

Investigation of *Klebsiella pneumonia* and *Acinetobacter baumannii* Outbreak at a Secondary Care Hospital in Saudi Arabia

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Abstract Background: Carbapenem-resistant *Acinetobacter baumannii* (*A. baumannii*) and *Klebsiella pneumonia* (*K. pneumonia*) are accused of high prevalence and ability to cause outbreaks in healthcare settings. The current work aimed to analyze one of the major *K. pneumonia* and *A. baumannii* outbreaks at a secondary care hospital in Riyadh, Saudi Arabia including the identification of patients' infectivity and mortality risk factors, antibiotic susceptibility test results of the bacterial isolates, and infection control measures employed to halt the outbreak. **Methods:** A cross-sectional study was conducted from February to August 2022. Data were collected from the General Directorate of Infection Prevention and Control, Saudi Ministry of Health, and analysed using SPSS version 27. **Results:** 50 cases were affected by the outbreak, either infected with *K. pneumonia* or *A. baumannii* or co-infected with both organisms. Risk factors for particular infection among affected patients were the underlying diseases ($p=0.026$), length of pre-infection stay ($p=0.004$), and ICU stay ($p=0.015$). *A. baumannii*-infected patients have higher mortality rates (70.0%). *K. pneumonia* and *A. baumannii* demonstrate low sensitivity to 4 tested antibiotics including Amikacin, Gentamicin, trimethoprim-sulfamethoxazole, and Tigecycline, the last resort antibiotic treatment. **Conclusion:** *K. pneumonia* and *A. baumannii* outbreaks were associated with a preventable clinical and financial burden. Active screening of healthcare-associated infections is crucial for early detection, successful management of infection, and prevention of outbreak occurrence. Infection control measures played a significant role in controlling the outbreak.

Keywords: *Acinetobacter baumannii*, *Klebsiella pneumonia*, outbreak, infection control, mortality

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1. Introduction

Carbapenem-resistant *Acinetobacter baumannii* (*A. baumannii*) and *Klebsiella pneumonia* (*K. pneumonia*) are emerging multidrug-resistant bacteria that the World Health Organization (WHO) considers critical pathogens due to their threat to human health and well-being. [1] Both organisms are gram-negative bacteria responsible for many healthcare-associated infections (HAIs) with significant increases in mortality, and hospital costs in addition to the serious challenges in relation to clinical treatment and infection control. [1,2,3]

According to the Centers for Disease Control and Prevention (CDC), 2017 data indicate that carbapenem-resistant *Acinetobacter* resulted in approximately 8,500 infections among hospitalized patients and caused 700 deaths, costing the U.S. healthcare system \$28 million. [4]

In the United States, Europe, and China, CRKP accounted for 60%–90% of clinical carbapenem-resistant Enterobacteriaceae (CRE) infections, potentially leading to a mortality rate of 40%–50%. [5] Remarkably, considering that CRKP was first identified in the U.S. in 2001, it quickly became the most prevalent carbapenemase. [6]

Studies from select Middle Eastern countries have shown a high point prevalence of MDRO (Multidrug resistance organisms) infections, including HAIs and community-associated infections (CAIs) especially among ICU-admitted patients. The overall prevalence of both these infections stood at 28.3%, comprising 11.2% HAIs and 16.8% CAIs, respectively [7,8].

In the Kingdom of Saudi Arabia (KSA), available data illustrates that *K. pneumoniae* caused 30% of the infections, whereas *A. baumannii* was responsible for 13.3%. [8] Clinically, it has been observed both in KSA and globally that diabetic patients are more susceptible to *A. baumannii* infections than the general populace. A

study from the western region of KSA revealed that 36% of *A. baumannii*-infected patients had co-morbidities, with 11% being diabetic. [9] More alarmingly, in 2013, an outbreak of *A. baumannii* was detected in the adult ICU of a major hospital in KSA. Investigations attributed the widespread infection in the ICU to *A. baumannii* contaminants on a computer mouse and stethoscopes, indicating a possible transmission route from healthcare workers to patients. [9]

To combat the propagation of MDROs and other antimicrobial-resistant infections, the WHO launched a Global Action Plan on Antimicrobial Resistance. [10] This plan targets five primary objectives, including "improving awareness and understanding of antimicrobial resistance, bolstering surveillance and research, reducing the incidence of infection, optimizing antibiotic usage, and securing sustainable investments to combat antimicrobial resistance". [11]

The purpose of this study was to report and express the pattern of such outbreaks in Saudi Arabia, risks of infection, and mortality predictors of the patients infected with *A. baumannii* and/or *K. pneumonia*, determine the antibiotic susceptibility test results of these pathogens in addition to describe the applied infection control measures to control the outbreak.

2. Patients and Methods

2.1. Study Design and Duration

An epidemiological analytical cross-sectional study of *K. pneumoniae* and *A. baumannii* outbreak that occurred in a period between 1st February and 21st August 2022.

2.2. Study Setting

The study was conducted in an ICU of a secondary care MOH hospital with a bed capacity of 200 beds in Riyadh, the capital and largest city of Saudi Arabia. Riyadh had a population of 7.682.000 million people in 2023 and 102 public and private hospitals.

2.3. Study Population

2.3.1. Eligibility Criteria

All patients admitted to the ICU of the hospital during the outbreak period and tested positive for *K. pneumonia* and/or *A. baumannii* either infection or colonization after 48 hours of admission.

2.3.2. Sampling

Convenient sampling was done from February to August 2022 in which the first positive test result was observed (only the first positive test result was considered).

2.4. Data Collection

Secondary data were collected from the General Directorate of Infection Prevention and Control (GDIPC) Registry, Ministry of Health, KSA. The collected data include the predefined MOH outbreak's line list of the patients (age, gender, admission source, device association, type of device, clinical outcome, the infectious status of the patient (infected/colonized), sample collection source, isolated organisms, antibiotic susceptibility test results (culture results).

2.5. Data Analysis

Data were analyzed using SPSS software, version 27. Descriptive statistics in the form of frequencies and percentages are used to describe categorical variables, while means and standard deviations or medians and interquartile ranges are used to describe continuous variables. A Chi-Squared test was used to detect the association between qualitative variables. While, Independent sample t test, and Analysis of Variance test were used to detect the association between quantitative variables.

2.6. Ethical Considerations

The study was approved by the ethical committee of the Institutional Review Board of the Ministry of Health, KSA, and the need for informed consent was waived due to the nature of the research. Confidentiality of the patient's information was maintained throughout the study. The collected data had been used for research purposes only and will not be disclosed to anyone outside the research team.

3. Results

3.1. Characteristics of Patients Affected by the Outbreak

On February 1st, 2022, one patient tested positive for *K. pneumonia*, and on February 4th another patient tested positive for *A. baumannii*, the cases of both pathogens continued to spread causing infection and colonization to other patients in the intensive care unit until it classified as an outbreak according to Saudi MOH outbreak management guideline case definition. In February, there were 9 cases of *A. baumannii* and 10 cases of *K. pneumonia*. In March, there were 9 cases of *A. baumannii* and 6 cases of *K. pneumonia*. April had 1 case of *A. baumannii* and 6 cases of *K. pneumonia*. May had 4 cases of *A. baumannii* and 7 cases of *K. pneumonia*. June had no cases of either *A. baumannii* or *K. pneumonia*. July had no cases of *A. baumannii* and 5 cases of *K. pneumonia*. August had no cases of *A. baumannii* and 6 cases of *K. pneumonia*.

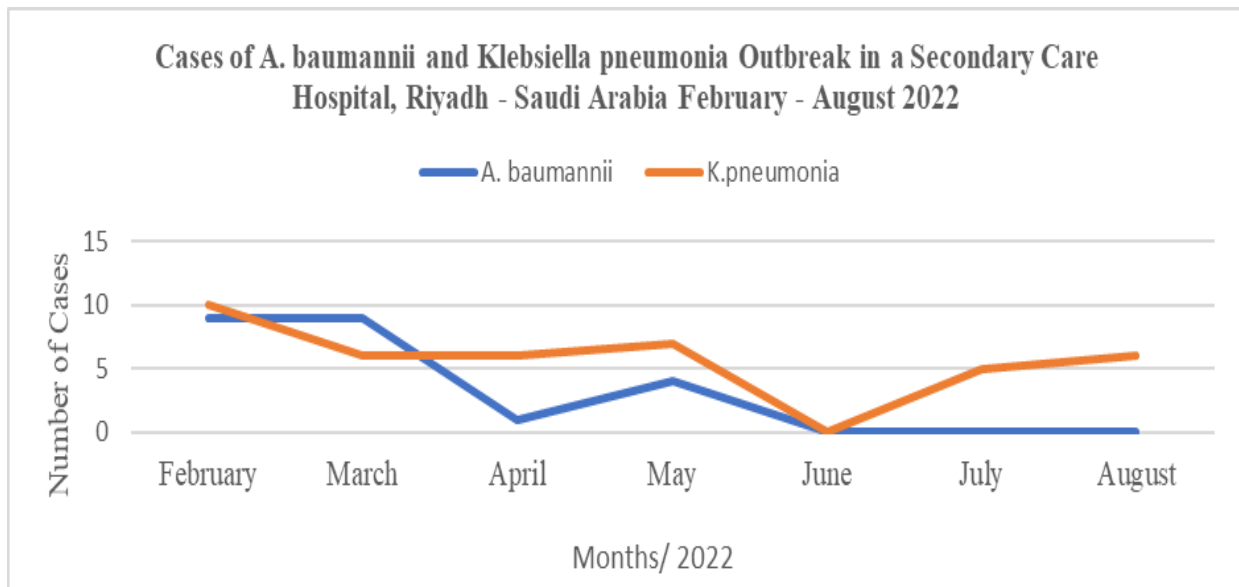


Figure 1. Number of cases of *A. baumannii* and *K. pneumonia* infections from February to August 2022. (Total number of cases 63 since 13 cases had co-infection)

A total of 50 patients were affected by the *A. baumannii* and/ or *K. pneumonia* outbreak and analyzed. A slightly higher number of patients were male (52.0%) and seniors ≥ 50 years old (78%). Most of the patients were admitted from the community (72.0%) and had underlying diseases such as diabetes mellitus (DM) (8.0%), hypertension (HTN) (32.0%), both diabetes and hypertension (44.0%), and other diseases (12.0%). A majority of the patients (78.0%) had tested positive for COVID-19. The most common clinical specimens collected from the patients were sputum (58.0%) followed by blood (32.0%) and urine (10.0%). In terms of infectious status, nearly half of the patients were infected (44.0%), and the others were colonized (56.0%). Invasive management was common in the majority of the patients, 92.0% of the patients had invasive mechanical ventilation and foley catheters. Over half of the patients (56.0%) died, while (34.0%) were discharged and (10.0%) were transferred.

3.2. Risk Factors of Infection among the Studied Patients Affected by the Outbreak

Table (1) revealed that there was no statistically significant difference between the studied patients with different infection types (*K. pneumonia*, *A. baumannii*, or co-infection) as regards their age, gender, source of admission, COVID 19 infection, device association, sample type, and infection/colonization status ($p > 0.05$).

Regarding underlying diseases, the majority of patients with *k. pneumonia* were diabetics and hypertensives (55.6%). Moreover, the largest percentage of patients with *A. baumannii* were either hypertensive (40.0%) or both hypertensive and diabetics (30.0%). The largest percentage of patients with coinfection were either hypertensive (38.5%) or both hypertensive and diabetics (30.8%). And there was statistically significant difference between them ($p = 0.026$).

As regards the length of pre infection hospital stay, it was significantly longer among patients with co-infection

(71.1 ± 69.1) than patients with *k. pneumonia* (33.3 ± 29.8) and *A. baumannii* (12.5 ± 6.2), $P = 0.004$. Furthermore, the length of ICU stay was significantly longer among patients with co-infection (84.0 ± 56.5) than patients with *k. pneumonia* (61.6 ± 39.4) and *A. baumannii* (31.0 ± 18.6), $P = 0.015$.

3.3. Clinical Outcomes among Patients Affected by the Outbreak

Table (2) shows that among the patients with *K. pneumonia* ($n = 27$), 15 (55.6%) deceased, 10 (37.0%) were discharged, and 2 (7.41%) were transferred. Meanwhile, for patients with *A. baumannii* ($n = 10$), 7 (70.0%) died, 2 (20%) were discharged, and 1 (10%) was transferred. For those with both infections ($n = 13$), 6 (46.2%) died, 6 (46.2%) were discharged, and 1 (7.6%) were transferred. Overall, among all the patients, 28 (56%) died, 18 (36%) were discharged, and 4 (8%) were transferred.

3.4. Mortality Predictors of the Patients Affected by the Outbreak ($n = 23$)

Table (3) shows that a large portion of fatal cases were males, old age, admitted from the community, co-infected with COVID-19, both diabetics and hypertensives with device association invasive mechanical ventilation and Foley catheterization. And there was no statistically significant difference between them ($p > 0.05$).

In addition, among the total deaths of infected patients, patients who had sputum specimens had a higher mortality rate 53.3% in *k. pneumonia*, 85.7% in *A. baumannii* patients and 50.0% in patients with co-infection. And there was no statistically significant difference between them ($p = 0.282$). Furthermore, Patients who were colonized with *K. pneumonia* were likely to die (73.3%) compared to (28.6%) in *A. baumannii* patients and (33.3%) in patients with co-infection. And there was no statistically significant difference between them ($p = 0.263$).

The mean length of pre-infection stays, and ICU stays was non significantly longer among patients with co-

infection (42.8±38.0) and (59.3±37.7) compared to *K. pneumonia* patients (30.9±16.2) and (43.1±29.0) and *A. baumannii* patients (13.4±7.4) and (32.0±20.8), at $p=$ (0.056) and (0.263) respectively.

Table 1. Risk factors of infections among patients affected by the outbreak

		Organism						P value
		K. pneumonia (n=27)		A. baumannii (n=10)		Coinfection (n=13)		
		Count	%	Count	%	Count	%	
Age in years	Young (1-20)	1	3.7	0	0.0	0	0.0	0.795
	Adult (21-49)	5	18.5	3	30.0	2	15.4	
	Old (≥ 50)	21	77.8	7	70.0	11	84.6	
Gender	Male	14	51.9	6	60.0	6	46.2	0.805
	Female	13	48.1	4	40.0	7	53.8	
Admitted from	Community	19	70.4	8	80.0	9	69.2	0.818
	Hospital	8	29.6	2	20.0	4	30.8	
Diagnosis	Non-COVID	9	33.3	1	10.0	1	7.7	0.110
	COVID	18	66.7	9	90.0	12	92.3	
Underlying diseases	Absent	2	7.4	0	0.0	0	0.0	0.026*
	Hypertension	7	25.9	4	40.0	5	38.5	
	DM	1	3.7	3	30.0	0	0.0	
	Both DM and HTN	15	55.6	3	30.0	4	30.8	
	others	2	7.4	0	0.0	4	30.8	
Device association	No	4	14.8	0	0.0	0	0.0	0.157
	Yes	23	85.2	10	100.0	13	100.0	
Sample type	Sputum	15	55.6	8	80.0	6	46.2	0.382
	Blood	8	29.6	2	20.0	6	46.2	
	Urine	4	14.8	0	0.0	1	7.7	
Infection status	Colonized	19	70.4	5	50.0	4	30.8	0.056
	Infected	8	29.6	5	50.0	9	69.2	
Pre infection stay length in days	Mean±SD	33.3±29.8		12.5±6.2		71.1±69.1		0.004*
	Median/ IQR	24.0/23.0		10.5/8.25		40.0/124.0		
Length of ICU stay in days	Mean±SD	61.6±39.4		31.0±18.6		84.0±56.5		0.015*
	Median/ IQR	51.0/51.0		23.0/29.0		62.0/99.0		

IQR; Interquartile range/ Statistical analysis was carried out using Qui-square test and Analysis of Variance test/ *P value ≤ 0.05 is considered statistically significant.

Table 2. Clinical outcomes of the patients infected with *K. pneumonia* and/ or *A. baumannii*

Clinical Outcomes	Total		<i>K. pneumonia</i>		<i>A. baumannii</i>		Both		P value
	N	%	N	%	N	%	N	%	
Deceased	28	56.0	15	55.6	7	70.0	6	46.2	0.385
Discharged	18	36.0	10	37.0	2	20.0	6	46.2	
Transferred	4	8.0	2	7.4	1	10.0	1	7.6	
Total	50	100.0	27	100.0	10	100.0	13	100.0	

Statistical analysis was carried out using a Qui-square test.

Table 3. Predictors of mortality among patients affected by the outbreak

		Organism						<i>P value</i>
		<i>K. pneumonia</i> (n=15)		<i>A. baumannii</i> (n=7)		Co-infection (n=6)		
		n	%	n	%	n	%	
Age in years	Young (1-20)	1	6.7	0	0.0	0	0.0	0.653
	Adult (21-49)	3	20.0	1	14.3	0	0.0	
	Old (≥ 50)	11	73.3	6	85.7	6	100.0	
Gender	Male	8	53.3	4	57.1	4	66.7	0.856
	Female	7	46.7	3	42.9	2	33.3	
Admitted from	Community	11	73.3	6	85.7	5	83.3	0.764
	Hospital	4	26.7	1	14.3	1	16.7	
Diagnosis	Non-COVID	4	26.7	0	0.0	0	0.0	0.132

	COVID	11	73.3	7	100.0	6	100.0	
Risk Factors	NIL	2	13.3	0	0.0	0	0.0	0.236
	Hypertension	2	13.3	2	28.6	2	33.3	
	DM	1	6.7	3	42.9	0	0.0	
	Both DM and HTN	9	60.0	2	28.6	3	50.0	
	Others	1	6.7	0	0.0	1	16.7	
Device association	No	2	13.3	0	0.0	0	0.0	0.393
	Yes	13	86.7	7	100.0	6	100.0	
Sample type	Sputum	8	53.3	6	85.7	3	50.0	0.282
	Blood	4	26.7	1	14.3	3	50.0	
	Urine	3	20.0	0	0.0	0	0.0	
Infection status	Colonized	11	73.3	2	28.6	2	33.3	0.078
	Infected	4	26.7	5	71.4	4	66.7	
Pre infection stay length in days	Mean±SD	30.9±16.2		13.4±7.4		42.8±38.0		0.056
	Median/ IQR	28.0/18.0		14.0/12.0		27.5-51.0		
Length of ICU stay in days	Mean±SD	43.1±29.0		32.0±20.8		59.3±37.7		0.263
	Median/ IOR	42.0/63.0		27.0/29.0		50.0/43.0		

IQR; Interquartile range/ Statistical analysis was carried out using Qui-square test and Analysis of Variance test.

3.5. Antibiotic Susceptibility Results of *K. pneumonia* and *A. baumannii* isolates

Regarding *K. pneumonia* isolates, antimicrobial sensitivity patterns of *K. pneumonia* clinical isolates were tested against 19 antibiotics: Amikacin, Gentamicin, Ertapenem, Imipenem, Meropenem, Cefazoline, Cefuroxime, Ceftazidime, Ceftriaxone, Cefepime, Ampicillin, Amoxicillin-Clavulanate, Piperacillin-Tazobactam, Ceftolozane-Tazobactam, Trimethoprim-Sulfamethoxazole, Nitrofurantoin, Ciprofloxacin, Levofloxacin, and Tigecycline. The resistance rate was 100.0% to all tested antibiotics apart from Amikacin (70.0%), Gentamicin (45.0%), and Tigecycline (27.5%).

As regards *A. baumannii* isolates, antimicrobial sensitivity patterns of *K. pneumonia* clinical isolates were tested against 12 antibiotics: Amikacin, Gentamicin, Imipenem, Meropenem, Ceftazidime, Ceftriaxone, Cefepime, Piperacillin-Tazobactam, Trimethoprim-Sulfamethoxazole, Ciprofloxacin, Levofloxacin, and Tigecycline. The resistance rate was 100.0% to all tested antibiotics apart from Amikacin (95.6%), Gentamicin (95.6%), Trimethoprim-Sulfamethoxazole (95.6%), and Tigecycline (91.3%).

Right after the discovery of the outbreak, the Outbreak Management Team (OMT) was activated, and a lot of issues were observed thus an outbreak management plan (OMAP) was prepared with comprehensive instructive actions which were implemented with strict follow-up of its progress. An antimicrobial Stewardship committee meeting was done, active screening tests for all the patients and newly admitted patients were implemented, infected patients were isolated under contact precautions, link nurses were assigned to strictly monitor and observe hand hygiene practices of ICU's staff 24/7, ICU's staff have been retrained regarding the use of personal protective equipment (PPE) to avoid the misuse or overuse of PPE, routine environmental cleaning and terminal cleaning after patient's discharge or transfer were done. Rapid Response Team (RRT) from Ministry of Health provided educational sessions for the infection control team, ICU's HCWs, and housekeeping regarding the needed infection control precautions, policies, and

practices to manage the outbreak. A logbook for HCWs and visitors who entered patients' rooms was activated and contact tracing of HCWs, and patients was established.

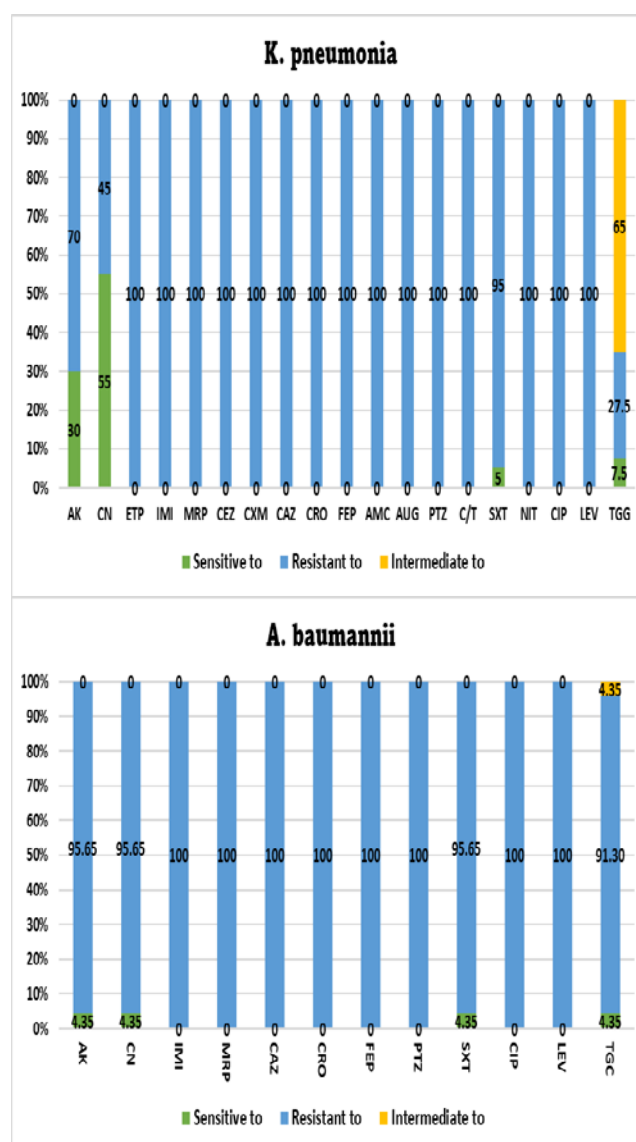


Figure 2. Antimicrobial sensitivity patterns of *K. pneumonia* and *A. baumannii* clinical isolates

Several issues had been observed including PPE shortage, unavailability of blood culture bottles for more than one month, ICU infrastructure such as unavailability of dirty utility, and open ICU cubicles. The previous issues were resolved, PPE and blood culture bottles were provided, the ICU was closed, and a new designated ICU with single rooms and dirty utilities was established and used in the right way. Therefore, infected patients were isolated in single rooms under contact precautions with a proper cohort of patients infected with the same pathogens.

4. Discussion

Carbapenem-resistant gram-negative bacterial infections are a pressing public health concern due to their rapid spread and limited treatment options. [12]

The current study found that the mortality for *A. baumannii* infected patients of 70.0% was non significantly higher than of *K. pneumonia* at 55.6% and patients infected with both pathogens at 46.2% at $p=0.385$, (Table 2), which is consistent with results of Chhatwal et al., 2021; Lv et al., 2022a). [12,13]

• Gender

Our study demonstrates that the mortality of male patients infected with *K. pneumonia* (53.3%) or *A. baumannii* (57.1%), or both *K. pneumonia* and *A. baumannii* (66.7%) was non significantly higher than the mortality of female patients ($p=0.856$), (Table 3) which is consistent with the existing studies. The existing studies showed that the mortality rate of male patients infected with *K. pneumonia* was 60% of (Wu et al. 2022), 69.3% was the mortality rate of *A. baumannii* male patients (Zhou et al. 2019), and 80.6% was the mortality rate of male patients co-infected with *K. pneumonia* and *A. baumannii* (Lv et al. 2022). [12,14,15]

• Age

The results of the current study show that the mortality of old aged patients (≥ 50 years) is non significantly dominant among *K. pneumoniae*-infected patients (73.3%), *A. baumannii*-infected patients (85.7%), and patients co-infected with both *K. pneumonia* and *A. baumannii* (100%), $P=0.653$ (Table 3). The previous finding was consistent with the findings of (Wu et al. 2022), (Zhou et al. 2019), and of (Lv et al. 2022), [12,14,15]. The reason for this may be due to older patients usually have comorbidities and fewer B and T cells production from the immune system to fight infections.

• Type of Hospital Admission

This study shows that the mortality among patients is much higher when admitted from the community than when admitted from another hospital (73.3%) for *K. pneumonia* patients, (85.7%) for *A. baumannii*, and (83.3%) for patients with co-infection (Table 3). Our results are different than the results of the study (Zhou et al. 2019) conducted in China. The mortality rate of patients admitted from the community was (53.6%) while it was (46.4%) for patients admitted from another hospital. [14] Nevertheless, the reason for the lower mortality of patients admitted from another hospital may be because they had a high quality of care in a specialized tertiary care hospital or due to their clinical characteristics which made them

stable thus, they were transferred to secondary care hospitals until recovery and discharge.

• Underlying Diseases

In the present study, the majority of patients with *K. pneumonia* were diabetics and hypertensives (55.6%). Moreover, the largest percentage of patients with *A. baumannii* or co-infection were either hypertensive (40.0%) and (38.5%) or both hypertensive and diabetics (30.0%) and (30.8%). And there was statistically significant difference between them ($p=0.026$), Table 1. Moreover, our study demonstrates a high mortality rate among patients both diabetics and hypertensive infected with *K. pneumonia* (60.0%) or co-infected (50.0%). The mortality rate was higher among diabetic patients infected with *A. baumannii* (42.8%), Table 3.

This study shows a higher mortality in *K. pneumonia* or *A. baumannii* patients co-infected with COVID-19 than those who survived. The mortality of COVID-19 patients co-infected with *K. pneumonia* is (73.3%), and (100%) with patients co-infected with *A. baumannii* or had both co-infection (Table 3). Furthermore, the results of our study are not compatible with the existing studies, as the mortality rate of COVID-19 patients co-infected with *K. pneumonia* increased to 29% (Wu et al. 2022), whereas the mortality rate was 68% for COVID-19 patients co-infected with *A. baumannii* (Said et al. 2022). [16,17] However, we cannot explain that the high mortality of our study is attributed to those underlying diseases. This is because the patients might have other comorbidities and risk factors that contributed to their high mortality.

• Clinical Specimen

In this study, the mortality rate of *K. pneumonia* or *A. baumannii*-infected patients whose pathogens were isolated from the blood or urine is generally low (Table 3). Our findings are approximately in line with the existing studies of (Martín-Aspas et al. 2018 and Alrahmany et al. 2022 Wang et al. 2018) which were conducted in Spain, Oman, and China. [18,19,20]

Admittedly, *A. baumannii* and *K. pneumonia* are strongly related to respiratory infection and colonization, particularly in ICU patients who use respiratory invasive management. In this study, we can observe that a sizeable portion of the patients were diagnosed from sputum samples. Our results suggest that a great number of infected and colonized patients diagnosed from sputum specimens are significantly associated with mortality and higher than the mortality of (Alrahmany et al. 2022 Wang et al. 2018) which was before COVID-19.

• Infectious Status

This study demonstrated that the mortality of *K. pneumonia*-infected patients (26.7%) is much lower than the mortality rate of colonized patients (73.3%), Table 3. This finding is consistent with the (25%) mortality rate reported in a Chinese study (Jiao et al. 2015). The mortality rate among *K. pneumonia* colonized patients is (73.3%) in the current study which contrasts with the existing study by (Jiao et al. 2015) where the mortality rate was 25%. [21]

Our results revealed that up to (71.4%) of *A. baumannii* infected patients died during the outbreak which is significantly more than the rate of the existing study in Spain (9%) by (Martín-Aspas et al. 2018). [14] These

findings highlight the importance of HAI surveillance system and active screening tests to ensure the absence of infection and colonization and their crucial consequences which threaten the patient's life as well as applying infection control measures to prevent further transmission of infection from colonized and infected patients equally.

• Invasive Management

The current study illustrates that (86.7%) of *K. pneumoniae*-infected patients who had invasive mechanical ventilation and/or a Foley catheter have died. Our mortality findings for *K. pneumonia* are consistent with the previous study of (80%-86.7%) by (Jiao et al. 2015). [21] Additionally, our study revealed that (100%) is the mortality rate of *A. baumannii* with invasive mechanical ventilation and/or a Foley catheter. The current study's mortality rate is consistent with Zhou et al. 2019. The mortality rate of *A. baumannii*-infected patients with a Foley catheter (91.2%) was somewhat higher than those with invasive mechanical ventilation (78.5%). [14]

• Length of Pre-infection Stay (in days)

The current study revealed that the mean length of pre-infection stays among patients with co-infection (71.1 ± 69.1) is significantly longer than patients infected with *k. pneumonia* alone (33.3 ± 29.8) or *A. baumannii* alone (12.5 ± 6.2) at $p=0.004$, (Table 1). Moreover, the mean length of pre-infection stays among patients who died with co-infection (59.3 ± 37.7) is non-significantly longer than patients infected with *k. pneumonia* alone (43.1 ± 29.0) or *A. baumannii* alone (32.0 ± 20.8) at $p=0.056$, (Table 3).

• Length of Stay in ICU (in days)

Furthermore, the length of ICU stay was significantly longer among patients with co-infection (84.0 ± 56.5) than patients with *k. pneumonia* (61.6 ± 39.4) and *A. baumannii* (31.0 ± 18.6), $P=0.015$ (Table 1). The mean length of stay in the ICU of *K. pneumonia* deceased patients is (43.1 ± 29.0 days) which is much higher than the mean length of stay in the ICU of *K. pneumonia* deceased patients of the existing study (13 days) by (Jiao et al. 2015). [21] Our study demonstrates that the mean of the length of stay in ICU among *A. baumannii* deceased patients is (32.0 ± 20.8 days) which is also higher than the length of stay in ICU among *A. baumannii* deceased patients (16.12 ± 6.40 days) of (Xiao et al. 2017). [22]

The observed increase in length of pre-infection stays and in ICU among patients in our study could be related to multiple factors including but not limited to the patient's characteristic and clinical issues (Age, Immunity status, comorbidities, and COVID-19 infection) which predispose them to infection. Furthermore, the longer hospital stay might lead to infection with antimicrobial-resistant *A. baumannii* or *K. pneumonia* and the failure of treatment, which would result in a longer ICU stay and mortality.

In the present study, the implemented control measures include hand hygiene, contact precautions, and surveillance cultures. These measures are compatible with control measures in other existing studies. [23,24] However, it took a long time to stop the outbreak in our case, especially with *K. pneumonia*. This can be referred to the admission of infected patients from other hospitals without any proof of their infectious status or microbiological test results from the transferring hospital and the defect of the infection control team's attitude regarding implementing infection control measures and

setting the patient without contact precautions which might be the reason for cross-transmission of infection between HCWs and patients. Further, the long duration of the outbreak may be caused by improper use of personal protective equipment (PPE) by HCWs, as well as the high resistance of the pathogens to antibiotics and hospital disinfectants.

In this study, the observed nurse-to-patient ratio was 1:1 which is considered optimal according to Saudi MOH standards for ICU. In contrast, we found that there was a high incidence of infection aligned with the long duration of the outbreak. This may indicate a poor commitment to infection control practices in the hospital.

Limitations:

While this study provides substantial insights into *A. baumannii* and *K. pneumonia* during an outbreak at a Saudi secondary care hospital, there are several limitations to acknowledge:

- ✓ Because the study is based on secondary data, it does not report all of the risk variables of the demographic and clinical characteristics of the affected individuals in the outbreak.
- ✓ Despite this study being one of the major outbreaks in KSA, the sample size was relatively small. This could limit the study's statistical power and affect the accuracy of the results. It may also impair the ability to identify statistically significant changes between subgroups.
- ✓ There are no previous studies on some of the objectives of this study. This limits the ability to compare the findings with other studies in the literature.
- ✓ Furthermore, no clear criteria for differentiating infection from colonization exists.
- ✓ Additionally, the study was conducted at a single hospital, which may not be representative of the entire healthcare system of Saudi Arabia. The results may not be generalized to other hospitals or healthcare settings in the country.

5. Conclusion

It is evident from the results of our study that the length of hospital and ICU stay plays a significant role in the occurrence of outbreak. The healthcare workers play a crucial role in averting outbreaks. Modern teaching techniques can be used to help them better understand infections, outbreaks, transmission of infections, and the clinical and financial burden associated with them. Next, infection control policies, practices, and measures, including standard and contact precautions, can be implemented, along with the hospital's antimicrobial program.

Abbreviations

- A. baumannii*: *Acinetobacter baumannii*.
- K. pneumonia*: *Klebsiella pneumonia*.
- ICU: Intensive care unit.
- WHO: World Health Organization.
- HAIs: Healthcare-associated infections.

CDC: Centers for Disease Control and Prevention.
 CRKP: Carbapenem-resistant *Klebsiella* Pneumonia.
 CRE: Carbapenem-resistant Enterobacteriaceae.
 MDRO: Multidrug resistance organisms.
 CAIs: community-associated infections.
 KSA: Kingdom of Saudi Arabia
 GDIPC: General Directorate of Infection Prevention and Control.
 OMT: Outbreak Management Team.
 OMAP: Outbreak management plan.
 RRT: Rapid Response team.
 PPE: Personal protective equipment.
 HCWs: Health care workers.

Competing Interests

The authors have no competing interests.

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