Journal of Hospital Infection 103 (2019) 115–120

Available online at www.sciencedirect.com

Journal of Hospital Infection

journal homepage: www.elsevier.com/locate/jhin

Can real-time polymerase chain reaction allow a faster recovery of hospital activity in cases of an incidental discovery of carbapenemase-producing Enterobacteriaceae and vancomycin-resistant Enterococci carriers?

R. Saliba [a,b], C. Neulier [c], D. Seytre [b], A. Fiacre [d], F. Faibis [d], P. Leduc [c], M. Amara [e], F. Jauréguy [a,b], E. Carbonnelle [a,b], J.-R. Zahar [a,b,*], L. Marty [f]

[a] *IAME, UMR 1137, Université Paris 13, Sorbonne Paris Cité, France*
[b] *Service de Microbiologie Clinique et Unité de Contrôle et de Prévention du risque Infectieux, Groupe Hospitalier Paris Seine Saint-Denis, AP-HP, Bobigny, France*
[c] *Service de Prévention du Risque Infectieux, CH André Mignot, Versailles, France*
[d] *Département de Microbiologie, Grand Hôpital de l'Est Francilien site Marne la Vallée, France*
[e] *Département de Microbiologie et Hygiène, CH André Mignot, Versailles, France*
[f] *Unité d'Hygiène Inter Hospitalière Nord Seine et Marne Grand Hôpital de l'Est Francilien site Marne la Vallée, France*

ARTICLE INFO

Article history:
Received 30 April 2019
Accepted 1 July 2019
Available online 4 July 2019

Keywords:
Real-time PCR
Carbapenemase-producing Enterobacteriaceae
Vancomycin-resistant Enterococci
Infection control
Outbreak
Rectal screening

SUMMARY

Background: Detection of faecal carriers of carbapenemase-producing Enterobacteriaceae (CPE) and vancomycin-resistant Enterococci (VRE) has become a routine medical practice in many countries. In an outbreak setting, several public health organizations recommend three-weekly rectal screenings to rule-out acquisition in contact patients. This strategy, associated with bed closures and reduction of medical activity for a relatively long time, seems costly.

Aim: The objective of this study was to test the positive and negative predictive values of reverse transcription polymerase chain reaction (RT-PCR; GeneXpert®) carried-out at Day 0, compared with conventional three-weekly culture-based rectal screenings, in identifying, among contact patients, those who acquired CPE/VRE.

Methods: A multicentre retrospective study was conducted from January2015 to October2018. All contact patients (CPs) were included identified from index patients (IPs) colonized or infected with CPE/VRE, incidentally discovered. Each CP was investigated at Day 0 by PCR (GeneXpert®), and by the recommended three-weekly screenings.

Findings: Twenty-two IPs and 159 CPs were included. An average of 0.77 secondary cases per patient was noted, with a mean duration of contact of 10 days (range 1–64). Among the 159 CPs, 16 (10%) had a CPE/VRE-positive culture during the monitoring period. Rectal screenings were positive at Day 0 (10 patients), Day 7 (two patients), Day 14 (four patients). Thirteen of 16 patients with positive culture had a positive PCR at Day 0. Overall, a concordance of 97.5% (155/159) was observed between the three-weekly

* Corresponding author. Address: 125 rue de Stalingrad 93000, Bobigny, France. Tel.: +33 6 0307 9088.
E-mail address: jrzahar@gmail.com (J.-R. Zahar).

https://doi.org/10.1016/j.jhin.2019.07.004

screenings and Day 0 PCR results. When performed on CPs at Day 0 of the identification of an IP, PCR (GeneXpert®) allowed the reduction in turnaround time by five to 27 days, compared to three-weekly screenings. Positive predictive value and negative predictive value were 100% and 98%, respectively.

Conclusions: The use of RT-PCR (GeneXpert®) can avoid the three-weekly rectal samplings needed to rule-out acquisition of CPE/VRE.

Introduction

Carbapenemase-producing Enterobacteriaceae (CPE) and vancomycin-resistant enterococci (VRE) emerged globally over the last decade, resulting in antibiotic-resistant infections that are difficult to treat and costly to healthcare facilities [1]. The search and isolate policy is considered the main infection prevention and control strategy. Rapid, accurate detection of intestinal CPE and VRE colonization is critical to minimize transmission, and hence reduce costly, difficult-to-treat infections caused by these emerging extensively drug-resistant (XDR) bacteria [2].

The 2013 French National Guidelines recommend implementation of a strict isolation policy, including cohorting patients with CPE in a dedicated ward with dedicated healthcare workers (HCWs) and an extensive screening policy of contact patients. In case of identifying a non-cohorted index patient, recommendations are to close the ward concerned and apply a screening policy to all contact patients. Weekly rectal swabbing is recommended to investigate possible acquisition among contact patients. Contact patients are considered non-carriers if three consecutive weekly negative rectal swabs are obtained; they are then no longer monitored. This strategy seems to be costly as it is associated with a reduction in medical activity. Moreover, it could expose patients to higher risk of complications as they will usually remain isolated until screening is complete [3].

The current process for detecting CPE in clinical samples is usually performed using selective cultures and may require up to 72 h to obtain the results [4].

Different molecular assays have been developed and have shown their effectiveness in identifying the resistance genes from bacterial colonies. Real-time polymerase chain reaction (RT-PCR) assays have been reported to have lower limits of detection than conventional agar-based culture methodologies [4—7]. When used directly on rectal samples, they offer laboratories the ability to reduce turnaround times. However, there is no data on their effectiveness in this specific situation. Moreover, no previous study has demonstrated whether they have a potential added value for infection control management in an epidemiological setting. Therefore, evaluating the clinical utility of PCR-based assays as a screening tool, is needed.

The main objective of this study was to test in a multicentre retrospective survey the effectiveness of RT-PCR (GeneXpert®) carried out at Day 0 in identifying among contact patients those who acquired XDR. An additional objective was to define the negative predictive value (NPV) of this technique; a high NPV would support using this strategy in place of the standard three-week sampling and testing regimen.

Part of these results was presented at the 29th ECCMID Congress.

Materials and methods

A multicentre retrospective study was conducted in three large French hospitals (Avicenne Hospital AP-HP, Mignot Hospital — Hospital Center of Versailles, Grand Hospital Eastern Ile Site de Marne-la-Vallée) from January 2015 to October 2018. In these hospitals, the 2013 French National Guidelines recommendations [8] for the prevention of spread of XDR are systematically applied. Thus, in case of identifying an index patient, patients are cohorted and an extensive screening policy for all isolated contact patients is applied. Contact patients are only considered non-carriers, and isolation discontinued, if three consecutive weekly rectal swabs screenings are negative by recommended culture techniques.

An index patient was defined as a non-cohorted patient colonized or infected with CPE or VRE incidentally discovered post-hospitalization. Contact patients were defined as all the adults (>18 years old) staying in the same unit during the same period as an index patient, sharing the same HCWs and for whom, at least three-weekly rectal screenings were performed during the same hospitalization and after the end of their exposure using conventional culture techniques, plus an RT-PCR (GeneXpert®) assay performed on the first screening sample. A secondary-case patient was defined as a contact patient for whom CPE or VRE was later identified by the weekly rectal screenings. A non-colonized patient was defined as a contact patient who remained CPE- or VRE-negative during his stay in the hospital. Exposure time was defined as the duration of contact between the index patient and a secondary-case patient before being identified as CPE or VRE positive or a control patient throughout his stay in the same ward [9].

Data were collected retrospectively in case and control patients by reviewing medical and microbiological records. Collected data included demographic characteristics, including age, gender, ward of contact (medical, surgical, or intensive care unit), exposure time, duration of hospitalization on the ward, and antibiotic administration during the exposure period.

CPE and VRE detections were performed using, respectively, Xpert® Carba-R and Xpert® vanA/vanB (Cepheid, GeneXpert) following manufacturer recommendations, on the first screening sample. CPE detection by culture consisted of direct plating of the rectal swab on ChromID® CARBA SMART medium (BioMérieux, Marcy-l'Étoile, France) for 24 h; likewise, screening of VRE was carried out on ChromID® VRE medium (BioMérieux, Marcy-l'Étoile, France). Antibiotic susceptibility testing according to Comité de l'antibiogramme de la Société Française de Microbiologie — European Committee on Antimicrobial Susceptibility Testing (CA-SFM — EUCAST) guidelines [10] was performed on each type of suspected colony grown on selective media. Confirmation of resistance was accomplished

using Carba NP test and β-Carba test (Bio-Rad, Marnes-la-Coquette, France) [11,12] and Xpert® Carba-R on suspected CPE isolates and Xpert® vanA/vanB on suspected VRE isolates.

Statistical methods

The sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were calculated for all tested isolates. Statistical analysis was performed using 95% confidence intervals (CIs) calculated using Student's *t*-test.

Results

During the study period, 22 non-cohorted patients, hospitalized in different wards, carrying or infected with CPE (59%) or VRE (41%) were incidentally discovered post-hospitalization. The mean age of these index patients was 68 years and their average length of hospital stay, 12 days (range between 1 and 50 days). Sixteen index patients over 22 (72.7%) were exposed to antibiotics during their hospital stay. CPE accounted for 13 (59%) cases, with OXA-48 being the most prevalent mechanism of resistance (Table I).

Among the 159 contact patients (as defined previously) only 17 (10.7%) acquired an XDR. In fact, eight index patients of 22 generated at least one secondary-case patient, the average being 0.77 secondary cases per patient (range between 0 and 3). The mean duration of contact in the whole population was 10 days (range between 1 and 64 days). Among the 159 patients, 96 (60.4%) patients were receiving antibiotic therapy during the contact period (Table II).

According to French recommendations, all contact patients were followed up weekly and were screened by rectal swabbing. Furthermore, RT-PCR (GeneXpert®) was carried out on rectal swabs of the 159 contact patients at Day 0 and 14 patients were detected as CPE carriers. Conventional agar-based methodology used for weekly rectal screenings, was positive in 16 patients. Ten had a positive culture result on the first day of screening (Day 0), two at the second screening week and four at the third screening week. In one case, PCR was positive at Day 0, whereas conventional culture remained negative for the three-weekly rectal screenings. In three other cases, all related to VRE acquisition, PCR was negative at Day 0, while cultures were positive at the second or third round of screening.

Table I
Characteristics of the index patients

	Total index patients $N = 22$ (%)
Female sex	11 (50)
Age, mean	68
Hospitalization duration (days), mean	12
Ward of admission	
Medical	15 (68.2)
Surgical	4 (18.2)
Intensive care unit	3 (13.6)
Antibiotic therapy during hospitalization	16 (72.7)
Secondary cases generated	8 (36.4)
Mechanisms of resistance	
VRE (vanA)	9 (40.9)
CPE (OXA 48)	11 (50)
CPE (NDM)	1 (4.5)
CPE (KPC)	1 (4.5)

CPE, carbapenemase-producing Enterobacteriaceae; VRE, vancomycin-resistant enterococci.

Overall, a concordance of 97.5% (155/159) was observed between the three-weekly rectal screens using culture techniques and Day 0 RT-PCR (GeneXpert®) results. When performed on all contact patients at Day 0 after identifying of an index patient, RT-PCR (GeneXpert®) allowed the reduction in turnaround time by five to 27 days (six days on average) compared to the conventional three-weekly culture-based rectal screening method. Among the four discordances, one case had a positive PCR at Day 0 for CPE OXA-48, whereas, conventional culture methodology stayed negative for the three-weekly rectal screens. In the three remaining discordant cases, all VRE acquisition, PCR was negative at Day 0, while cultures were positive at the second screening in one case, and the third screening in the two other cases (Table III).

No statistically significant differences were found in age, duration of contact and antibiotic consumption between secondary-case patients diagnosed during the first screening and those found to be negative at the first screening but identified as carriers later at the second or third screenings.

Discussion

In our multicentre retrospective study, a concordance of 97.5% (155/159) was observed between the three-weekly rectal screenings using culture techniques and Day 0 RT-PCR (GeneXpert®) results. All secondary cases among contact patients were considered as having acquired the XDR bacteria within the first day of contact with the index patient and before the identification of carriage. Indeed, after identification, all case indexes were systematically cohorted according to the French recommendations and contact patients were not in contact with any other index patient or known carrier during their hospital stay. Among the four discordances, one case had a positive PCR at Day 0, whereas, conventional culture methodology remained negative for the three-weekly rectal screenings. This may be explained by the fact that the patient had been receiving antibiotics, affecting the expression of the resistance genes in culture, or, because it was an OXA-48 gene detected, the possibility of a transiently carriage of *Shewanella* spp. which naturally produce OXA-48 variants [5]. It needs to be considered also that molecular methods may be more sensitive than the culture method that was the reference standard in our study. Knowing that heavily colonized patients are more likely to yield opportunities for horizontal transmission, it raises the issue of whether the excellent sensitivity of PCR and detection of very low levels of colonization is significant, regarding the consequent costly infection-control measures [2].

In the three remaining discordant cases, all VRE acquisition, PCR was negative at Day 0, while cultures were positive during the second screening in one case, and the third screening in the two other cases. The absence of detection in these three cases at Day 0 may be associated with low undetectable bacterial load in the rectal swab specimens, becoming detectable at the second or third screenings or even with sample techniques [13]. However, looking closer at those cases, all three were parts of

Table II
Description of the characteristics of the contact patients

	Total contact patients $N = 159$ (%)	Secondary cases $N = 17$ (%)	Negative cases $N = 142$ (%)	P
Female sex	78 (49)	10 (58.8)	68 (47.9)	0.44
Age, median CI (min 25–75%, max)	70	80 (61–85)	72 (60.2–83.7)	0.54
Duration of contact with IP (days), median CI (25–75%)	10.4 (1, 64)	5 (3, 7)	10 (4, 15)	0.03
Ward of admission				
Medical	120 (75.5)	12 (70.6)	108 (76)	0.56
Surgical	27 (17)	5 (29.4)	22 (15.5)	0.17
Intensive care unit	12 (7.5)	0 (0)	12 (8.5)	0.36
Antibiotic therapy during hospitalization	96[a] (60.4)	11 (64.7)	85 (59.9)	0.79
Mechanisms of resistance	17 (10.7)			
VRE (vanA)	10 (6.3)	10 (58.8)	0	
CPE (OXA 48)	6 (3.8)	6 (35.3)	0	
CPE (NDM)	1 (0.6)	1 (5.9)	0	

CI, confidence interval; CPE, carbapenemase-producing Enterobacteriaceae; IP, index patient; VRE, vancomycin-resistant Enterococci.
[a] Penicillin + β-lactamase inhibitor 26; cephalosporins 32; carbapenems 5; fluoroquinolones 13; aminoglycosides 7; metronidazole 13; other antibiotics 27.

Table III
Description of the characteristics of discordant cases between the three-weekly rectal screening using culture techniques and Day 0 real-time polymerase chain reaction (PCR; GeneXpert®)

	Case 1	Case 2	Case 3	Case 4
Day 0 real-time PCR	Positive	Negative	Negative	Negative
1st week screening	Negative	Negative	Negative	Negative
2nd week screening	Negative	Positive	Negative	Negative
3rd week screening	Negative	Negative	Positive	Positive
Sex	M	M	M	F
Age	55	81	69	91
Duration of contact with index patient (days)	2	4	14	7
Ward of admission	Surgical	Medical	Medical	Medical
Antibiotic therapy during hospitalization	Yes	No	No	Yes
Mechanisms of resistance	CPE (OXA 48)	VRE (vanA)	VRE (vanA)	VRE (vanA)

CPE, carbapenemase-producing Enterobacteriaceae; F, female, M, male; VRE, vancomycin-resistant enterococci.

complicated outbreaks that generated several secondary cases. Therefore, it was also possible to suggest that those three patients were 'true-negative' at Day 0 and acquired the VRE later during their hospital stay.

Detection of faecal carriers of XDR bacteria has become a routine clinical practice in many parts of the world and is recommended by public health organizations for the containment of their spread. Among different approaches used, more recently, molecular approaches have been developed to increase detection sensitivity and decrease reporting time [14].

When performed on all contact patients at Day 0 of the discovery of an index patient, RT-PCR (GeneXpert®) allowed a reduction in the turnaround time by five to 27 days (six days on average) compared with the conventional three-weekly culture-based rectal screenings method. The result of a diagnostic assay has a clinical implication, and as a screening tool for XDR bacteria, that implication is the implementation of infection-control measures. The rapid cohorting of carriers is crucial to prevent outbreaks and reduce the social impact and the cost of infection-control measures empirically implemented for high-risk patients, who end up being negative for XDR bacteria colonization [5]. Moreover, the knowledge of the PPV and NPV is essential for decision making by the infection-control team with respect to the value of a positive and a negative test result. Some authors have studied the performance of RT-PCR (GeneXpert®), but most have studied its effectiveness in detecting resistance mechanisms on bacterial strains [15–19]. In addition, the limited number of authors who have been interested in evaluating the performance of GeneXpert® directly on rectal swabs, compared with the routine culture techniques, have studied its effectiveness only at the admission of patients considered as 'high-risk' for CPE carriage [2,4–7,14,20–22]. Hence, there are few data on the effectiveness of RT-PCR in this specific situation and no previous study has demonstrated whether they have a potential added value for infection control management in an epidemiological setting. To the best of our best knowledge, this is the first report to evaluate the clinical utility of PCR-based assays as a screening tool. This study suggested that RT-PCR (GeneXpert®), carried out at Day 0 is efficient in identifying among contact patients those who acquired XDR, with an NPV of 98%.

According to the 2013 French National Guidelines recommendations [8] and the international recommendations [23], in

cases of identifying an index patient, an extensive screening policy for all isolated contact patients must be applied. Contact patients are only considered non-carriers and no longer isolated, if three-weekly rectal swab screenings came back with a negative result, by recommended culture techniques. This strategy seems to be costly as it is associated with bed closures and a reduction in medical activity, for a relatively long duration of time. In addition to that, it could expose the isolated patients to a higher risk of complications as they are possibly receiving less optimal management for their medical condition, compared to non-isolated patients with the same medical condition.

The major strength of our study is the finding that, in an outbreak context, if the screening RT-PCR (GeneXpert®) test for a patient at Day 0 is negative, the risk that colonization will be discovered later remains weak. Thereby, the contact patient's isolation will only be limited to those who have been screened by RT-PCR as positive, meaning that they have acquired the XDR bacteria.

This study has several limitations. First, its retrospective nature and the lack of retrospective clinical data allowing for better targeting of patients at risk of acquisition of XDR bacteria, bearing in mind that Hilliquin *et al.* demonstrated recently in their large multicentre case—control study, that at least three risk factors are associated with KP OXA- 48 acquisition in contact patients of a non-cohorted index patient: (1) geographical proximity (2) antibiotic therapy during exposure time and (3) at least one invasive procedure [9]. Second, the sample size with the limited number of secondary cases. Third, it could not be excluded that the negative results on culture and/or on PCR were possibly the consequence of poor-quality sampling (no macroscopic staining was visualized), and this information was not available retrospectively.

In conclusion, PCR (GeneXpert®) can provide valuable information for infection-control programs, and avoid three-weekly rectal samplings to rule out acquisition of CPE or VRE. When included in a clinical algorithm, it can reduce the cost of the implementation of infection-control measures. Further studies need to be conducted comparing different RT-PCR techniques to the three-weekly rectal screenings using culture techniques, on a larger number of patients, taking into account different risk factors of XDR acquisition and transmission.

Conflict of interest statement
None to report.

Funding sources
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

[1] Wilson HJ, Khokhar F, Enoch DA, Brown NM, Ahluwalia J, Dougan G, et al. Point-prevalence survey of carbapenemase-producing Enterobacteriaceae and vancomycin-resistant enterococci in adult inpatients in a university teaching hospital in the UK. J Hosp Infect 2018 Sep;100(1):35—9.

[2] Lowman W, Marais M, Ahmed K, Marcus L. Routine active surveillance for carbapenemase-producing Enterobacteriaceae from rectal swabs: diagnostic implications of multiplex polymerase chain reaction. J Hosp Infect 2014;88(2):66—71.

[3] Otter JA, Burgess P, Davies F, Mookerjee S, Singleton J, Gilchrist M, et al. Counting the cost of an outbreak of carbapenemase-producing Enterobacteriaceae: an economic evaluation from a hospital perspective. Clin Microbiol Infect 2017;23(3):188—96.

[4] Huang T-D, Bogaerts P, Ghilani E, Heinrichs A, Gavage P, Roisin S, et al. Multicentre evaluation of the Check-Direct CPE® assay for direct screening of carbapenemase-producing Enterobacteriaceae from rectal swabs. J Antimicrob Chemother 2015;70(6):1669—73.

[5] Hoyos-Mallecot Y, Ouzani S, Dortet L, Fortineau N, Naas T. Performance of the Xpert® Carba-R v2 in the daily workflow of a hygiene unit in a country with a low prevalence of carbapenemase-producing Enterobacteriaceae. Int J Antimicrob Agents 2017;49(6):774—7.

[6] Tenover FC, Canton R, Kop J, Chan R, Ryan J, Weir F, et al. Detection of colonization by carbapenemase-producing Gram-negative Bacilli in patients by use of the Xpert MDRO assay. J Clin Microbiol 2013;51(11):3780—7.

[7] Otter JA, Dyakova E, Bisnauthsing KN, Querol-Rubiera A, Patel A, Ahanonu C, et al. Universal hospital admission screening for carbapenemase-producing organisms in a low-prevalence setting. J Antimicrob Chemother 2016;71(12):3556—61.

[8] Lepelletier D, Berthelot P, Lucet J-C, Fournier S, Jarlier V, Grandbastien B, et al. French recommendations for the prevention of "emerging extensively drug-resistant bacteria" (eXDR) cross-transmission. J Hosp Infect 2015;90(3):186—95.

[9] Hilliquin D, Le Guern R, Thepot Seegers V, Neulier C, Lomont A, Marie V, et al. Risk factors for acquisition of OXA-48-producing Klebsiella pneumonia among contact patients: a multicentre study. J Hosp Infect 2018;98(3):253—9.

[10] European Committee on Antimicrobial Susceptibility Testing. Breakpoint tables for interpretation of MICs and zone diameters. Version 9.0, valid from 2019-01-01. Available from: https://www.sfm-microbiologie.org/casfm-eucast [last accessed July 2019].

[11] Dortet L, Cuzon G, Plésiat P, Naas T. Prospective evaluation of an algorithm for the phenotypic screening of carbapenemase-producing Enterobacteriaceae. J Antimicrob Chemother 2016;71(1):135—40.

[12] Compain F, Gallah S, Eckert C, Arlet G, Ramahefasolo A, Decré D, et al. Assessment of carbapenem resistance in Enterobacteriaceae with the rapid and easy-to-use chromogenic β Carba Test. J Clin Microbiol 2016;54(12):3065—8.

[13] Dyakova E, Bisnauthsing KN, Querol-Rubiera A, Patel A, Ahanonu C, Tosas Auguet O, et al. Efficacy and acceptability of rectal and perineal sampling for identifying gastrointestinal colonization with extended spectrum β-lactamase Enterobacteriaceae. Clin Microbiol Infect 2017;23(8):577.e1—3.

[14] Tato M, Ruiz-Garbajosa P, Traczewski M, Dodgson A, McEwan A, Humphries R, et al. Multisite evaluation of Cepheid Xpert Carba-R assay for detection of carbapenemase-producing organisms in rectal swabs. J Clin Microbiol 2016;54(7):1814—9.

[15] Nijhuis R, Samuelsen O, Savelkoul P, van Zwet A. Evaluation of a new real-time PCR assay (Check-Direct CPE) for rapid detection of KPC, OXA-48, VIM, and NDM carbapenemases using spiked rectal swabs. Diagn Microbiol Infect Dis 2013;77(4):316—20.

[16] Traczewski MM, Carretto E, Canton R, Moore NM, Carba-R Study Team. Multicenter evaluation of the Xpert Carba-R assay for detection of carbapenemase genes in Gram-negative isolates. J Clin Microbiol 2018;56(8). https://doi.org/10.1128/JCM.00272-18.

[17] Smith M, Diederen B, Scharringa J, Leversteijn-van Hall M, Fluit AC, Cohen Stuart J. Rapid and accurate detection of carbapenemase genes in Enterobacteriaceae with the Cepheid Xpert Carba-R assay. J Med Microbiol 2016;65(9):951—3.

[18] Tanner H. Verification of the Cepheid Xpert Carba-R assay for the detection of carbapenemase genes in bacterial isolates cultured on alternative solid culture media. J Hosp Infect 2017;97(3):254—7.

[19] Findlay J, Hopkins KL, Meunier D, Woodford N. Evaluation of three commercial assays for rapid detection of genes encoding clinically relevant carbapenemases in cultured bacteria. J Antimicrob Chemother 2015;70(5):1338—42.

[20] Moore NM, Cantón R, Carretto E, Peterson LR, Sautter RL, Traczewski MM, et al. Rapid identification of five classes of carbapenem resistance genes directly from rectal swabs by use of the Xpert Carba-R assay. J Clin Microbiol 2017;55(7):2268—75.

[21] Kim D-K, Kim HS, Pinto N, Jeon J, D'Souza R, Kim MS, et al. Xpert CARBA-R Assay for the detection of carbapenemase-producing organisms in intensive care unit patients of a Korean tertiary care hospital. Ann Lab Med 2016;36(2):162—5.

[22] Rezende TFT, Doi AM, Quiles MG, Pignatari ACC, Manfrendi S, Grothe C, et al. Detection of colonization by carbapenem-resistant organisms by real-time polymerase chain reaction from rectal swabs in patients with chronic renal disease. J Hosp Infect 2017;96(2):123—8.

[23] Schwaber MJ, Carmeli Y. An ongoing national intervention to contain the spread of carbapenem-resistant enterobacteriaceae. Clin Infect Dis 2014;58(5):697—703.