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Presence of the KPC Carbapenemase Gene in Enterobacteriaceae Causing Bacteremia and Its Correlation with In Vitro Carbapenem Susceptibility

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During 6 months, we obtained Enterobacteriaceae isolates from patients with gram-negative bacteremia at a 1,250-bed teaching hospital in St. Louis, MO, and compared carbapenem susceptibilities with the presence of blaKPC, a transferable carbapenemase gene. Three (1.2%) out of 243 isolates were blaKPC positive. Ertapenem nonsusceptibility had a low positive predictive value.

The serine carbapenemase KPC (Klebsiella pneumoniae carbapenemase) has emerged as a beta-lactamase capable of inactivating carbapenem antibiotics. First identified in Klebsiella pneumoniae (21), KPC has since been detected in other Enterobacteriaceae (7). The gene encoding KPC, blaKPC, is plasmid transmissible among Enterobacteriaceae, which has implications for infection control (3, 20). The presence of blaKPC may not always result in carbapenem resistance in vitro (19), thereby impeding detection during routine workup. KPC-producing bacteria have primarily been reported from the New York City area; however, blaKPC is present among Enterobacteriaceae isolates as far west as Arkansas (7). The aim of this study was to systematically screen Enterobacteriaceae bacteremia isolates for reduced susceptibility to carbapenems and to correlate results with the presence of blaKPC.

(This work was presented in abstract form at the 47th International Conference on Antimicrobial Agents and chemotherapy, Chicago, IL, September 2007 [12a].)

Microbiological and molecular analyses were performed on bacterial isolates from inpatients with Enterobacteriaceae bacteremia at Barnes-Jewish Hospital in St. Louis, MO. We included patients with bacteremia occurring between 1 August 2006 and 31 January 2007. Isolates were tested for susceptibility to the three carbapenem antibiotics (ertapenem, imipenem, and meropenem) and noncarbapenem antibiotics, using the 2006 and 31 January 2007. Isolates were tested for susceptibil-

ity to one or more carbapenems (Table 1). Two isolates infected three patients (Table 2) and included one KPC positive. Three isolates were nonsusceptible only to meropenem (100% [three/three] and 100% [240/240], respectively) and high specificity (98.3% [236/240]), similar to results for imipenem (100% [three/three] and 100% [240/240], respectively) and meropenem (66.6% [two/three] and 99.6% [239/240], re-
spectively) (Table 1). The positive predictive value (PPV) of ertapenem nonsusceptibility for detecting \( \text{bla}_{\text{KPC}} \) was 43% (three/seven) versus 100% (three/three) for imipenem and 66.6% (two/three) for meropenem. The PPV of ertapenem as sole carbapenem showing resistance was 0% (zero/three); the PPV of resistance to all three carbapenems for detecting \( \text{bla}_{\text{KPC}} \) was 100% (two/two). One (33%) of the patients infected with a \( \text{bla}_{\text{KPC}} \) isolate and 41 (18.6%) of the patients infected with a \( \text{bla}_{\text{KPC}} \) isolate died.

\( \text{KPC} \)-positive bacteria were present in 1.3% (3/223) of bacteremia episodes in our study, which is relatively low. However, plasmid transfer and subsequent dissemination can occur (3, 21). In a study by Landman et al., the susceptibility of \( \text{K. pneumoniae} \) isolates to carbapenems decreased from 97% to 76% within 5 years, probably due to \( \text{bla}_{\text{KPC}} \) (11). In a United States-wide surveillance study, the prevalence of \( \text{bla}_{\text{KPC}} \) among various \( \text{Enterobacteriaceae} \) was 0.5% (7), whereas a study of Brooklyn hospitals reported 38% prevalence in \( \text{K. pneumoniae} \) (11). Our data confirm that \( \text{bla}_{\text{KPC}} \) is not restricted to the Northeastern United States and warrant surveillance of carbapenem susceptibilities among \( \text{Enterobacteriaceae} \).

Ertapenem has been proposed as the carbapenem that most accurately detects the presence of \( \text{bla}_{\text{KPC}} \) by disk diffusion (1, 4, 12). This may be because diameter cutoffs for inhibition zones were set more stringently for ertapenem than for other carbapenems (6). Ertapenem was the most frequently nonsusceptible carbapenem in our study; however, the PPV of ertapenem nonsusceptibility for identifying \( \text{bla}_{\text{KPC}} \) was low (43%). This is possibly due to carbapenem resistance mediated by mechanisms other than \( \text{bla}_{\text{KPC}} \) (16). Other studies (15, 19) have found that carbapenem susceptibility testing by the disk diffusion method is unreliable at predicting the presence of \( \text{bla}_{\text{KPC}} \). Possible explanations for undetected \( \text{bla}_{\text{KPC}} \) carriage are an unexpressed \( \text{bla}_{\text{KPC}} \) gene, the inoculum effect (4), and misinterpretation of the resistance pattern to signify an extended-spectrum beta-lactamase producer (15). An MIC that is in the upper range of susceptibility may be the only indication of \( \text{bla}_{\text{KPC}} \). Lowering the imipenem MIC breakpoints (13) or PCR-based screening (2, 9) might increase the chance of detecting resistance.

A limitation of our study is that we did not assess isolates for additional beta-lactamas than other \( \text{bla}_{\text{KPC}} \), which is a constellation increasingly encountered (12, 14). We also had a relatively small sample size and a single-center design, and we restricted analysis to bacteremia isolates. We did not test gram-negative bacteria outside the \( \text{Enterobacteriaceae} \) family for \( \text{bla}_{\text{KPC}} \) (18). In conclusion, our study is among the first prospective investigations into the endemic epidemiology of \( \text{bla}_{\text{KPC}} \)-positive bacteria, demonstrating that \( \text{bla}_{\text{KPC}} \) is currently present at a low level in a major Midwestern city. Disk diffusion tests currently remain the simplest screening tests to

### Table 1. Characteristics of \( \text{Enterobacteriaceae} \) strains exhibiting in vitro carbapenem nonsusceptibility and/or harboring the \( \text{bla}_{\text{KPC}} \) gene

<table>
<thead>
<tr>
<th>Source patient</th>
<th>Organism</th>
<th>Carbapenem</th>
<th>Noncarbapenem</th>
<th>( \text{bla}_{\text{KPC}} ) genotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source patient</td>
<td>Organism</td>
<td>Ertapenem</td>
<td>Imipenem</td>
<td>Meropenem</td>
</tr>
<tr>
<td>1</td>
<td>( \text{K. pneumoniae} )</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>2</td>
<td>( \text{K. pneumoniae} )</td>
<td>R</td>
<td>S</td>
<td>R</td>
</tr>
<tr>
<td>3</td>
<td>( \text{E. cloacae} )</td>
<td>I</td>
<td>R</td>
<td>S</td>
</tr>
<tr>
<td>4</td>
<td>( \text{P. mirabilis} )</td>
<td>I</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>5</td>
<td>( \text{E. coli} )</td>
<td>I</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>6</td>
<td>( \text{Citrobacter freundii} )</td>
<td>I</td>
<td>S</td>
<td>S</td>
</tr>
</tbody>
</table>

* S, susceptible; I, intermediate; R, resistant. In additional susceptibility testing, the \( \text{K. pneumoniae} \) isolate recovered from patient 1 was immediately susceptible to tigecycline and susceptible to colistin. Also, the \( \text{E. cloacae} \) isolate from patient 2 was immediately susceptible to tigecycline and susceptible to colistin.

* Recovered from a patient with polymicrobial \( \text{Enterobacteriaceae} \) bacteremia.

### Table 2. Characteristics of patients with bacteremia caused by \( \text{bla}_{\text{KPC}} \)-positive \( \text{Enterobacteriaceae} \)

<table>
<thead>
<tr>
<th>Source patient</th>
<th>Age (yrs)</th>
<th>Underlying disease</th>
<th>Location from which admitted</th>
<th>Location at time of blood culture</th>
<th>Source of infection</th>
<th>Type of bacteremia</th>
<th>Organism</th>
<th>Adequate empirical antibiotic treatment</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>61</td>
<td>Primary biliary cirrhosis with hepatopetal syndrome</td>
<td>Home (central Illinois)</td>
<td>ICU</td>
<td>Respiratory tract</td>
<td>Hospital acquired</td>
<td>( \text{K. pneumoniae} )</td>
<td>No (ceftazidime + ciprofloxacin)</td>
<td>Died</td>
</tr>
<tr>
<td>2</td>
<td>79</td>
<td>Enterocutaneous fistula post-hernia repair</td>
<td>Long-term care facility (St. Louis, MO)</td>
<td>Non-ICU</td>
<td>Central venous catheter</td>
<td>Community acquired, health care associated</td>
<td>( \text{E. cloacae} )</td>
<td>No (piperacillin-tazobactam)</td>
<td>Recovered</td>
</tr>
<tr>
<td>3</td>
<td>53</td>
<td>PVD/DM-associated gangrene</td>
<td>Long-term care facility (St. Louis, MO)</td>
<td>Non-ICU</td>
<td>Skin/soft tissue</td>
<td>Community acquired, health care associated</td>
<td>( \text{P. mirabilis} )</td>
<td>Yes (piperacillin-tazobactam)</td>
<td>Recovered</td>
</tr>
</tbody>
</table>

* ICU, intensive care unit; PVD, peripheral vascular disease; DM, diabetes mellitus. A bacteremia was considered hospital acquired if it occurred >48 h after admission. Community-acquired infections were defined as health care associated by using published criteria (8). Inadequate empirical antibiotic treatment was defined as no antibiotic being given to which the bacteria were susceptible within 24 h of the positive blood culture being obtained (10).

* Recovered from a patient with polymicrobial \( \text{Enterobacteriaceae} \) bacteremia.
detected bla_\text{KPC}-positive bacteria in clinical microbiology laboratories.

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