Spinal Cord (2017) 55, 390–395

www.nature.com/sc

ORIGINAL ARTICLE

Klebsiella pneumoniae carbapenemase-producing *K. pneumoniae* (KPC-KP) in brain and spinal cord injury patients: potential for prolonged colonization

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Study design: Retrospective cohort study.
Objectives: To determine the prevalence of brain and spinal cord injury (BSCI) patients among all patients with *Klebsiella pneumoniae* carbapenemase-producing *K. pneumoniae* (KPC-KP) and to evaluate clinical characteristics and duration of colonization.
Setting: Tertiary care academic medical center.
Methods: Electronic medical records of BSCI patients with KPC-KP from February 2009 to December 2014 were reviewed to determine clinical characteristics. Patients with multiple KPC-KPs were defined as those with isolates in different calendar months, and patients with a single positive isolate were compared with those with repeatedly positive isolates. Variables with a *P*-value of $\leqslant 0.05$ were considered statistically significant. Two archived isolates recovered from separate cultures of the same patient were compared with pulsed-field gel electrophoresis to calculate the duration of colonization.
Results: Of the 218 patients with KPC-KP, 86 (39%) had BSCI and 27 (31%) had multiple KPC-KPs. The KPC-KPs from 20 (74%) patients with multiple isolates were available for analysis. Patients with repeated positive isolates were more likely to be younger ($P=0.05$), African American ($P=0.05$), suffer gunshot injuries ($P=0.01$) and other trauma ($P=0.03$) and have decubitus ulcers ($P=0.05$). Of the 20 patients with multiple isolates for analysis, 13 (65%) patients were colonized with the same strain type over time, and the strain persisted on average 373 days.
Conclusion: BSCI patients comprise a significant percentage of our KPC-KP population. Owing to repeated hospitalizations and prolonged colonization, they represent a substantial reservoir for these multidrug-resistant pathogens.
Spinal Cord (2017) **55,** 390–395; doi:10.1038/sc.2016.136; published online 18 October 2016

INTRODUCTION

The development and use of antibiotics has transformed the practice of medicine, combating life-threatening bacterial diseases and saving lives. Despite these benefits, owing to their use and overuse, emerging antimicrobial resistance has become a global threat. The Centers for Disease Control and Prevention estimates that every year >2 million people in the United States develop antimicrobial-resistant infections, resulting in >23 000 deaths and adding $35 billion in excess costs for health care and lost productivity.[1]

In response to this crisis, the Obama administration released a 5-year plan to combat antimicrobial resistance in March 2015. The plan, in part, calls for evaluating populations at risk for developing drug-resistant pathogens and names carbapenem-resistant Enterobacteriaceae as a specific threat.[2] The most widespread carbapenem-resistant Enterobacteriaceae in the United States are the *Klebsiella pneumoniae* that contain *K. pneumoniae* carbapenemase (KPC) genes.[3] KPC-containing *K. pneumoniae* (KPC-KPs) have emerged as one of the most worrisome types of antimicrobial-resistant organism because not only are they resistant to the carbapenem class of antibiotics, considered among the drugs of last resort, but are also typically multidrug-resistant, leaving few if any treatment options.

By nature of their underlying disease and related complications, including loss of mobility, difficulty clearing secretions, urinary stasis and frequent use of invasive devices, patients with brain and spinal cord injuries (BSCIs), are at increased risk for developing drug-resistant infections.[4–6] Several studies investigated the common bacterial species and their antimicrobial susceptibilities from urinary tract isolates of SCI patients and showed increased resistance to fluoroquinolones.[7–9] Prevalence data of multidrug-resistant organisms (MDROs) in this population are limited. A recent study by Suda *et al.*[10] compared antimicrobial susceptibility patterns of common bacterial pathogens from all sources of inpatients with SCI and disorder (SCI/D) and non-SCI/D patients and reported an increase in MDROs in SCI/D patients, with 17.6% of Enterbaceriaceae carrying extended-spectrum β-lactamases (ESBLs) and 2.4% carrying carbapenemases. Another study reported 41.7% prevalence of ESBL producers in *Escherichia coli* and *Klebiella* species from the urinary isolates of hospitalized SCI patients.[4] Detailed studies of KPC-KP in this patient population have not published.

We sought to determine the prevalence of BSCI patients among all of our KPC-KP patients, to characterize their KPC infections and to determine duration of colonization in the patients with repeated

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Received 24 February 2016; revised 19 August 2016; accepted 22 August 2016; published online 18 October 2016

positive KPC-KP cultures. The study will be useful to elucidate clinical characteristics, control transmissions and develop antibiotic treatment policies for KPC-KP in this patient population.

MATERIALS AND METHODS

Study setting and design

Northwestern Memorial Hospital is an 885-bed teaching hospital in Chicago, IL, USA. The hospital neighbors and shares an academic affiliation with a rehabilitation hospital that specializes in areas such as brain injury, stroke and SCI. Patients are often transferred between the two facilities because of this relationship and the proximity.

A retrospective cohort study was performed to identify all KPC-KP cases at our institution from February 2009, when our first KPC-KP isolate was identified, to December 2014. Electronic medical records were reviewed to determine underlying medical conditions for all KPC-KP patients reported during the study period. BSCI was defined as chronic (>3 months) complete or incomplete motor dysfunction of either posttraumatic or a medical disorder of the brain or spinal cord, and their medical records underwent further review to determine clinical and microbiological characteristics. The institutional review board of Northwestern University approved this study protocol.

Clinical characteristics

All data were originally collected as part of routine clinical care. The following data were abstracted: demographics, type of BSCI, reason for injury, time from injury to first KPC-KP isolate, other medical comorbidities that were utilized to calculate a Charlson comorbidity score,[11] geographical location prior to admission, number of prior hospital admissions in the 1 year before detection of the first KPC-KP isolate, reason for hospital admission, whether the KPC-KP isolate was present on admission, length of hospital stay, presence of urinary retention, presence of decubitus ulcers, KPC-directed antimicrobial usage, and attributable mortality. Each time a patient had a positive culture for KPC-KP, the medical record was reviewed to determine whether the patient had an infection or colonization. Colonization was defined as KPC-KP recovered from stool alone, from a clinical site without related symptoms or from a clinic site in a patient who had symptoms but improved either without antimicrobial therapy or without KPC-KP-directed antimicrobial therapy.[12] All data are presented for the patient's first admission unless otherwise stated.

Microbiological characteristics

The microbiological records spanning the length of the study period for each patient were reviewed. The following data were collected: site of KPC-KP culture; present or past history of cultures positive with other MDROs, including vancomycin-resistant enterococci, ESBL-producing Gram-negative bacteria and methicillin-resistant *Staphylococcus aureus*; and microbiological response to therapy. The presence of the KPC gene was confirmed by KPC-specific polymerase chain reaction (PCR). Patients with multiple KPC-KPs were defined as those with KPC-KP isolates detected in different calendar months. When multiple KPC-positive cultures were identified in a patient, only one KPC isolate from each month was included in the study.

Bacterial strain typing

For strain typing, the first and last archived KPC-KP isolates recovered from the same patient during the study period were compared with pulsed-field gel electrophoresis (PFGE), and the time between the two isolates was used to calculate the duration of colonization. For PFGE, preparation of bacterial gel plugs and cell lysis were performed as previously described.[13] Whole-cell DNA was digested in a 1% agarose gel with XbaI restriction enzyme at 37 °C for 2 h. Electrophoresis was performed with a CHEF-DRII system (Bio-Rad Laboratories, Hercules, CA, USA) over 18.5 h at 14 °C with 5–13 s of linear ramping at 200 V. PFGE patterns were interpreted visually using the criteria proposed by Tenover *et al.*[14] Identical pairs of strains shared identical PFGE band patterns.

Statistical analysis

Data were collected on a standardized form and entered onto Microsoft Excel spreadsheets (Microsoft Excel 2000, Microsoft Corporation, Redmond, WA, USA). Summary statistics were reported. Discrete variables were described by percentages and continuous variables were described by means. Clinical characteristics were analyzed for the entire cohort and also stratified by whether a patient had a single positive KPC-KP isolate or repeated positive isolates. Variables with a *P*-value of $\leqslant 0.05$ were considered statistically significant. In addition, for patients with repeated positive isolates, clinical characteristics were compared for those with identical vs discrete strain types.

RESULTS

Prevalence and characteristics of the cohort

The first KPC-KP isolate was detected at our institution in February 2009, and between February 2009 and December 2014, 218 unique patients had a KPC-KP isolated, 86 (39%) of whom were patients with BSCI. Of these 86 patients, 27 (31%) had more than one KPC-KP isolated over time, and isolates from 20 (74%) of these patients were available for detailed strain typing analysis (Figure 1).

Of the 86 patients with BSCI, 4 patients were excluded from further analyses owing to incomplete information. Table 1 summarizes the patient population and characteristics. The mean age of the study group was 53.1 ± 17.5 and 53 (65%) were male. Fifty-five (67%) patients had spinal cord injuries and 27 (33%) had brain injury. The average Charlson score determined at the first admission was 3.9 (range 2–13). Of note, all patients had a Charlson score of at least 2 owing to their underlying BSCI. Fifty-five (67%) patients were hospitalized with average length of stay of 26.6 days (range 2–214) and 27 (33%) patients were admitted for infection. The average number of admissions in the 1 year before the first KPC-KP isolation was 2 (range 0–12). Urinary retention was present in 63 (77%) patients, and 30 (37%) patients had decubitus ulcers. Before the first hospital admission, 35 (43%) patients resided at a long-term care facility. One patient died from concomitant KPC-KP and multidrug-resistant *Pseudomonas aeruginosa* septic shock unresponsive to antibiotic therapy. The average time from injury to first KPC-KP isolate was 6.3 years (range 0–44). Fifty-five (67%) patients carried MDROs in addition to KPC-KP.

Patients with repeat KPC-KPs were more like to be younger African American males ($P=0.05$) whose BSCI was related to gunshot injuries and other trauma as opposed to an underlying medical condition ($P<0.05$) and were more likely to have decubitus ulcers ($P=0.05$). In both patient groups of those with and without repeated KPC-KPs, the organism was most often isolated from urine. Similarly, in both groups, although KPC-KP was determined to represent only colonization at the time of isolation in 53 (65%) patients, the majority received antibiotic treatment. The majority also harbored other drug-resistant pathogens in addition to KPC-KP.

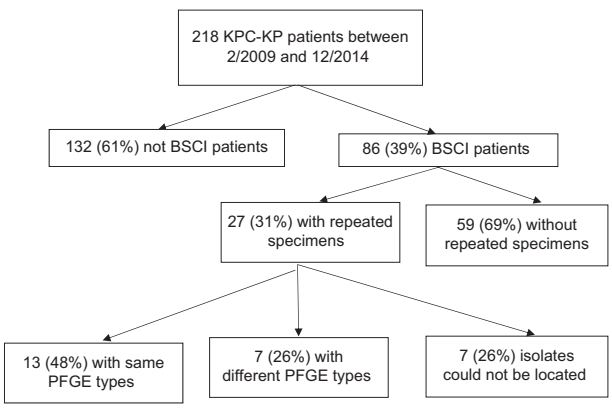

Figure 1 Identification of BSCI patients with KPC-KP.

Table 1 Clinical characteristics of BSCI patients with KPC-KP

Characteristics	*Values*[a]			P-*value*[b]
	All patients (n = *82*)	*Patients without repeated specimens* (n = *55*)	*Patients with repeated specimens* (n = *27*)	
Age in years; mean ± s.d., median (range)	53.1 ± 17.5, 54 (17–92)	55.7 ± 18.1, 56 (19–92)	47.7 ± 15.3, 46 (17–78)	0.05
Males	53 (65%)	33 (60%)	20 (74%)	0.23
African American	35 (43%)	19 (35%)	16 (59%)	0.05
Admitted	55 (67%)	36 (65%)	19 (70%)	0.8
Admitted for infection	27 (33%)	19 (35%)	8 (30%)	0.8
Charlson for first hospital stay; mean (range)	3.9 (2–13)	3.9 (2–9)	3.7 (2–13)	0.69
KPC-KP was POA	31 (38%)	18 (33%)	13 (48%)	0.22
Resident at LTAC	35 (43%)	24 (44%)	12 (44%)	1.0
LOS[c] in days; mean ± s.d., median (range)	26.6 ± 34.7, 17 (2–214)	30.3 ± 39, 19.5 (5–214)	19.7 ± 22.2, 10 (2–92)	0.19
No. of prior admissions; mean ± s.d., median (range)	2 ± 2.4, 1 (0–12)	2.4 ± 1.9, 2 (1–8)	3 ± 3, 2 (0–12)	0.27
Reason for injury				
MVA	17 (21%)	8 (15%)	9 (33%)	0.08
GSW	12 (15%)	4 (7%)	8 (30%)	0.01
Other trauma	16 (20%)	15 (27%)	1 (4%)	0.03
CVA	14 (17%)	12 (22%)	2 (7%)	0.14
Tumor	6 (7%)	4 (7%)	2 (7%)	0.91
Infection	3 (3%)	1 (2%)	2 (7%)	0.16
Other	14 (17%)	11 (20%)	3 (11%)	0.36
Urinary retention	63 (77%)	45 (82%)	18 (67%)	0.46
Decubitus ulcer	30 (37%)	15 (27%)	15 (56%)	0.05
Mortality from KPC-KP	1	0	1	—
Patients with MDROs[d] other than KPC	55 (67%)	36 (65%)	19 (70%)	0.8
No. of MDROs				
2 MDROs	27 (33%)	21 (38%)	6 (22%)	0.24
3 MDROs	21 (26%)	11 (20%)	10 (37%)	0.15
4 MDROs	7 (8%)	4 (7%)	3 (11%)	0.55
Years from injury to KPC isolate; mean ± s.d., median (range)	6.3 ± 9.9, 1 (0–44)	5.7+9.4, 1 (0.02–44)	8.6 ± 10.8, 1.3 (0.1–33)	0.22
Site of KPC isolate				
Urine	55 (67%)	35 (64%)	20 (74%)	0.59
Blood	5 (6%)	3 (5%)	2 (7%)	0.74
Stool	10 (12%)	8 (15%)	2 (7%)	0.38
Stool and blood	1 (1%)	0	1 (4%)	0.11
Respiratory	9 (11%)	7 (13%)	2 (7%)	0.49
Wound	2 (2%)	2 (4%)	0	0.26
Colonization with KPC	53 (65%)	38 (69%)	15 (56%)	0.47
Received antibiotics	63 (77%)	41 (75%)	22 (81%)	0.11

Abbreviations: BSCI, brain and spinal cord injury; CVA, cerebrovascular accident; GSW, gunshot wound; KPC, *Klebsiella pneumoniae* carbapenemase; KPC-KP, *Klebsiella pneumoniae* carbapenemase-producing *K. pneumoniae*; LOS, length of stay; LTAC, long-term acute care facility; MDRO, multidrug-resistant organism; MVA, motor vehicle accident; POA, present on admission.
[a]Value is at the time of the first KPC-KP isolate.
[b]*P*-value is calculated using Fisher's Exact Test for categorical variables and unpaired-*t*-test for continuous variables.
[c]LOS for the first KPC-KP isolate of those who were admitted.
[d]These included vancomycin-resistant enterococci, extended-spectrum beta-lactamase *Enterobacteriaceae* and methicillin-resistant *Staphylococcus aureus*.

Characteristics of patients with repeat KPC-KP stratified by strain typing results

Clinical characteristics. The clinical characteristics of the 20 patients whose repeat isolates were available for strain typing are summarized (Table 2). The mean age was 45.4 years (range 17–75) and the majority of patients were male (80%) and African American (75%). The average Charlson score determined at the first admission was 3.5 (range 2–13). Seventeen patients (85%) suffered SCI, including injuries from motor vehicle accident (40%), gunshot wound (30%) and other trauma (10%). Urinary retention was present in 16 (80%) patients, and 13 (65%) patients had decubitus ulcers. Most patients in the group (70%) were hospitalized with average length of stay of 9.2 days (range 2–43), and the majority of admitted patients (72%) were carrying KPC-KP at the time of admission. The average number of prior admission in the 1 year before the first KPC-KP isolation was 3.3 (range 0–10). Before the first hospital admission, 10 patients (50%) resided at a long-term care facility. None of these patients died during the study period. Patients with distinct strain types were more likely to have suffered motor vehicle accident compared with those with identical strain types, who were more likely to have suffered from gunshot wound.

Microbiological characteristics. Comparison of microbiological characteristics of patients with identical vs distinct types is also listed (Table 3). The most striking difference between these two groups is the time from injury to first KPC-KP isolate, with a mean time from injury to isolate of 5.2 years for those with identical strains compared with 14.1 years for those with distinct strains. It likely explains why patients with distinct strains are a little older and, given the prolonged time they have lived with their BSCI, why they have a higher percentage of urinary retention and decubitus ulcers.

MDROs other than KPC-KP were detected in 15 (75%) patients, and these included vancomycin-resistant enterococci, ESBLs and methicillin-resistant *Staphylococcus aureus*. Nine of the 13 patients

Table 2 Clinical characteristics of BSCI patients with multiple KPC-KPs

Characteristics	*Values*[a]		
	All patients (n = *20*)	*Patients with identical strain types* (n = *13*)	*Patients with different strain types* (n = *7*)
Age in years; mean ± s.d., median (range)	45.4 ± 14.6, 43 (17–75)	43.9 ± 16.4, 43 (17–75)	48 ± 11.2, 43 (38–66)
Males	16 (80%)	11 (85%)	5 (71%)
African American	15 (75%)	10 (77%)	5 (71%)
Charlson score for first hospital stay; mean (range)	3.5 (2–13)	3.5 (2–13)	3.6 (3–5)
Admitted	14 (70%)	9 (69%)	5 (71%)
Admitted for infection	12/14 (86%)	7/9 (78%)	5/5 (100%)
KPC-KP was POA	10/14 (72%)	7/9 (78%)	3/5 (60%)
Resides at LTAC	10 (50%)	6 (46%)	4 (57%)
LOS[b] in days; mean ± s.d., median (range)	9.2 ± 11.6, 5 (2–43)	10 ± 12.6, 8 (3–43)	7.6 ± 10.2, 4 (2–27)
No. of prior admissions; mean ± s.d., median (range)	3.3 ± 3.2, 2 (0–10)	4 ± 3.6, 4 (0–12)	1.9 ± 1.6, 1 (0–4)
Spinal cord injury	17 (85%)	10 (77%)	7 (100)
Reason for injury			
MVA	8 (40%)	3 (23%)	5 (71%)
GSW	6 (30%)	5 (38%)	1 (14%)
Other trauma	2 (10%)	1 (8%)	1 (14%)
Infection	1 (5%)	1 (8%)	0
Other	3 (15%)	3 (23%)	0
Urinary retention	16 (80%)	10 (77%)	6 (86%)
Decubitus ulcers	13 (65%)	8 (62%)	5 (71%)
Mortality from KPC-KP	0	0	0

Abbreviations: BSCI, brain and spinal cord injury; GSW, gunshot wound; KPC-KP, *Klebsiella pneumoniae* carbapenemase-producing *K. pneumoniae*; LOS, length of stay; LTAC, long-term acute care facility; MVA, motor vehicle accident; POA, present on admission.
[a]Value is at the time of the first KPC-KP isolate.
[b]LOS for the first KPC-KP isolate of those who were admitted.

(69%) carrying identical KPC-KP strains and 6 of the 7 (86%) patients carrying distinct KPC-KP strains had at least one other MDRO. Patients with unique strain types of KPC-KP harbored more MDROs with 43% having 3 MDROs vs 23% of those with identical strains and 29% having all 4 MDROs vs only 8% in those with identical KPC-KPs. KPC-KP was isolated from urine in 16 patients (80%), from blood in 1 patient (10%), rectal surveillance culture in 1 patient (5%) and rectal surveillance culture and blood in 1 patient (5%). KPC-KP was classified as representing colonization in 45% of patients that was similar in patients with either identical or distinct strains. Although nearly half of patients were only colonized with KPC-KP, a majority of patients (80%) received antibiotic treatment for the isolated KPC-KP (Table 3).

Bacterial strain typing

Two isolates from each patient were compared with PFGE. The time interval between the two study isolates in the cohort ranged from 1 day to 843 days, with a mean of 316 days. Thirteen patients (65%) had identical strains with mean time between isolates of 373 days (range 1–843 days), and 7 patients (35%) had strains with distinct PFGE band pattern with mean time between isolates of 209 days (range 54–484 days). As stated, the time for persistence of the same KPC-KP strain ranged from 1 day to 843 days with an average time of 373 days.

DISCUSSION

Spread of KPC-KP in the United States has been reported in multiple studies.[3,15] Risk factors for acquiring KPC-KP include medical comorbidities, immunosuppression, prior antibiotic exposure and presence of an indwelling urinary catheter.[16] Likewise, the incidence of KPC-KP has been reported in several special patient populations. In immunosuppressed patients with diabetes, malignancies, liver cirrhosis, chronic alcohol abuse and kidney failure, carbapenem-resistant KP was detected in 20% of patients.[17] A high rate of colonization and infection with KPC-KP was also identified in patients from long-term care facilities.[18] Our study is the first to describe and characterize the long-term carriage of KPC-KP in patients with BSCI. We found that, in our hospital, 39% of KPC-KP-positive patients were patients with BSCI, and 31% of the patients were repeatedly positive for KPC-KP. Suda *et al.*[10] reported that 2.4% of Enterobacteriaceae isolates were resistant to carbapenem in SCI patients. Our results indicate that KPC-KP is the major carbapenemase-carrying species in this patient population. Although the incidence of KPC-KP has to be determined by further studies, our observation indicates that screening BSCI patients for KPC-KP may be important for preventing the spread of this MDRO.

It was noticed that patients with motor vehicle accident and gunshot wound accounted for more than half (66%) of the BSCI patients with repeated KPC-KP cultures. This result may be due the metropolitan location of our hospital and the proximity of a rehabilitation center; thus the significance of this social demographic characteristic requires further investigation. If further studies bear this out, addressing strategies to prevent these types of trauma may be important in the armamentarium to combat emergence and spread of these MDROs.

In prior studies, patients infected with KPC-KP were reported to have mortality rates ranging from 23% to 75%. Lack of active antimicrobial agents and underlying comorbidities were determined to contribute to these high mortality rates.[19] Similar to the incidence of carbapenem-resistant *Enterobacteriaceae* in the general population,

Table 3 Microbiological characteristics of BSCI patients with KPC-KP

Characteristics	*Values*[a]		
	All patients (n = *20*)	*Patients with identical strain types* (n = *13*)	*Patients with different strain types* (n = *7*)
Patients with MDROs[b] other than KPC	15 (75%)	9 (69%)	6 (86%)
No. of MDROs			
2 MDROs	6 (30%)	5 (38%)	1 (14%)
3 MDROs	6 (30%)	3 (23%)	3 (43%)
4 MDROs	3 (15%)	1 (8%)	2 (29%)
Years from injury to KPC isolate; mean ± s.d., median (range)	8.3 ± 9.3, 6.5 (0.08–32)	5.2 ± 6.1, 0.75 (0.08–17)	14.1 ± 11.8, 13 (0.58–32)
Site of KPC isolate			
Urine	16 (80%)	10 (77%)	6 (86%)
Blood	2 (10%)	1 (8%)	1 (14%)
Stool	1 (5%)	1 (8%)	0
Stool and blood	1 (5%)	1 (8%)	0
Colonization with KPC	9 (45%)	6 (46%)	3 (43%)
Received antibiotics	16 (80%)	10 (77%)	6 (86%)
Length of time between KPC-KP study isolates in days; mean ± s.d., median (range)	315.6 ± 282.1, 189.5 (1–843)	372.9 ± 321, 383 (1–843)	209.1 ± 159.6, 141 (54–484)
Length of KPC strain persistence by PFGE in days; mean (range)	NA	373 (1–843)	NA

Abbreviations: BSCI, brain and spinal cord injury; KPC, *Klebsiella pneumoniae* carbapenemase; KPC-KP, *Klebsiella pneumoniae* carbapenemase-producing *K. pneumonia*; MDRO, multidrug-resistant organism; NA, not applicable; PFGE, pulsed-field gel electrophoresis.
[a]Value is at the time of the first KPC-KP isolate.
[b]These included vancomycin-resistant enterococci, extended-spectrum beta-lactamase *Enterobacteriaceae* and methicillin-resistant *Staphylococcus aureus*.

KPC-KP most commonly presented in urine in the BSCI patients. KPC-KP was recovered from urine in 67% of our patients. Compared with a 5.5% mortality rate among patients with only urine cultures,[20] only 1 (1.2%) of the 82 patients in our study died from KPC-KP-related infection. Further studies to investigate and validate the lower than average mortality rate of KPC-KP in BSCI patients are warranted.

In a recent study, the mean time of KPC-KP carriage was reported to be 387 days with 65% of patients having positive culture at 1 year.[21] Our study demonstrates that KPC-KP can persist in BSCI patients for as long as 843 days. Among the 20 patients who presented with repeated positive cultures of KPC-KP, the mean time of carriage was 373 days. Our patients commonly had multiple readmissions. The average number of admissions in the 1 year before KPC-KP isolation was 2, with the highest number being 12. Given their frequent readmissions, these patients represent a repeated source of potential transmission within the health-care setting. Patients diagnosed with KPC-KP infection or colonization are placed in contact isolation precautions during the index and all subsequent hospital stays. Identifying KPC-KP-positive patients upon admission is important to prevent its spread. Until a cost-effective screening method for KPC-KP is developed, universally screening for KPC-KP-positive patients upon admission is not feasible. Selectively screening high-risk patient populations may reduce the risk of KPC-KP transmission.

Owing to the high morbidity and mortality associated with KPC-KP infections, patients are commonly treated with broad spectrum antimicrobials or antimicrobial combinations. It is important, however, to differentiate between KPC-KP colonization and infection as these agents often have significant side effects and treatment of colonization can lead to further antibiotic resistance with no therapeutic benefit. In our study, 77% of patients received antibiotic treatment, while only 35% of patients were identified to have clinical infections. The majority of our patients carried KPC-KP in the urine. After reviewing >100 patients with bacteriuria, Qureshi *et al.*[22] reported that 80% of patients showed no clinical symptoms of urinary tract infection, and none of the patients developed secondary infections or death. Our result is consistent with this finding and raises the question of overtreatment of KPC-KP based on the culture results. Clinicians should be educated not to treat colonization in general but particularly in these MDROs for which treatment of true infections often requires use of antibiotics as last resort.

Successful infection prevention and control strategies likely differ in patients with distinct vs identical strain types. In our study, 35% of patients carried distinct PFGE types. Although it is possible that the original strain morphed over time or that new endemic strains emerged owing to repeated antibiotic selective pressure, in these patients, it is also possible that they acquired a new strain type from the health-care setting. Implementing effective infection prevention strategies may reduce the risk of KPC-KP transmission to these patients. Conversely, 65% of our patients carried the same KPC-KP for an extended period of time. For these patients, alternative strategies have to be identified to reduce the burden of KPC-KP. Strict attention to antimicrobial stewardship principles is likely the best strategy to prevent development and persistence of KPC-KP and other MDROs. The best strategy for management of BSCI KPC-KP patients remains to be determined.

We were unable to analyze the isolates from all patients with repeated positive KPC-KP culture. Only 20 patients were included in the strain comparison analysis. Owing to the small sample size, statistical analysis for significance could not be performed. A larger prospective study to validate and expand upon these findings would be beneficial.

In conclusion, the study identified that BSCI patients comprise a significant percentage of our KPC-KP population. Owing to repeated hospitalizations and prolonged colonization, they represent a substantial reservoir for these multidrug-resistant pathogens.

DATA ARCHIVING

There were no data to deposit.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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