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Research article

Emerging Patterns of Meropenem Resistance in *Pseudomonas aeruginosa* from Burn Patients: Epidemiological Data from Central Iraq

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ABSTRACT

Infected burns are among the most serious clinical cases with high mortality rates, especially when infected with multidrug-resistant (MDR) bacteria. Pseudomonas aeruginosa infection in burns significantly contributes to the high mortality associated with bacterial burn infections. This study aimed to conduct a bio-surveillance of burn cases infected with *P. aeruginosa* and their resistance to meropenem. A total of 305 burn cases were examined, with samples collected from the burn and wound hospital in Baghdad. Of these, 180 samples came from skin and soft tissue infections (SSTIs) associated with systemic sepsis, 100 from SSTIs, and 25 from minor burn injuries. *P. aeruginosa* was isolated and identified using biochemical methods. The Kirby–Bauer disk diffusion method was used to assess the response of the bacterial isolates to meropenem. Results showed that out of 82 *P. aeruginosa* infection cases. The percentage of isolates resistant to meropenem was 62.19%, sensitive was 34.14%, and those with intermediate response was 3.6%. The highest resistance to meropenem was observed in SSTIs with systemic sepsis. The study concludes that the incidence of *P. aeruginosa* infection is high, and resistance to meropenem is correlated with the severity of the infection.

Keywords: Antibiotics, Burn, Meropenem, *Pseudomonas aeruginosa*.

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1. INTRODUCTION

Burn injuries are a big public health issue worldwide, especially in developing countries, because inadequate healthcare facilities and the lack of provision of infection control measures delay the management of complications [1]. Infectious diseases are the most public and serious complications in burn patients, which seriously contribute to longer hospital stays, increased healthcare costs, and higher rates of morbidity and mortality [2]. There are various pathogens responsible for burn wound infections. *Pseudomonas aeruginosa* is one of the most common opportunistic bacteria. It has resistance to a wide spectrum of antibiotics and a high potential to develop resistant mechanisms, making it a challenging pathogen in medical institutions [3].

The nature of burn wounds is highly conducive to *P. aeruginosa* biofilm formation and colonization of biotic and abiotic surfaces, leading to chronic infections [4]. The pathogen's high effectiveness and exposure to the widespread use of antibiotics have led to the emergence of multidrug-resistant (MDR), extensively drug-resistant (XDR), and even pan-drug-resistant (PDR) strains [5]. These resistant strains decrease the effectiveness of traditionally used antibiotics like cephalosporins, aminoglycosides, carbapenems, and fluoroquinolones, making colistin highly important, despite its significant toxicity [6].

Burn injuries are common in Iraq because of local accidents, occupational trauma, and war exposure [7]. Despite the high prev-

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alence of burn injuries, monitoring antimicrobial resistance (AMR) patterns of *P. aeruginosa* among burn patients in central Iraq remains limited. Insufficient use of antibiotics results from the failure to monitor and standardize treatment protocols, leading to the development of drug resistance. Understanding local epidemiological and resistance of *P. aeruginosa* is important for rising active infection control policies and antibiotic treatment guidelines in the hospitals [8].

Meropenem is a broad-spectrum carbapenem antibiotic frequently used to treat severe bacterial infections, especially the burn cases caused by MDR *P. aeruginosa*. The mechanism of action of this antibiotic is inhibiting the synthesis of bacterial cell walls by binding to penicillin-binding proteins, which subsequently leads to cell lysis. This antibiotic is highly effective against different pathogenic bacterial species that cause serious infections such as sepsis, pneumonia, and complicated skin or burn wound infections [9].

The current study aims to highlight the epidemiological trends and meropenem resistance patterns of *P. aeruginosa* in the burn patients in central Iraq through a surveillance study.

2. MATERIALS and METHODS

2.1. Study Design

The present research involved a cross-sectional study conducted at a Burns Hospital in Baghdad, Iraq, from September 2023 to March 2024. This study exclusively included patients with burn injuries admitted to a specialized referral center for burn care. In this study, infected skin and soft tissue (SSTIs) were defined as erythema, swelling, heat, or purulence around the wound, accompanied by clinical signs of infection such as fever and an increased number of blood leukocytes. Colonization was defined as the presence of bacteria in the absence of clinical signs of infection.

2.2. Infection Control or Antibiotic Protocols

The cases involved in the present study received controlled systemic administration of antibiotics and used them as advised by the clinician. Infection control protocols include regular washing of the patient's body every 24–48 hours as needed, and frequent changes of central lines (every three days unless clinically advised). Sample collection and identification, including debridement, are performed upon admission and as needed afterward. The use of carbapenems (such as meropenem) is part of the empirical sepsis regimen, especially for Intensive Care Unit (ICU) patients with suspected bacterial infections, such as *P. aeruginosa*.

2.3. Isolation and Identification

The samples were collected after removing all ointments and creams covering the infected burn wound areas. They were taken from different anatomical sites of the infected burn wounds in the presence of a clinician. In cases of multiple infections, the first samples were involved in the study. The clinical samples (swabs) were transferred aseptically to the laboratory and immediately cultured on MacConkey agar, blood agar, and neutral agar. Gram staining was performed on each sample. Non-fermented colonies on MacConkey agar were cultured on cetrimide agar. Biochemical tests, including catalase and oxidase, were conducted. VITIK 2 technology was used to confirm the presence of *P. aeruginosa* isolates. The isolates were stored short-term by culturing them on nutrient agar and kept at 4°C for 2 to 3 weeks. For longer storage, isolates were preserved at −20°C in nutrient broth containing 20% glycerol [10].

2.4. Antibiotic Susceptibility Testing

The Kirby–Bauer disk diffusion method was used to identify meropenem-resistant *P. aeruginosa* (MRPA) and meropenem-sensitive *P. aeruginosa* (MSPA), as well as isolates that exhibited an intermediate response to meropenem. The previous method was followed. The diameters were compared with the diameters on the Clinical and Laboratory Standards Institute (CLSI) breakpoint charts to determine the sensitivity (S), intermediate (I), and resistance (R) of bacteria to imipenem [10-11].

2.5. Statistical analysis

Statistical analyses were done using Origin software version 8.6 (OriginLab, Northampton, MA, USA). Categorical variables, including the source of infection and resistance pattern, were reported as absolute frequencies and percentages. Continuous variables were presented as mean ± standard deviation (SD). All analyses were prespecified, with no post hoc hypothesis testing.

3. RESULTS

3.1. Infection with *P. aeruginosa*

During the study period, 305 samples were collected from patients with burn wound infections. The number of patients infected with *P. aeruginosa* was 82, with the same isolates of *P. aeruginosa*, which were a significant contributor, accounting for 26.88% (82/305) of the bacterial isolates.

3.2. Demographics and Clinical Features

The mean age of the patients in this study was 42.1 ± 16.7 years, with an age range from 18 to 73 years. Among the isolates, 58.5% (48/82) were collected from male patients and 41.5% (34/82) from female patients. The demographic information of the studied population was summarized in Table 1.

Table 1. Demographic and clinical features of the clinical cases involved in the study

	Variable	Values
1.	Range of age	18-73 Years
2.	Mean age	42.1 ± 16.7 Years
3.	Gender male/female ratio	1.411
4.	Kind of burn	Thermal (85.24%), electrical (13.11%), chemical (1.6%)
5.	ICU admission	62.29%
6.	Total Body Surface Area (TBSA)	11%–25%: 65.5 % 26%–50%: 29. 5% > 50%: 4.9%

3.3. Clinical Sources and Distribution

SSTIs emerged as the primary clinical source of *P. aeruginosa*, accounting for 59.01% of cases, excluding those with sepsis. While the prevalence of sepsis was 32.78%. However, the low-burn wound infection was 8.19%. Interestingly, most *P. aeruginosa* isolates were isolated from the first group of patients. 62.7% were traced back to patients in the intensive care unit (ICU), highlighting the nosocomial nature of these infections. Furthermore, the total body surface area (TBSA) of 26%–50% showed the highest rate of *P. aeruginosa* infection compared to the others Table 2.

3.4. Meropenem Resistance Patterns

The Kirby–Bauer disk diffusion method was used to identify meropenem resistance patterns among 82 *P. aeruginosa* isolates

from 305 cases of infected burn wounds. High resistance levels were observed in cases of SSTIs with sepsis, followed by cases of SSTIs without sepsis. The present study showed that 62.19% of the isolates were resistant, while 34.14% of *P. aeruginosa* isolates were sensitive to meropenem (Table 2).

Table 2. Distribution of *P. aeruginosa* isolates and their meropenem susceptibility patterns among burn patients with different clinical conditions. Percentages represent the proportion of cases out of 305 total burn patients. Resistant, sensitive, and intermediate isolates were determined based on CLSI guidelines. SSTIs = skin and soft tissue infections.

	Percentages of cases (305 cases)	No of cases that isolated *P. aeruginosa*	No of resistant isolates to meropenem	No of sensitive isolates to meropenem	No of Intermediate
SSTIs with sepsis	59.01%	49	30 (36.58%)	18 (21.95 %)	1 (1.2 %)
SSTIs without sepsis	32.78%	31	20 (24.39%)	9 (10.97 %)	2 (2.44 %)
Low burn infection	8.19%	2	1 (1.2 %)	1 (1.2 %)	0 (0%)
Total	100%	82	51 (62.19 %)	28 (34.14 %)	3 (3.65 %)

4. DISCUSSION

The findings of this study offer valuable epidemiological data on the burden of *P. aeruginosa* infections and their resistance to meropenem among burn patients in central Iraq. The high rate of *P. aeruginosa* isolated from burn wounds confirms its dominance as an opportunistic pathogen in post-burn infections, consistent with global reports that identify these bacterial isolates as a leading cause of morbidity and mortality in burn units [12]. Burn wounds create an ideal environment for *P. aeruginosa* colonization due to broken skin barriers, necrosis, and compromised immune responses, making infections in burn patients especially difficult to treat [13].

The 62.19% rate of resistance to meropenem that was observed is of concern and highlights the rising trend of multidrug-resistant (MDR) and extensively drug-resistant (XDR) *P. aeruginosa* strains in burn and wound hospitals. Such high levels of resistance have also been described in other Middle Eastern and North African nations, where overuse and empirical use of carbapenems have led to selective pressure and the development of resistance [14]. Meropenem, a previously effective therapy for severe *P. aeruginosa* infections, is losing its effectiveness and represents a serious therapeutic problem. Resistance mechanisms include metallo-β-lactamases (MBL) production, overexpression of efflux pumps, loss of outer membrane porins, and biofilm formation, which entraps the bacteria and limits the penetration of antibiotics, thereby supporting survival in burn wounds [15].

The resistance was significantly highest in SSTI with systemic sepsis (36.58%), showing a direct proportionality between the severity of infection and resistance. Severe systemic infections demand extended hospitalization and higher dosage of antibiotics, and thus might favor more resistant pathogens [16].

Less resistant infections were found in cases of minor burns, indicating that the emergence and selection of resistant isolates depend on the severity and duration of the infection. Given that delayed or ineffective therapy greatly increases fatal outcomes in MDR *P. aeruginosa* infections, the high mortality rate of infected patients further emphasizes the clinical significance of antibiotic resistance [17]. These results highlight the importance of implementing efficient antimicrobial stewardship programs in Iraqi burn hospitals. To control the outbreak of resistant strains that infect the burn wounds. It is critical to closely follow up the resistant isolates to carbapenems and strictly adhere to infection control guidelines. Alternative therapies, such as phage therapy, combination antibiotic therapy, and the use of novel anti-pseudomonal agents, should be considered [18]. Furthermore, molecular research on the genes and mechanisms underlying resistance would provide important insights for focused interventions.

5. Conclusion

In the present study, a highly important result of the meropenem resistance rate (62.19%) was reported; the findings demonstrate the substantial burden of *P. aeruginosa* infections among burn patients in central Iraq. The current study showed that the severity of burn infection is associated with infection with *P. aeruginosa* that is resistant to meropenem. Thus, the current study demonstrates that *P. aeruginosa* is a significant risk to burn patients in Iraq and that complex infections.

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Conflict of interest

The authors declare that they have no conflict of interest.

Ethical Approval

This study was approved by the Ethics Committee of the University of Baghdad (CSEC/0984/0102; September 04, 2023). Since it was a retrospective analysis of routinely collected clinical data, individual patient consent was waived in accordance with national ethical guidelines.

Author contributions

Rusul H. Ahmed: Resources; Methodology, Supervision; Validation; Roles/Writing, Writing–review, Investigation; Project administration; Roles/Writing - original draft; and Writing-review & editing.

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