A single-day point-prevalence study of faecal carriers in long-term care hospitals in Madrid (Spain) depicts a complex clonal and polyclonal dissemination of carbapenemase-producing Enterobacteriaceae

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Objectives: The objective of this study was to describe the prevalence and microbiological characteristics of carbapenemase-producing Enterobacteriaceae (CPE) colonizing patients in long-term care hospitals (LTCHs) in Madrid, Spain.

Methods: Three LTCHs were included in a single-day point-prevalence survey (September 2013). Rectal swabs, collected from all hospitalized patients (137 in LTCH-A, 121 in LTCH-B and 83 in LTCH-C), were plated onto chromogenic media. Population structure (PFGE and MLST), genes encoding carbapenemases and ESBLs and plasmids carrying carbapenemase genes were characterized.

Results: The prevalence of CPE carriers was 4.1% (14/341) [2.9% (4/137), LTCH-A; 4.1% (5/121), LTCH-B; and 6.0% (5/83), LTCH-C]. OXA-48 was the most prevalent carbapenemase (nine K. pneumoniae, two E. coli, one Enterobacter cloacae and one Citrobacter braakii) followed by VIM-1 (one K. pneumoniae and one Raoultella ornithinolytica). One patient (LTCH-C) was co-colonized with OXA-48-producing K. pneumoniae and E. coli. K. pneumoniae and E. coli isolates also coproduced CTX-M-15 (n = 11) or CTX-M-9 (n = 1) enzymes. K. pneumoniae clustered into six PFGE types corresponding to ST11 (n = 1), ST15 (n = 6), ST307 (n = 1) and ST405 (n = 2). E. coli from LTCH-A and LTCH-C exhibited two different PFGE types associated with ST68. OXA-48 and VIM-1 enzymes were found in different clones in LTCH-A and LTCH-C. However, OXA-48 was the only carbapenemase detected in LTCH-B, mainly associated with K. pneumoniae ST15. KPC, IMP and NDM enzymes were not detected. blaOXA-48 was located on an ~60 kb plasmid with a pOXA-48a-IncL/M backbone.

Conclusions: We describe the first point-prevalence study of CPE faecal carriers in LTCHs in Spain. OXA-48, the most prevalent carbapenemase, showed a complex dissemination pattern with clonal and polyclonal bacterial populations.

Introduction

The worldwide dissemination of carbapenemase-producing Enterobacteriaceae (CPE) constitutes an important challenge for the healthcare system. Initially, CPE appeared to cause hospital-acquired infections, but more recently they have spread into different healthcare settings, including long-term care hospitals (LTCHs), and also into the community.

LTCHs constitute important reservoirs for MDR bacteria, such as ESBL-producing Enterobacteriaceae. Previous admission into these institutions has been identified as a risk factor for intestinal colonization of ESBL producers and more recently for CPE. Moreover, it has been demonstrated that continuous bidirectional movement of patients between these institutions and acute care hospitals facilitates the spread and maintenance of MDR bacteria. As a result, control interventions to curtail this spread have been successfully implemented in countries with a high prevalence of CPE in healthcare institutions, including LTCHs. Despite these facts, the prevalence of CPE faecal carriers in LTCHs remains unknown in most geographical areas. Our objective was to describe the prevalence and microbiological characteristics of CPE colonizing patients hospitalized in three different LTCHs in Madrid, Spain.
Faecal carriage of CPE in LTCHs in Spain

Materials and methods

Facilities and patient recruitment

Three LTCHs in the Madrid area (LTCH-A, LTCH-B and LTCH-C) were recruited for a single-day (September 2013) point-prevalence survey. LTCH-A (198 beds) was located in the southern area of the Madrid community, while LTCH-B (192 beds) and LTCH-C (144 beds) were in the northern area. In each LTCH, specimen collection was undertaken by local hospital staff. Screening of patients for carriage of CPE is part of a regional plan to control and prevent infections caused by CPE, promoted by the public health authorities of our region.

Surveillance cultures and CPE detection

Rectal swabs were collected and then processed at Ramón y Cajal University Hospital. Samples were plated onto ChromoID-ESBL, CARBA and OXA-48 agars (bioMérieux, Marcy-l’Étoile, France) and incubated at 37°C for 48 h. A unique colony per colour and morphology growing on each selective chromogenic agar-medium was selected for microbiological studies. Bacterial identification was confirmed by the MALDI-TOF MS method (Bruker Daltonics, Germany). Screening for carbapenemase production included both the Carba-NP and modified Hodge tests and assessment of the inhibition-based profile using the ROSCO KPC/MBL and OXA-48 Confirm Kit (ROSCO Diagnostica, Taastrup, Denmark).11,12 Production of ESBLs was also screened for by the double-disc synergy test.4 The presence of genes encoding carbapenemases (blaTEM, blaOXA-48, blaKPC, blaIMP and blaNDM) and ESBLs (blaSHV, blaTEM and blaCTX-M) as well as the genetic environment of blaOXA-48 were investigated by PCR and sequencing.3,4,13 Antibiotic susceptibility testing was performed by microdilution (MicroScan; Beckman Coulter, CA, USA) and Etest (bioMérieux) according to EUCAST guidelines (http://www.eucast.org). Isolates classified as intermediate and resistant were considered as non-susceptible.

Clonal relatedness

Isolates were typed by PFGE using XbaI-digested DNA.5 Klebsiella pneumoniae and Escherichia coli isolates were also characterized by MLST (http://mlst.ucc.ie/mlst/dbs/Ecoli.html and http://www.pasteur.fr/recherche/genopole/PGF/mlst/Kpneumoniae.html) and MLST (http://mlst.ucc.ie/mlst/dbs/Ecoli). The majority of the isolates (13/15) were classified as intermediate and resistant were considered as non-susceptible.

Conjugation assay and plasmid characterization

Conjugation was attempted with all carbapenemase-producing isolates per duplicate using E. coli K-12 BM21 as recipient. Determination of the size of plasmids harbouring blaOXA-48 and RFLP was performed in all E. coli transconjugants.6 In WT isolates in which no transconjugants were obtained, the blaOXA-48 hybridization assay was performed. The plasmid incompatibility group was determined by the PCR-based replicon typing (PBRT) scheme.14 The repA, traU and parA genes were detected by PCR to relate the OXA-48-encoding plasmids to the pOXA-48a-IncL/M plasmid.

Statistical analysis

Statistical significance for comparison of proportions was calculated by Fisher’s exact test (P < 0.05 was considered statistically significant). Exact binomial methods were used to calculate 95% CIs for prevalence rates.

Results

Rate of CPE and ESBL-producing Enterobacteriaceae colonization

A total of 341 patients were screened across all three LTCH sites (n = 137, LTCH-A; n = 121, LTCH-B; and n = 83, LTCH-C). The total prevalence of CPE faecal carriers was 4.1% (14/341; 95% CI 2.9%–6.2%). Among the different LTCHs, colonization rates were as follows: 2.9% (4/137; 95% CI 0.1%–5.7%), LTCH-A; 4.1% (5/121; 95% CI 0.6%–7.6%), LTCH-B; and 6.0% (5/83; 95% CI 0.9%–11.4%), LTCH-C (P > 0.05) (Figure 1). The mean age of CPE-colonized patients was 81 years (range = 30–88 years) and 7/14 were female. Moreover, 28.6% (4/14) of CPE carriers were also co-colonized by ESBL-producing Enterobacteriaceae (3 K. pneumoniae and 1 E. coli). Overall, 31.2% (103/341; 95% CI 25.3%–35.0%) of patients were colonized with ESBL-producing Enterobacteriaceae. The corresponding frequency in different centres is also shown in Figure 1.

Bacterial isolates and carbapenemase characterization

Fifteen CPE isolates were identified from 14 patients with positive CPE faecal carriage. K. pneumoniae (n = 10) was the most prevalent species, followed by E. coli (n = 2), Enterobacter cloacae (n = 1), Citrobacter braakii (n = 1) and Raoultella ornithinilytica (n = 1) (Table 1). The majority of the isolates (13/15) were OXA-48 producers (Table 1).

All K. pneumoniae and E. coli isolates coproduced CTX-M enzymes (CTX-M-15 and CTX-M-9) (Table 1). The highest bacterial

Figure 1. Colonization prevalence of ESBL-producing Enterobacteriaceae and CPE among patients admitted into LTCHs. Error bars represent 95% CIs.
were susceptible to colistin. tigecycline MICs were \( \geq \) 8 mg/L. Amikacin was one of the most effective drugs against CPE isolates. The MIC range of imipenem, meropenem, and ertapenem combinations was 0.75 to 6 mg/L, 0.25 to 4 mg/L, and 0.38 to 8 mg/L, respectively.

**Conjugation assay, plasmid characterization and bla\textsubscript{OXA-48} genetic environment**

Nine OXA-48-producing E. coli transconjugants were obtained (Table 1). All transconjugants were typed for bla\textsubscript{OXA-48}, which was located on a 60 kb plasmid non-typable by the PBR method. The presence of repA, traU, and parA genes was detected, suggesting that those plasmids had a pOXA-48a-Incl/M backbone. All plasmids showed highly related restriction profiles and bla\textsubscript{OXA-48} was part of the Tn19992 composite transposon. No transconjugants were obtained from C. braakii, E. cloacae, and K. pneumoniae ST405. For VIM-1-producing isolates, transconjugants were only obtained from K. pneumoniae ST405 (Table 1). The VIM-1-encoding plasmid had a restriction profile related to the OXA-48-encoding plasmids and also amplified for repA, traU, and parA genes.

**Discussion**

We outline the first point-prevalence study of CPE carriers in LTCHs in Spain. This study was conducted due to the increasing prevalence of these isolates in acute care hospitals in our geographical area, with the objective of identifying hidden CPE faecal carriers contributing to explain this prevalence and to support further control interventions.

In some countries such as the USA or Israel, where carbapenemase epidemiology is characterized by a wide dissemination of KPC-producing K. pneumoniae, several studies have been conducted describing a prevalence of colonized LTCH patients, which ranged from 8% to 30%, but currently scarce data about its prevalence are available in Europe. One study conducted in Italy reported a colonization rate with metallo-\( \beta \)-lactamase-producing isolates (Table 1) that received non-susceptible to ciprofloxacin, trimethoprim/sulfamethoxazole, tobramycin, and gentamicin was 86.6%, 73.3%, 73.3%, and 66.6%, respectively. In two K. pneumoniae and one E. cloacae, tigecycline MICs were \( \geq 2 \) mg/L. Amikacin was one of the most active antibiotics (13.3% non-susceptible isolates). All isolates were susceptible to colistin.

**K. pneumoniae and E. coli clonal relatedness**

K. pneumoniae isolates were clustered into six PFGE types corresponding to ST11 (n = 1), ST15 (n = 6), ST307 (n = 1) and ST405 (n = 2). K. pneumoniae ST15 (PFGE types Kpn-1 and Kpn-2) was the most prevalent K. pneumoniae OXA-48 clone (Table 1). Interestingly, ST15 was associated with a VIM-1-producing isolate (PFGE type Kpn-1) in LTCH-A. Although LTCH-C was located in the northern area of Madrid as was LTCH-B, the OXA-48 dissemination was associated with a polyclonal K. pneumoniae population (ST11, ST15, ST307, and ST405) (Table 1). Finally, E. coli isolates that were isolated in two different LTCHs (A and C) exhibited two different PFGE types and both grouped into ST68.

**Antimicrobial susceptibility**

All isolates were non-susceptible to ampicillin, extended-spectrum cephalosporins and \( \beta \)-lactam/\( \beta \)-lactamase inhibitor combinations. MICs of imipenem, meropenem, and ertapenem ranged from 0.75 to 6 mg/L, 0.25 to 4 mg/L, and 0.38 to 8 mg/L, respectively.

Non-susceptibility to ciprofloxacin, trimethoprim/sulfamethoxazole, tobramycin, and gentamicin was 86.6%, 73.3%, 73.3%, and 66.6%, respectively. In two K. pneumoniae and one E. cloacae, tigecycline MICs were \( \geq 2 \) mg/L. Amikacin was one of the most active antibiotics (13.3% non-susceptible isolates). All isolates were susceptible to colistin.

## Table 1. Microbiological characteristics of CPE isolates

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<th>LTCH (no. of isolates)</th>
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<th>Resistance genes</th>
<th>Molecular typinga (no. of isolates)</th>
<th>Plasmids in transconjugantsb, size (kb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTCH-A (4)</td>
<td>K. pneumoniae (1)</td>
<td>VIM-1</td>
<td>Kpn-1 (15)</td>
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<td>Escherichia coli (1)</td>
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<td></td>
<td></td>
<td>CTX-M-15</td>
<td>Kpn-3 (405)</td>
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<td>LTCH-C (6)</td>
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AMK, amikacin; CIP, ciprofloxacin; GEN, gentamicin; TGC, tigecycline; TOB, tobramycin; SXT, trimethoprim/sulfamethoxazole; NT, no transconjugants were obtained.

aUnderlined PFGE types and STs correspond to CPE clones detected in different LTCHs.
bPatient co-colonized by K. pneumoniae ST15 and E. coli ST68, both producing OXA-48.
cAll plasmids had a pOXA-48a-IncL/M backbone and showed a highly related restriction profile.

diversity was detected in LTCH-A since all the carbapenemase-producing isolates (n = 4) belonged to different bacterial species (K. pneumoniae VIM-1, E. coli OXA-48, E. cloacae OXA-48, and C. braakii OXA-48) (Table 1).

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producers of 6.3%, while in another study in Belgian nursing homes, CPE colonization was not detected among residents. We found that 4.1% of LTCH residents in the Madrid area were colonized by CPE. These data, in parallel with those from acute care hospitals in the same geographical area and national surveillance studies in Spain, demonstrate a successful penetration of CPE into healthcare facilities. Moreover, the higher prevalence of ESBL carriers found in the studied LTCHs when compared with the most recent data from patients admitted into acute care hospitals in our country also depicts these centres as reservoirs for MDR isolates.

In Spain, as in other European countries, CPE rates have increased dramatically during recent years. Currently, OXA-48 is the most common enzyme circulating in acute care hospitals, associated with K. pneumoniae epidemic clones such as ST11, ST405 and ST15. In our study, we detected all these clones circulating in LTCHs, probably as a consequence of movement of patients between these sites and acute care hospitals. One of these clones, ST405, was detected for >1 year in a hospital-wide outbreak in Madrid and ST11 is the main clone in our institution (D. Gijón, P. Ruiz-Garbajosa and R. Cantón, Ramón y Cajal University Hospital, unpublished data), denoting different local amplification in different institutions. In LTCHs, cross-transmission events can occur resulting in the dissemination of not only one epidemic clone, but also the dissemination of carbapenemase genes in multiple clones and bacterial species, as we described particularly for blaOXA-48. Currently, the spread of blaOXA-48 has been associated with the dissemination of a particular IncL/M plasmid backbone. In this work, blaOXA-48 was also located in plasmids related to pOXA-48a, which were disseminated in different K. pneumoniae high-risk clones and even in other enterobacterial species. Moreover, these OXA-48-encoding plasmids showed the same restriction profile as plasmids found in the ST11 epidemic strain found in our institution (data not shown). This reflects a successful combination of high-risk epidemic clones, especially from K. pneumoniae, and plasmids prone to acquire antibiotic resistance genes.

In summary, this survey demonstrates an important reservoir of CPE and ESBL-producing Enterobacteriaceae among patients admitted into LTCHs in Madrid. LTCH patients should be considered as a high-risk group for CPE colonization that can act as hidden disseminators. As a consequence, admission surveillance cultures or molecular detection should be implemented in this high-risk group of patients for early detection of CPE carriage. The dissemination of CPE across healthcare institutions points to the need to establish coordinated infection control policies at regional and national levels involving both acute care hospitals and LTCHs.

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Transparency declarations

None to declare.

References


