4%)	3390(85.6%)	172.90 (1)	< 0.001
Non-Bloodstream Infection	5922	381 (6.4%)	5541 (93.6%)		
HCAI Status					
HCAI	8566	904 (10.6%)	7662 (89.4%)	63.93(1)	< 0.001
Non HCAI	1316	47 (3.6%)	1269 (96.4%)		
Antibiotic 1					
Beta Lactam	8552	797 (9.3%)	7755 (90.7%)	6.75 (1)	0.001
Non-Beta Lactam	1330	154(11.6%)	1176 (88.4%)		
Antibiotic 2					
Beta Lactam	8552	797(9.3%)	7755 (90.7%)	6.756(1)	0.001
Non-Beta Lactam	1330	154 (11.6%)	1176 (88.4%)		
Category					
Major Specialist Hospital	3467	279(8.0%)	3188 (92.0%)	15.257 (1)	< 0.001
State Hospital	6415	672 (10.5%)	5743(89.5%)		

Note: $p < 0.05$ is a significant determinant

* Chi-square analysis

could have helped to further understand the etiology that leads to mortality among MDRO patients. Length of stay and sociodemographic data were also not available. The availability of these data would be valuable for demonstrating the association between this variable and mortality outcome.

Conclusion

MDRO infections are a significant public health concern because of their high mortality rates and potential for widespread transmission. Based on our study, *Acinetobacter baumanii* is the most commonly isolated organism in state hospitals and major specialist hospitals. It also contributes to the highest mortality among MDRO-infected patients. Among the risk factors that increase the risk of mortality among MDRO-infected patients are HCAI, sterile specimens, Gram- bacteria, state hospitals and medical-based departments. Prevention strategies include appropriate use of antimicrobials and proper infection control practices. Improved surveillance and reporting mechanisms, such as including final diagnoses, are necessary to better understand the

Table 6 Simple logistic regression and multivariate regression analyses of the independent variable and the mortality outcome

Variable	Regression Coefficient	Crude OR (95% CI)	Wald statistic (df)	*p* value [a]	Adj OR (95% CI)	Wald Statistic	*p* value[b]
Year							
Post Covid (2020–2022)	-0.57	0.57(0.48–0.66)	48.83 (1)	< 0.001	0.59 (0.50–0.69)	38.91	**< 0.001**
Pre Covid (2018–2019)*		1					
Department							
Medical	0.59	1.80 (1.52–2.14)	45.85 (1)	< 0.001	1.47(1.22–1.75)	17.34	**< 0.001**
Non-Medical		1					
Previous Encounter to Healthcare Facility							
Yes	-0.19	0.83 (0.72–0.96)	6.50(1)	< 0.001	-	-	-
No		1					
History of Surgical Intervention Within 1 Month							
Yes	-0.746	0.47 (0.37–0.60)	36.76 (1)	< 0.001	0.66 (0.51–0.85)	10.55	**0.001**
No		1					
History of Surgical Implant Within 1 Year							
Yes	-2.24	4.80 (2.13–10.81)	14.33	< 0.001	0.32(0.14–0.73)	7.31	**0.007**
No		1					
Type of Specimen							
Sterile	0.92	2.51(2.18–2.88)	170.90	< 0.001	2.33(2.02–2.68)	134.51	**< 0.001**
Non-Sterile		1					
Isolated Organism							
Gram Negative	0.34	3.19(2.36–4.30)	57.61	< 0.001	1.63(1.37–1.93)	29.93	**< 0.001**
Non-Gram Negative		1					
Isolate Status							
Infection	-2.24	0.11	4311.64	< 0.001	-	-	-
Type of Infection					-	-	-
Bloodstream Infection (BSI)	0.89	2.45(2.13–2.80)	164.71	< 0.001			
Non-Bloodstream Infection		1					
HCAI Status							
HCAI	1.16	3.19(2.36–4.30)	57.61	< 0.001	2.91(2.15–3.94)	47.70	**< 0.001**
Non HCAI		1					
Antibiotic 1							
Beta Lactam	-0.24	0.79(0.65–0.94)	6.73	0.009	-	-	-
Non-Beta Lactam		1					
Antibiotic 2							
Beta Lactam	-0.24	0.79(0.65–0.94)	6.73	0.009	-	-	-
Non-Beta Lactam		1					
Category							
State Hospital	0.29	1.34(1.16–1.55)	15.17	< 0.001	1.21(1.05–1.42)	6.519	**0.011**
Major Specialist Hospital		1					

[a] Simple logistic regression analysis

[b] Multiple logistic regression analysis

The model is based on forward LR. Nagelkerker R2 = 0.099

There was no multicollinearity (VIF < 10). There are no outliers. The model assumption was met

The Hosmer–Lemeshow test was not significant ($p = 0.123$)

The sensitivity is 100.0, the specificity is 0.0, and the accuracy is 90.4

The mortality outcomes of 90.4% of the patients were predicted to be either alive or dead

The model fits well

burden of MDRO infections and guide research funding allocation.

Abbreviations

MDRO	Multidrug Resistant Organism
ESBL-*Klebsiella pneumoniae*	Extended Spectrum Beta Lactamase -*Klebsiella pneumoniae*,
MRSA	Methicillin-Resistant *Staphylococcus Aureus*
ESBL-E.Coli	Extended Spectrum Beta Lactamase *Escherichia Coli*
CRE	Carbapenem-resistant *Enterobacterales*
VRE	Vancomycin-resistant *Enterococcus*
HCAI	Healthcare Associated Infection
HA-MDRO	Hospital Acquired Multidrug Resistant Organism
BSI	Bloodstream Infection
HAP	Hospital Acquired Pneumonia
SSI	Surgical Site Infection
SSTI	Skin and Soft Tissue Infection
UTI	Urinary Tract Infection
BAL	Bronchoalveolar Lavage
CSF	Cerebro Spinal Fluid
PD	Peritoneal Dialysis
aOR	Adjusted odds ratio
OR	Odds Ratio
p value	Probability value

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Author contributions
SE designed the project and data collection tools. MNA provide the data. All the authors cleaned, analysed and interpreted the data. NM drafted the paper. SE reviewed and gave technical advisory towards the manuscript as well as contributed important revisions. All authors read and approved the manuscript. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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Data availability
The data that support the study findings are available from the Ministry of Health Malaysia. Restrictions apply to the data availability, which was used under license for the current article, so it is not publicly available. Nevertheless, data are available from the authors upon reasonable request together with the permission of the Ministry of Health Malaysia.

Declarations

Ethics approval and informed consent to participate
Ethics clearance and approval were obtained from the Medical Research and Ethics Committee (MREC) of the Ministry of Health Malaysia [NMRR ID-23-01759-ZOY (IIR)] and the Research Ethics Committee from the National University of Malaysia [UKM PPI/111/8/JEP-2023-201] prior to the conduct of this study. We also obtain permission from the Director of Medical Development Division, Ministry of Health Malaysia who is the custodian of the data required for this study. The assigned healthcare personnel obtained informed consent from patients prior to initiating data collection at the hospital level, ensuring that individuals are fully aware of the purpose, process, and potential implications of their participation. Patient names were kept on a password-protected database and were linked only with a study identification number. All the data involved in this study are restricted to use by the investigator.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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