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Klebsiella Pneumoniae Infection in Burn Patients and Associated Therapeutic Challenges

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Abstract | **Original Research Article**

Introduction: Burn patients are particularly susceptible to healthcare-associated infections. *Klebsiella pneumoniae*, a Gram-negative bacillus frequently isolated in this setting, poses major therapeutic challenges owing to the emergence of multidrug-resistant, carbapenemase producing strains. ***Objective:*** To characterize the antimicrobial resistance profile of *K. pneumoniae* isolated from burn patients at Mohammed VI University Hospital, Marrakech, and to assess the frequency of pan-drug-resistant, therapeutically untreatable situations. ***Methods:*** A retrospective descriptive study was conducted from January 2023 to December 2024, encompassing 216 *K. pneumoniae* isolated from 1,429 bacteriologically documented infected burn patients. Susceptibility testing was performed according to CA-SFM/EUCAST guidelines using the BD Phoenix M50 automated system. Carbapenemases were identified by immunochromatographic assay [NG-Test CARBA 5] and/or PCR. ***Results:*** *K. pneumoniae* accounted for 15% of documented infections. Resistance rates were high across all antibiotic classes: 73% to third-generation cephalosporins[C3G], 61% to ertapenem, 52% to imipenem, and 31% to colistin. Carbapenemase production was detected in 66% of isolates, with predominance of New Delhi metallo-β-lactamase [NDM] [45%], followed by oxacillinase 48[OXA-48] [21%] and co-production of both enzymes in 5.5% of cases. Overall, 68% of strains were multidrug-resistant [MDR], and 19% of patients faced a pan-drug-resistant situation requiring the use of high-dose carbapenems combined with colistin, despite the absence of in vitro efficiency. ***Conclusion:*** This study highlights a concerning epidemiological situation, characterized by a high prevalence of carbapenemase-producing *K. pneumoniae* in burn patients. The emergence of colistin resistance and the frequency therapeutic dead end situations underscore the urgent need to strengthen microbiological surveillance and antimicrobial stewardship programmes.

Keywords: *Klebsiella pneumoniae*, Burn patient, Multidrug resistance, Carbapenemases, NDM, OXA-48.

INTRODUCTION

Burn patients face a markedly elevated risk of bacterial infection. The breakdown of the cutaneous barrier, combined with immunosuppression secondary to systemic inflammatory stress and prolonged exposure to invasive devices, creates conditions that are particularly conducive to nosocomial colonisation and infection [1,2].

In this setting, antimicrobial resistance has emerged as a foremost clinical challenge, contributing to a significant increase in morbidity and mortality in an already vulnerable patient population.

Klebsiella pneumoniae, a Gram-negative bacillus belonging to the order Enterobacterales, is among the most frequently implicated pathogens in burn-related infections [3,4]. Over recent years, the emergence and spread of multidrug-resistant strains in particular those producing extended-spectrum β-lactamases and carbapenemases have substantially complicated therapeutic management [5,6].

The aim of this study was to assess the therapeutic challenges encountered in the management of *K. pneumoniae* infections in burn patients treated at Mohammed VI University Hospital of Marrakech.

Materials and Methods

This was a retrospective descriptive study conducted from January 2023 to December 2024, including all burn patients admitted to Mohammed VI University Hospital of Marrakech, who presented with a microbiologically documented *K. pneumoniae* infection.

Isolated strain were recovered from suppurative wound infections, blood cultures, and catheter-related infections. Antimicrobial susceptibility testing was performed by minimum inhibitory concentration [MIC] determination via microdilution using the BD Phoenix M50 automated system, in accordance with CA-SFM/EUCAST recommendations. Colistin resistance was confirmed by broth microdilution. Carbapenemases were identified by immunochromatographic testing [NG-Test CARBA 5] and/or PCR.

The therapeutic dead end was attributed to resistance to all antibiotics tested and available in Morocco

Results

Over the study period, 1,429 burn patients presented with a documented bacterial infection. The mean patient age was 38 years [range: 1–94 years], and the male to female ratio was 1.29. *K. pneumoniae* accounted for 15% of all documented infections [n = 216].

Among the 216 *K. pneumoniae* isolates, high resistance rates were observed across all antibiotic classes [Table 1]: 73% [n = 159] were resistant to C3G, 67% [n = 145] to C4G, 61% [n = 132] to ertapenem, 52% [n = 112] to imipenem, and 31% [n = 69] to colistin.

Significant co-resistance to other antibiotics was also identified: 77% [n = 166] to ciprofloxacin, 73% [n = 157] to trimethoprim-sulfamethoxazole, 67% [n = 144] to gentamicin, and 54% [n = 116] to amikacin.

Table 1: Antimicrobial resistance profile of K. pneumoniae isolates [n = 216]

Antibiotic	Resistant isolates n[%]	Count [n = 216]
Third-generation cephalosporins[C3G]	73%	n = 159
Fourth-generation cephalosporins[C4G]	67%	n = 145
Ertapenem	61%	n = 132
Imipenem	52%	n = 112
Ciprofloxacin	77%	n = 166
Trimethoprim-sulfamethoxazole	73%	n = 157
Gentamicin	67%	n = 144
Amikacin	54%	n = 116
Colistin	**31%**	**n = 69**

Carbapenem resistance was predominantly mediated by carbapenemase production [60% of cases]. NDM-type carbapenemases were identified in 45% of isolates [n = 97], followed by OXA-48 in 21% [n = 46]. Co-production of NDM and OXA-48 was documented in 5.5% of patients [n = 12] [Table 2].

Table 2: Distribution of carbapenemases identified among K. pneumoniae isolates

Carbapenemase type	% of total isolates [n = 216]	% among CPE [n = 143]	Count
NDM	45%	67%	n = 97
OXA-48	21%	32%	n = 46
NDM + OXA-48 co-production	5.5%	8%	n = 12
Total CPE	**66%**	**100%**	**n = 143**

Overall, 68% of *K. pneumoniae* isolates [n = 148] were classified as multidrug-resistant [MDR].

Among the affected patients, 19% [n = 42] were in therapeutic dead-end situation with no available effective treatment alternative, requiring the use of high-dose carbapenems in combination with colistin, even in the absence of demonstrated in vitro efficacy.

Discussion

Data collected at Mohammed VI University Hospital of Marrakech, over the 2023–2024 period confirm the central role of *K. pneumoniae* in nosocomial infections among burn patients, with a prevalence of 15%. These figures are consistent with previously published series: Krir *et al.,* reported a 12.6% isolation rate burn patients, and Maamar *et al.,* reported 13.9% [7,8].

Carbapenem resistance represents the most alarming finding of this study. Long regarded as the last resort treatment for severe infections caused by multidrug-resistant Enterobacterales, carbapenems are losing their effectiveness in the face of the progressive dissemination of carbapenemases [9,10]. In burn patients, this phenomenon is further amplified by prolonged antibiotic therapy, extended hospital stays,

and repeated use of invasive devices factors widely recognized as driving the emergence of resistant bacteria [11,12].

The predominance of carbapenemase-producing strains in 60% of cases [131/216] observed in our setting is particularly concerning. NDM-type carbapenemases ranked first, accounting for 45% of all isolates [67% of carbapenemase-producing strains], followed by OXA-48 in 21% of isolates [32% of carbapenemase-producing strains], with co-production of both enzyme types in 8% of carbapenemase-producing strains [12/143]. These findings are consistent with the Tunisian study by Maamar *et al.,*on carbapenemase-producing Enterobacterales in burn patients, which reported a marked predominance of NDM[59.5%] over OXA-48[33%], with co-expression of both genes in 7% of strains[8], and with the study by Dziri *et al.,*published in 2018, which identified NDM producers in 56%, OXA-48 producers in 33%, and co-producers in 6% of isolates[13].

The dissemination of these enzymes in the Mediterranean basin and North Africa has been well documented by Nordmann *et al.,* and Logan et al., who highlight the direct impact on available therapeutic options [9,10]. The high prevalence and co-expression of these enzymes observed in our study further complicate clinical management, owing to the broad and heterogeneous resistance profiles they confer.

The emergence of colistin resistance, an antibiotic considered a last-resort option for the treatment of carbapenem-resistant Enterobacterales infections, represents a critical warning signal. In our study, 31% of isolates were resistant to colistin. Several studies have reported a rising trend in colistin resistance among *K. pneumoniae* in recent years [14], exposing clinicians to genuine therapeutic dead end such as the one described by L. Dortet et al., with a prevalence of 24.1% of colistin resistant strains among all carbapenemase producing K. pneumoniae strains [15,16]

Faced with these extreme resistance profiles, nearly one in five patients in our study encountered a therapeutic dead-end situation. The use of antibiotic combinations including maximum dose carbapenems, sometimes combined with colistin despite the absence of demonstrated in vitro activity, illustrates the current limits of the available therapeutic armamentarium [10,14].

This study underscores the critical importance of reinforcing nosocomial infection prevention measures, particularly by improving hospital hygiene, and the restriction of inappropriate antibiotic use, in order to curb the spread of resistant strains and improve clinical outcomes in burn patients.

CONCLUSION

This retrospective study conducted at Mohammed VI University Hospital of Marrakech, documents a significant prevalence of *K. pneumoniae* infections among burn patients [15% of documented infections], associated with concerning resistance rates: 69% of MDR strains, a high proportion of carbapenemase-producing isolates [66%], and colistin resistance affecting nearly one-third of strains.

These findings highlight the extent of local therapeutic difficulties and the need for continuous, structured epidemiological surveillance to adapt clinical management protocols, particularly in response to the emergence and diversification of resistance mechanisms.

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