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ORIGINAL RESEARCH

# ESKAPE Pathogens: Antimicrobial Resistance Patterns, Risk Factors, and Outcomes a Retrospective Cross-Sectional Study of Hospitalized Patients in Palestine

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**Background:** Antimicrobial resistance to ESKAPE pathogens (*Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa,* and *Enterobacter* spp). remains a major challenge in hospital settings.

**Objective:** This study aimed to determine the ESKAPE antimicrobial resistance patterns and associated factors with multi-drug resistance strains among hospitalized patients in a single tertiary care medical hospital in Palestine.

**Methods:** A single-center retrospective cross-sectional study was conducted by reviewing patients' electronic medical records and laboratory results from November 1, 2021, to November 30, 2022, at the Palestine Medical Complex in Palestine. The study included patients aged > 18 years who had been infected with ESKAPE pathogens 48 hours after hospital admission.

**Results:** This study included 231 patients, of whom 90.5% had MDR infections. In total, 331 clinical samples of ESKAPE pathogens were identified. *A. baumannii* was the most prevalent MDR pathogen (95.6%) with Carbapenem-resistant exceeding 95%, followed by *K. pneumoniae* (83.8%) with extended-spectrum cephalosporin resistance exceeding 90%, *S. aureus* (68.2) with 85% oxacillin-resistance, *E. faecium* (40%) with 20% vancomycin resistance, *P. aeruginosa* (22.6%) with 30% carbapenem resistance. Furthermore, emergent colistin resistance has been observed in *A. baumannii, K. pneumoniae,* and *P. aerogenesis*. Risk factors for MDR infection included age ($p < 0.035$), department ($p < 0.001$), and invasive procedures such as IUC ($p < 0.001$), CVC ($p < 0.000$), and MV ($p < 0.008$). Patients diagnosed with MDR bacteria had increased 30-day mortality ($p < 0.001$).

**Conclusion:** The findings of this study show alarming MDR among hospitalized patients infected with ESKAPE pathogens, with resistance to first-line antimicrobial agents and emerging resistance to colistin, minimizing treatment options. Healthcare providers and the Ministry of Health must take steps, adopt policies to prevent antimicrobial resistance, adhere to infection control guidelines, implement antimicrobial stewardship programs to prevent and limit the growing health crisis, and support research to discover new treatment options.

**Keywords:** ESKAPE, antimicrobial resistance, nosocomial infections, hospital-acquired infections, Palestine

## Introduction

Antimicrobial resistance (AMR) is a serious global health concern. Overuse and misuse of antimicrobials due to the lack of antimicrobial stewardship programs have led to the development of resistant bacterial strains. In addition, the lack of clean water and good hygiene promote the spread of these resistant strains.[1] As a result, AMR leads to higher mortality and morbidity along with extended hospital stays, leading to increased healthcare costs. In a recent systematic analysis published in the Lancet about the global burden of AMR, in 2019 alone, 4.95 million death were attributed to AMR complications and

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1.27 million deaths were directly related to AMR.[2] A total of \$4.6 billion is spent annually on AMR treatment regimens in the United States.[3] Studies show that by 2030, AMR will push approximately 24 million people below the poverty line, particularly in low-income countries.[4]

ESKAPE stands for *Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa, and Enterobacter* spp. It also stems from the word "escape", because these pathogens escape antibiotic treatments.[5] ESKAPE pathogens are listed under critical and high-priority groups in the "WHO Priority Pathogens List" because of their ability to cause life-threatening conditions.[5] The treatment of patients with ESKAPE infection can be challenging for healthcare providers because of the limitations of antimicrobial agents, reduced treatment options, and increased disease burden.[6] AMR cases cannot be treated with first-line agents; thus, multiple antimicrobial agents are used, leading to toxicity and increased healthcare costs. For example, the cost of an AMR case is \$20,000.[7]

In Palestine, there are limited antimicrobial susceptibility and resistance pattern data. Two single-center studies in Palestine revealed a high incidence of extended-spectrum beta-lactamase (ESBL) in Enterobacteriaceae recovered from urinary tract infections, increasing antibiotic resistance for the most commonly used antibiotics.[8,9] Nevertheless, studies are yet to be conducted in Palestine to explore the prevalence and risk factors associated with the ESKAPE pathogens' resistance patterns.

This study aimed to determine the resistance patterns of ESKAPE pathogens among hospitalized patients admitted to the Palestinian Medical Complex in Ramallah, a tertiary care hospital in Palestine. Furthermore, determining risk factors associated with these infections and its effect on 30-day mortality rate. The results of this study will help in taking appropriate steps to build antimicrobial stewardship for treating and preventing infectious diseases.

## Methodology
### Methods

This retrospective cross-sectional study was conducted at the Palestinian Medical Complex, a single tertiary medical center, by reviewing electronic patient medical records from November 1, 2021, to November 30, 2022. The study included all inpatient records of patients aged 18 years and older with positive cultures for ESKAPE pathogens that were identified after at least 48 hours of hospital admission. Records with incomplete or missing data were excluded. Data were collected manually from patients' electronic medical records and recorded using Google Forms. The collected data included patient demographics (age and sex), admission and discharge dates, date of collection of clinical sample isolates, medical history of hospital-acquired infections, comorbidities, prior antibiotic use, medical procedures during admission, and laboratory results (isolates and antimicrobial susceptibility results). Sampling, culturing, and antibiotic susceptibility tests were performed according to the standard medical methods approved by the Palestinian Ministry of Health.

The Statistical Package for the Social Sciences (SPSS) program version 28 was used to analyze the data. The length of hospital stay (LOS) was determined by subtracting the discharge date from the admission date. Age was recoded as elderly (≥65 years) and adults (18–64 years). ESKAPE multidrug-resistant (MDR) pathogens were recoded into (yes or no) according to the Centers for Disease Control and Prevention (CDC) definition; as a lack of susceptibility to at least one agent in three or more antimicrobial categories[10]. Antibiotic classes were determined according to the CDC including; penicillins, macrolides, cephalosporins, fluoroquinolones, beta-lactams with increased activity, tetracyclines, trimethoprim-sulfamethoxazole, urinary anti-infectives, and lincosamides.[11]

Descriptive statistics were used to summarize patients' basic characteristics, isolates, and antimicrobial susceptibility results. Depending on the data type, a Chi-square test or univariate binary logistic regression was performed to identify the associated risk factors with MDR ESKAPE pathogens and to determine their impact on 30-day mortality. Statistical significance was set at $p < 0.05$.

### Ethical Consideration

The ethical committee of Birzeit University approved the study and waived the requirement to obtain written patient consent because this was a retrospective study that did not involve engaging patients and patient information was anonymous. (reference number: BZUPNH 2203) The study complied with the ethical guidelines of the Declaration of Helsinki.

# Results

## Demographic and Clinical Features of the Study Population

As shown in Table 1, 231 patients were included in the study. The mean age and interquartile range (IQR) of the study population were 64 (54–75), of which 138 (59.7%) were males and 93 (40.3%) were females. A total of 117 (50.6%) patients were admitted to the intensive care unit (ICU), 43 (18.6) to the surgery department, and 71 (30.7%) to other departments with a median length of stay of 17 days and a range of (3–165) days. Of these, 183 (79.2%) had at least one underlying disease. Figure 1 shows that the most common comorbidity was coronary artery disease (59.3%) followed by endocrine disorders (51.5%). A total of 199 (86.1%) patients had used antibiotics the month before acquiring infection and 30 (13%) had a history of hospital-acquired infection. In total, 207 patients (89.6%) underwent invasive procedures.

**Table 1** Risk Factors Associated with Acquisition of MDR ESKAPE Pathogens. (N=231)

| Risk factors | Category | Total | MDR ESKAPE | P-value |
|---|---|---|---|---|
| Age, median (25th - 75th) | | 64 (54–75) | | |
| Age | 64 or less | 121 (52.4) | 94 (77.7) | 0.035 |
| | 65 or more | 110 (47.6) | 97 (88.2) | |
| Gender | Male | 138 (59.7) | 111 (80.4) | 0.271 |
| | Female | 93 (40.3) | 80 (86) | |
| Department | ICU | 117 (50.6) | 106 (90.6) | 0.001 |
| | Surgery | 43 (18.6) | 36 (83.7) | |
| | Others | 71 (30.7) | 49 (69) | |
| Underlying Diseases | Yes | 183 (79.2) | 148 (80.9) | 0.156 |
| | None | 48 (20.8) | 43 (89.6) | |
| History of multiple hospital-acquired infections | Yes | 30 (13) | 28 (93.3) | 0.098 |
| | No | 201 (87) | 163 (81.1) | |
| Prior antibiotic use | Yes | 199 (86.1) | 167 (83.9) | 0.216 |
| | No | 32 (13.9) | 24 (75) | |
| Length of hospital stay, median (25th - 75th) OR (CI 95%) | | 17 (10–28) | 1.021 (0.999–1.044) | 0.067 |
| Invasive procedures | | | | |
| IUC | Yes | 182 (78.8) | 158 (86.8) | 0.001 |
| | No | 49 (20.2) | 33 (67.3) | |
| CVC | Yes | 118 (51.1) | 110 (93.2) | 0.000 |
| | No | 113 (49.9) | 81 (71.7) | |
| MV | Yes | 83 (35.9) | 76 (91.6) | 0.008 |
| | No | 148 (64.1) | 115 (77.7) | |
| Surgery | Yes | 79 (43.2) | 67 (84.8) | 0.538 |
| | No | 152 (56.8) | 124 (81.6) | |

(*Continued*)

**Table 1** (Continued).

| Risk factors | Category | Total | MDR ESKAPE | P-value |
|---|---|---|---|---|
| Nasogastric tube | Yes | 75 (32.5) | 67 (89.3) | 0.064 |
| | No | 156 (67.5) | 124 (79.5) | |
| Gastrostomy tube | Yes | 22 (9.5) | 20 (90.9) | 0.384 |
| | No | 209 (90.5) | 171 (81.8) | |
| Tracheostomy | Yes | 21 (9.1) | 19 (90.5) | 0.544 |
| | No | 210 (90.9) | 172 (81.9) | |
| PVC | Yes | 16 (6.9) | 15 (93.8) | 0.318 |
| | No | 215 (93.1) | 176 (81.9) | |
| Other | Yes | 23 (10) | 21 (91.3) | 0.384 |
| | No | 208 (90) | 170 (81.7) | |

**Abbreviations**: IQR, Inter quartile range; CI, confidence interval; ICU, intensive care unit; other departments, internal medicine; gynecology, cardiology; corona, orthopedics; IUC, indwelling urinary catheter; CVC, central venous catheter; MV, mechanical ventilation; PVC, peripheral venous catheter; other invasive procedures, jejunostomy, ABG tube, epidural tube, orogastric tube, rectal tube, bilateral chest tube, and nephrostomy tube.

## Distribution of the Study Isolates

A total of 331 clinical specimens (swabs or samples) positive for ESKAPE isolates were included. The most prevalent pathogen was *A. baumannii* (n= 135, 40.8%), followed by *K. pneumoniae* (n= 99, 29.9%), *S. aureus* (n= 44, 13.3%), *P. aeruginosa* (n= 31, 9.4%), *Enterobacter* (n= 17, 5.1%), and *E. faecium* (n= 5, 1.5%). The distribution of ESKAPE pathogens among different specimens is illustrated in Figure 2, with higher numbers of ESKAPE pathogens in wound specimens, followed by those in respiratory, urinary tract, and bloodstream specimens.

## Antimicrobial Resistance Profiles of ESKAPE Pathogens

Multidrug-resistant strains were most dominant in *A. baumannii* (95.6%), followed by *K. pneumoniae* (83.8%), *S. aureus* (68.2%), *E. faecium* (40%), *P. aeruginosa* (22.6%), and *Enterobacter* spp. (17.6%).
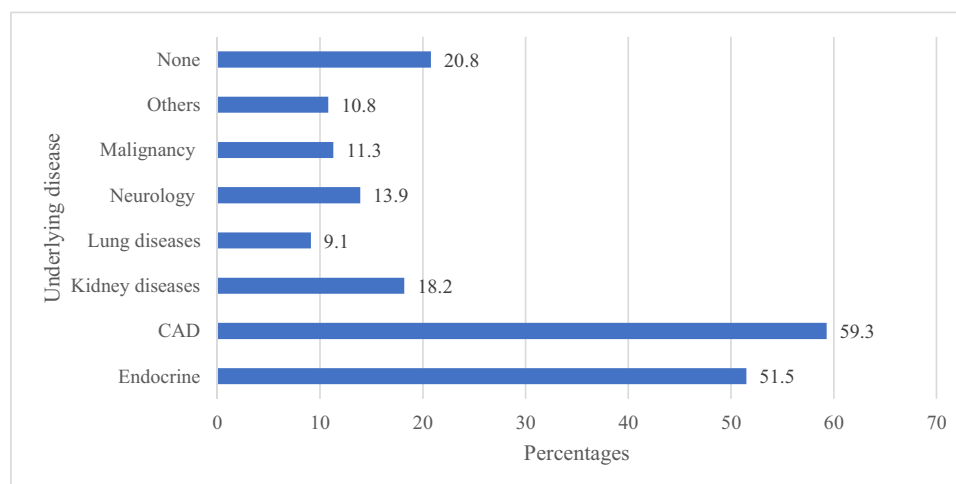


**Figure 1** Distribution of underlying diseases among sample participants (N=231).
**Abbreviation**: CAD, coronary artery diseases.
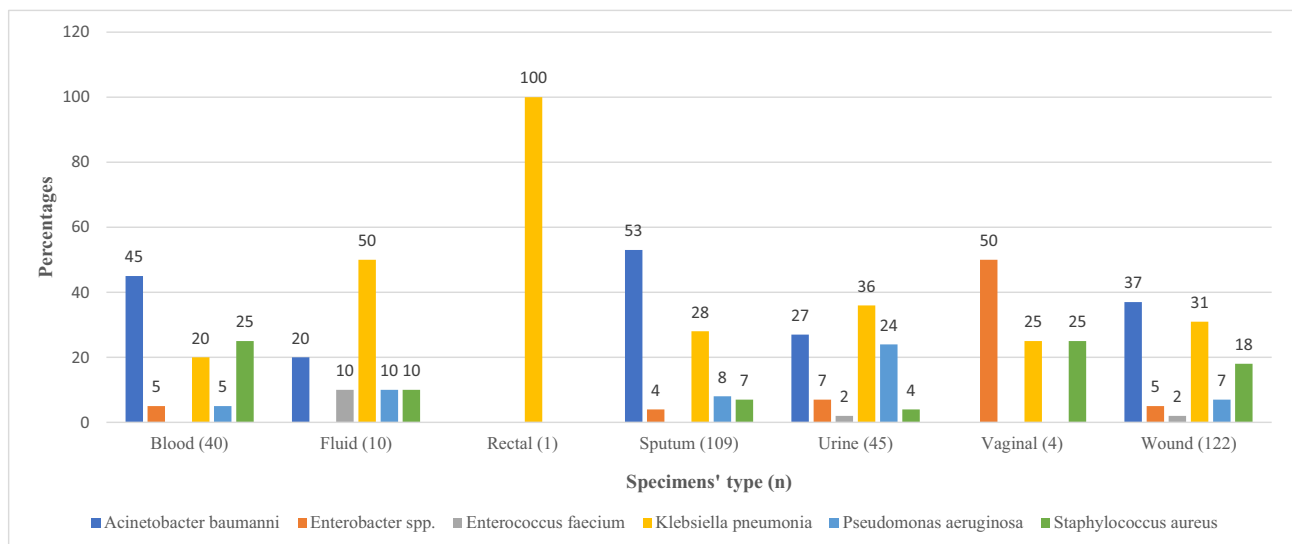
**Figure 2** Distribution of ESKAPE pathogens by clinical specimens (N=331).

Figure 3 shows the antimicrobial resistance patterns of the Gram-negative ESKAPE pathogens. *P. aeruginosa* strains were mainly resistant to fluoroquinolones (levofloxacin (52.4%) and ciprofloxacin (48.4%). A high-priority carbapenem-resistant *P. aeruginosa*, as classified by WHO,[1,12] was also documented; 29% of isolates were resistant to imipenem and 32.3% were resistant to meropenem (Figure 3A).

*K. pneumoniae* had higher resistance patterns for extended-spectrum cephalosporin (ceftazidime (93.5%), ceftriaxone (94.9%), and cefotaxime (93.4%), furthermore notable alarming emerging resistance was to colistin (2.3%) (Figure 3B).

*Enterobacter* spp. were resistant to carbapenem (meropenem, imipenem, and ertapenem (7.1%) for each) and third-generation cephalosporins (cefotaxime (56.3%), ceftazidime (50%), and ceftriaxone (50%)), which were categorized as critical priority pathogens (Figure 3C).

Figure (3D) shows the antibacterial resistance patterns of *A. baumannii including* carbapenem (meropenem (96.2%) and imipenem (96.1%)), which are classified as bacteria with critical priority by the WHO.[12] In addition, *A. baumannii* isolates were resistant to aminoglycosides (gentamicin (94.4%) and amikacin (95.1%)), beta-lactams with increased activity (piperacillin/tazobactam (96.2%)), extended-spectrum cephalosporins (ceftriaxone (97.2%), cefotaxime (97.4%), and ceftazidime (96.9%)), and fluoroquinolones (ciprofloxacin (95.3%)). Although most *A. baumannii* strains were susceptible to colistin, only one swab sample showed colistin resistance.

Figure 4 shows the resistance patterns of the Gram-positive ESKAPE pathogens; *E. faecium* showed significant resistance to ampicillin (100%), ciprofloxacin (100%), and Vancomycin-resistant *E. faecium* (20%), which are classified as high priority bacteria by WHO[12] (Figure 4A). *S. aureus* showed susceptibility to most antibiotics, with high resistance rates to oxacillin (85.7%), erythromycin (75%), cefoxitin (75%), and colistin (100%) (Figure 4B).

## Factors Associated with the Prevalence of ESKAPE Pathogens

Table 1 shows the risk factors associated with MDR pathogens, with P values <0.05 being statistically significant. Elderly patients were significantly more likely to be infected with MDR ESKAPE than younger (88.2% vs 77.7%, p= 0.035) Patients admitted to the ICU (90.6%) or surgery departments (83.7%) were significantly more likely to suffer from MDR pathogens than patients in other departments (69%, p= 0.001). Furthermore, patients who underwent invasive procedures, including indwelling urinary catheter (IUC) (86.8%, p= 0.001), central venous catheter (CVC) (93.2%, p<0.001), or mechanical ventilation (MV) (91.6%, p=0.008), were significantly at a higher risk of MDR ESKAPE than others.
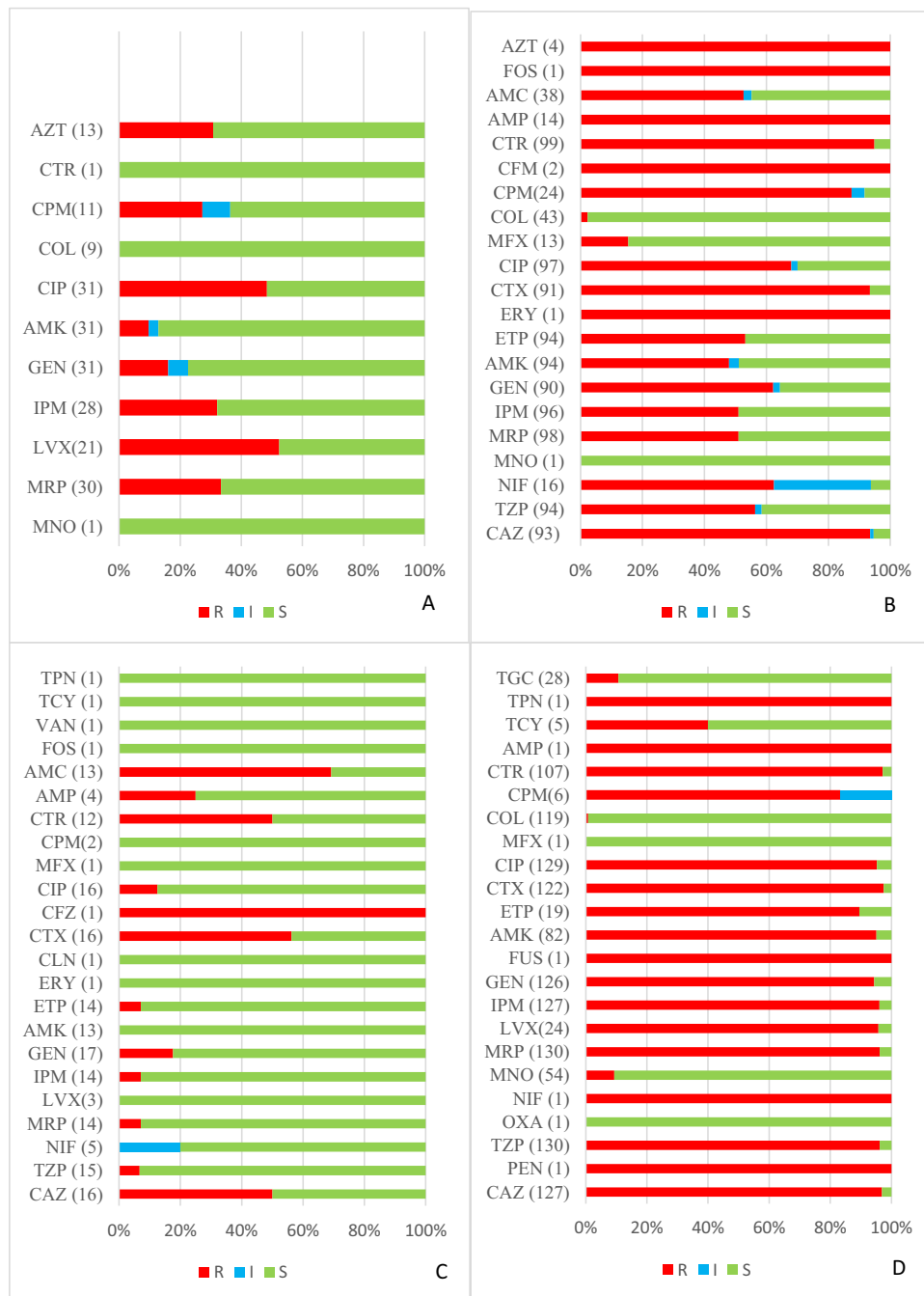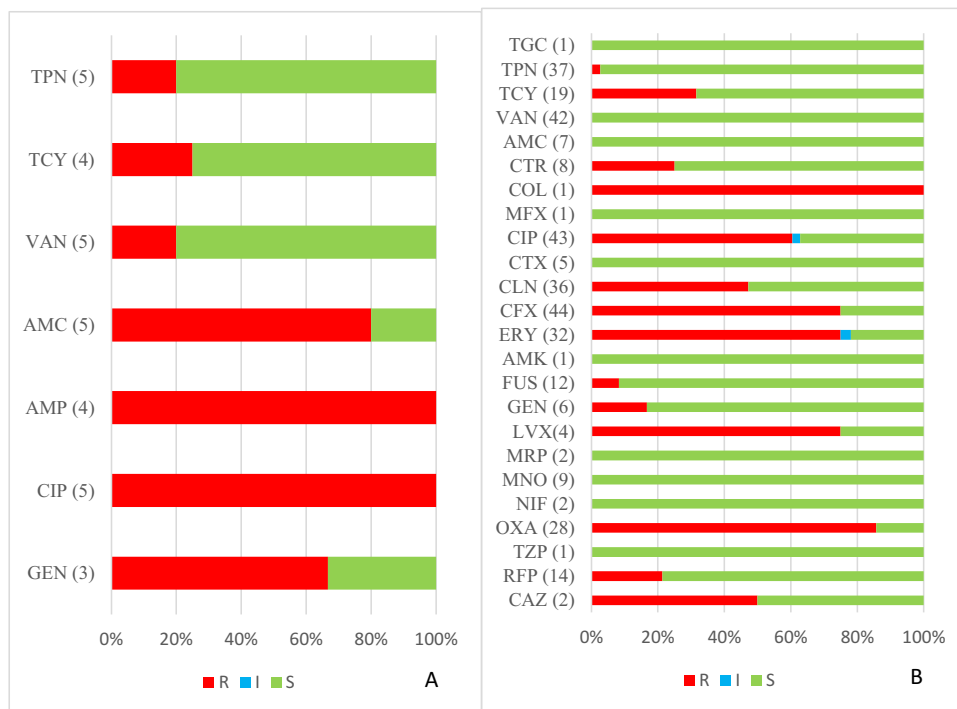
**Figure 3** Susceptibility profile of Gram-negative ESKAPE pathogens; **(A)** *Pseudomonas aeruginosa*, **(B)** *Klebsiella pneumonia*, **(C)** *Enterobacter* spp., **(D)** *Acinetobacter baumannii*.

**Abbreviations**: AMP, Ampicillin; AMC, Amoxicillin-Clavulanate; AMK, Amikacin; AZT, Aztreonam; CAZ, Ceftazidime; PEN, Penicillin; TZP, Piperacillin/ tazobactam; OXA, Oxacillin; NIF, Nitrofurantoin; MNO, Minocycline; MRP, Meropenem; LVX, Levofloxacin; IPM, Imipenem; GEN, Gentamicin; FUS, Fusidic acid; ETP, Ertapenem; CTX, Cefotaxime; CIP, Ciprofloxacin; MFX, Moxifloxacin; COL, Colistin; CPM, Cefepime; CTR, Ceftriaxone; TCY, Tetracycline; TPN, Teicoplanin; TGC, Tigecycline; CFM, Cefixime; ERY, Erythromycin; CFX, Cefoxitin; CLN, Clindamycin; FOS, Fosfomycin; CFZ, Cefazolin.

## Impact of ESKAPE Pathogens on Mortality

Table 2 shows the impact of antimicrobial resistance on the 30-day mortality rate, where 100 patients (43.3%) died within 30 days of acquiring the infection. The mortality rate was significantly higher among patients diagnosed with MDR ESKAPE (48.2%) than among those infected with sensitive strains of ESKAPE (20%) (p< 0.001).

**Figure 4** Susceptibility profile of Gram-positive ESKAPE pathogens; **(A)** *Enterococcus faecium*, **(B)** *Staphylococcus aureus*.
**Abbreviations**: AMP, Ampicillin; AMC, Amoxicillin-Clavulanate; AMK, Amikacin; CAZ, Ceftazidime; TZP, Piperacillin/ tazobactam; OXA, Oxacillin; NIF, Nitrofurantoin; MNO, Minocycline; MRP, Meropenem; LVX, Levofloxacin; GEN, Gentamicin; FUS, Fusidic acid; CTX, Cefotaxime; CIP, Ciprofloxacin; MFX, Moxifloxacin; COL, Colistin; CTR, Ceftriaxone; TCY, Tetracycline; TPN, Teicoplanin; TGC, Tigecycline; ERY, Erythromycin; VAN, Vancomycin; CFX, Cefoxitin; CLN, Clindamycin; RFP, Rifampin.

## Discussion

The emergence of antimicrobial resistance in ESKAPE pathogens has become a major concern worldwide in the management of infectious diseases, emphasizing the clinical impact of these microorganisms. In Palestine, some reports have described resistance patterns as an emerging part of a more significant crisis.[13] The findings of this study highlight the emergence of alarming patterns of resistance among ESKAPE pathogens in hospitalized patients in Palestine, which the WHO classifies as critical and a high priority for new drug research and development.

The most prevalent bacterium in our study was *Acinetobacter baumannii* (40.8%), with an alarming MDR pattern exceeding 90% to most antimicrobial agents, including carbapenems, cephalosporins, fluoroquinolones, and aminoglycosides. Furthermore, emerging resistance to colistin limits antimicrobial options for effective management and place the patient on a higher toxicities from a non preferred antimicrobial agent. Emerging resistance has also been reported in other regional countries, such as Egypt, India, Iran, and Kuwait, making it a worldwide problem, as illustrated by the WHO, with an urgent need for new drug research and development to save human lives.[14–17] *A. baumannii* is a major causative factor for hospital-acquired infections worldwide and develops resistance to antimicrobials through various mechanisms. These mechanisms include the production of different classes of β-lactamases and carbapenem inactivating enzymes, overexpression of multidrug efflux pumps, chemical modification of aminoglycosides, defects in outer

**Table 2** Impact of Antimicrobial Resistance (N=231)

| Category | | Total | MDR ESKAPE | | P-value |
|---|---|---|---|---|---|
| | | | **Yes** | **No** | |
| 30-day mortality | Yes | 100 (43.3) | 92 (48.2) | 8 (20) | 0.001 |
| | No | 131 (56.7) | 99 (51.8) | 32 (80) | |

membrane permeability, alteration of binding sites, and clustering and expression of drug resistance genes via integrons.[5,18]

Globally, AMR strains of *Acinetobacter baumannii* have become widespread, with the Mediterranean region reporting the highest percentage of critical priority carbapenem resistance bacteria, exceeding 90%, which is very similar to this study findings.[19] In a recent regional study in Lebanon, all *A. baumannii* isolates were resistant to carbapenem and a very high 30-day mortality rate was reported in these patients.[20]

The second most prevalent bacterium was *K. pneumoniae* (29.9%), of which (83.8%) were MDR. High susceptibility was only evident for colistin, with emerging cases of resistance leading to decreased treatment options for infection management. In a meta-analysis, colistin resistance was reported in six countries in the Middle East.[21] In a recent study conducted in Saudi Arabia, *A. baumannii* and *K. pneumoniae* were found to be the predominant ESKAPE pathogens. However, the resistance patterns were much higher in Palestine.

*Enterococcus faecium* significantly contributes to hospital-acquired infections and is becoming increasingly vancomycin-resistant. In this study, 20% of *E. faecium* strains were resistant to vancomycin, which is associated with increased hospital costs, LOS, and mortality.[22]

*S. aureus* was one of the Gram-positive ESKAPE pathogens that were less prevalent; however, in this study, 85% of *S. aureus* were resistant to oxacillin, which is much higher than in other studies. Furthermore, high resistance to ciprofloxacin (61.9%), clindamycin (47.2%), erythromycin (77.4%), and cefoxitin (75%) was evident. In another cross-sectional study conducted in Ethiopia, the resistance patterns were somewhat different: high resistance to penicillin (94.7%), trimethoprim/sulfamethoxazole (68.4%), tetracycline (57.9%), and ciprofloxacin (26.3%).[23]

Almost all pathogens, including *A. baumannii, K. pneumoniae, P. aeruginosa, S. aureus*, and vancomycin-resistant *Enterococcus*, demonstrated a resistance pattern exceeding 20%. This alarming situation may lead to health crises.

Many risk factors were associated with the acquisition of MDR ESKAPE pathogens, which was evident in this study and was statistically significant, including age, admission to the ICU department, and invasive procedures such as IUC, CVC, and MV, which is similar to the findings of a retrospective cohort study conducted in Saudi Arabia in 2022.[24] Furthermore, more than half of the participants had diabetes and some studies have shown that patients with diabetes are more vulnerable to antibiotic-resistant respiratory and urinary tract infections.[25] Considering these factors during patient assessment is essential to minimize drug resistance and select appropriate individualized antimicrobial treatments based on patient characteristics and risk factors.

In this study, 97 of the 110 (88%) elderly patients developed MDR infections. Similarly, a study in a tertiary general hospital in China found that drug-resistant healthcare-associated infections were more common among elderly patients aged ≥ 60 years.[26] In the elderly population, selecting antimicrobial agents can be challenging because of comorbidities, age-related physiological changes, and increased susceptibility to drug resistance bacterial infections. Furthermore, these changes affect drug pharmacokinetics and pharmacodynamics, making it challenging to manage antimicrobial therapies successfully.[27]

A significant association was observed between patients who were admitted to the ICU and the risk of infection with MDR organisms due to many factors, including the need for invasive procedures, induced immunosuppression, comorbidities, elderly patients, and frailty state.[28] Furthermore, patients admitted to the surgical department displayed a noteworthy association between the surgical department infection prevalence and MDR. The first 30 days after surgery is crucial because most wound infections occur during this period.[29] As shown in Figure 2, the most dominant specimen type was wounds (n = 122), with 37% of *A. baumannii* and 31% of *K. pneumoniae*.

LOS has been linked to increased healthcare costs and nosocomial MDR infections because LOS increases the risk of acquiring bacterial infections. Furthermore, a prospective incident study reported that LOS ≥ 7.8 days was associated with increased hospital-acquired infections (HAI). Patients with HAI had a median LOS of 30 days, whereas those without HAI had a median LOS of three days.[30]

This study showed an alarming result of a statistically significant high mortality rate among patients diagnosed with hospital-acquired infection due to MDR ESKAPE pathogens. This can also be linked to the fact that patients with a longer LOS have higher mortality rates.[31]

Prior antibiotic use and misuse are known to contribute to the rise of resistant bacterial strains because antibiotics eliminate susceptible strains, leaving MDR strains the survival and proliferation of MDR strains. Moreover, antibiotics disrupt the normal flora balance, allowing the colonization of resistant pathogens. Therefore, prior antibiotic use is considered a significant risk factor for acquisition of MDR nosocomial infections.[32] Prior antibiotic use was very high among the study participants, and 86.1% had consumed antibiotics the month before acquiring infection. Another study identified several risk factors for colonization or infection with multidrug-resistant *Acinetobacter baumannii*, including acute respiratory failure, mechanical ventilation, renal failure, and prior use of carbapenem antibiotics.[33]

Invasive procedures, such as CVC, IUC, and MV, are known to be associated with infections. In a study performed to assess nosocomial infection and antibiotic resistance threat in the Middle East, where types of hospital-acquired infections were discussed, Central Line-Associated Bloodstream Infections (CLABSIs) had higher mortality rates; hence, their prolonged use increases the risk of bloodstream infection, compromising health, and rising healthcare costs. Catheter-associated urinary tract infections (CAUTIs) account for 12% of nosocomial infections (CAUTI). They result from the patient's microflora entering the body through Foley catheters with poor drainage, thus providing a suitable environment for bacterial growth. Severe CAUTI can result in serious complications.[34,35] This study also found that mechanical ventilation had a statistically significant effect on the risk of infection. With an increased risk of infection by 3–21 times, based on the International Society of Infectious Diseases (ISID), mechanical ventilation and tracheal intubation play a major role in causing hospital-acquired pneumonia (HAP), especially in critically ill patients. In addition, ventilator-associated pneumonia (VAP) is a critical condition that requires attention because it has an attributable mortality rate of 13%, and its occurrence rate ranges from 5% to 67%. Furthermore, even if the patient survives VAP, it causes considerable morbidity, increased resource utilization, and hospital stays that are at least 4 days longer.[36]

## Limitations/Strength

This study has several limitations, including its retrospective cross-sectional design, which cannot establish causality and associations. Sampling bias was also an issue; this study was conducted in a single hospital; therefore, the findings cannot be generalized to a broader population. Furthermore, the data were collected manually, which opens room for human error, such as data entry mistakes and overlooking important details. Moreover, some raw data were categorized and grouped, which could have affected the statistical power of this study.

## Conclusion

This study emphasizes the emergence of alarming MDR ESKAPE pathogens among hospitalized patients in Palestine. *Acinetobacter baumannii* had the highest prevalence, while *Enterobacter* spp. had the lowest. In addition, a critical priority carbapenem-resistant *A. baumannii*, carbapenem-resistant *Enterobacter* spp., high-priority vancomycin-resistant *E. faecium*, and carbapenem-resistant *P. aeruginosa* have also emerged among hospitalized patients. Furthermore, emerging colistin resistance can be devastating and leave patients without treatment options. This study also identified significant risk factors influencing the overall results, including age, hospitalization department, and invasive procedures. The high rates of MDR of ESKAPE pathogens call for implementing extreme measures and protocols at the national level to tackle this devastating problem, such as infection control measures, antimicrobial stewardship programs, and societal education regarding the dangers of unnecessary antibiotics. Additional studies are required to better understand the underlying mechanisms, adopt further preventive measures, and design more effective treatments.

## Ethical Consideration

This study was approved by the ethical committee of Birzeit University (reference number: BZUPNH 2203). The study did not involve engaging patients, patient information was anonymous, and no personal data were collected or shared with any individual or entity. The collected information will only be used for research purposes. Patient records will be kept confidential and will not be used for other purposes.

## Disclosure

The authors declare that they have no conflicts of interest.

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