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Association between excreta management and incidence of extended-spectrum β-lactamase-producing Enterobacteriaceae: role of healthcare workers' knowledge and practices

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SUMMARY

Background: The spread of extended-spectrum β-lactamase-producing Enterobacteriaceae (ESBL-PE) in healthcare environments has become a major public health threat in recent years.

Aim: To assess how healthcare workers (HCWs) manage excreta and the possible association with the incidence of ESBL-PE.

Methods: Eight hundred HCWs and 74 nurse-supervisors were questioned through two self-report questionnaires in order to assess their knowledge and practices, and to determine the equipment utilized for excreta management in 74 healthcare departments. Performance on equipment utilized, knowledge and practices were scored as good (score of 1), intermediate (score of 2) or poor (score of 3) on the basis of pre-established thresholds. Linear regression was performed to evaluate the association between HCWs' knowledge/practices and the incidence of ESBL-PE.

Findings: Six hundred and eighty-eight HCWs (86%) and all nurse-supervisors participated in the survey. The proportions of respondents scoring 1, 2 and 3 were: 14.8%, 71.6% and 17.6% for equipment; 30.1%, 40.6 % and 29.3% for knowledge; and 2.0%, 71.9% and 26.1% for practices, respectively. The single regression mathematic model highlighted that poor practices (score of 3) among HCWs was significantly associated with increased incidence of ESBL-PE ($P = 0.002$).

Conclusions: A positive correlation was found between HCWs' practices for managing excreta and the incidence of ESBL-PE, especially in surgical units. There is an urgent need for development of public health efforts to enhance knowledge and practices of HCWs to better control the spread of multi-drug-resistant bacteria, and these should be integrated within infection control programmes.

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Introduction

Controlling the spread of extended-spectrum β-lactamase-producing Enterobacteriaceae (ESBL-PE) is challenging because of their pathogenicity, and their dissemination within both hospital and community settings [1,2]. Patient colonization of the digestive tract by *Escherichia coli* or *Klebsiella pneumoniae* [3] can be sustained for several months after hospital discharge, which may facilitate spread in the general population [4]. The prevalence of ESBL-PE varies worldwide but their presence is now relatively common in healthcare settings [5] and in animals [6]. In France, since 2006, multidrug-resistant organism (MDRO) surveillance programmes have focused on ESBL-PE, highlighting an increase in the incidence of ESBL-PE in French healthcare settings despite the implementation of infection control strategies [7].

This concerning endemic situation must be controlled in order to limit the emergence of carbapenemase-producing Enterobacteriaceae through importation from patients hospitalized abroad, and due to cross-transmission in French hospitals and worldwide [8–11]. High concentrations of ESBL-PE are found in human faeces (approximately 10^8 ESBL per gram wet weight), particularly in patients exposed to antibiotics [12]. In hospital, these MDROs can spread from the gut through different ways: from patient to patient, via the hands of healthcare workers (HCWs) or by patient room contamination [13,14]. This risk may be related to the quality of the equipment and materials in the hospital setting, and to the level of knowledge and practices of HCWs regarding excreta management. Lepainteur *et al*. showed that only 19% of HCWs disinfected bedpans directly in bedpan washer-disinfectors, and the majority (71%) rinsed bedpans, often in patient bathrooms (62%), before disinfection in washer-disinfectors [15]. In the context of a local endemic ESBL-PE situation, this quantitative study was performed to assess hospital equipment, and HCWs' knowledge and practices related to excreta management, and possible associations with the incidence of ESBL-PE in a large university hospital.

Materials and methods

Study design, inclusion of healthcare departments and HCWs

This survey was conducted at Nantes University Hospital over a three-month period from January to March 2014. The institutional infection control referent network was used to recruit HCWs. This network includes approximately 280 nurses and assistant nurses working in 74 healthcare units (medicine = 33, surgical = 31, physical medicine and rehabilitation = 5, long-term care facilities = 5). All referents received a letter asking them to participate in the survey, and to complete one questionnaire related to their knowledge and practices about excreta collection and elimination. Several questionnaires were also available in each unit and could be answered by other HCWs. At the same time, the nurse-supervisor of each healthcare unit had to complete a single questionnaire related to the excreta equipment.

Data collection

Questions related to healthcare units' equipment, and the knowledge and practices of HCWs included 13, seven and 13 items, respectively. Three scores were calculated by summarizing all the item responses, and one point was given for each positive answer (yes = 1 point; no = 0 point), as follows:

- Equipment in healthcare units: score of 1 (well-equipped units: 11–13 points), score of 2 (intermediate-equipped units: seven to 10 points) and score of 3 (poorly-equipped units: zero to six points),
- HCWs' knowledge: score of 1 (HCWs with high level of knowledge: seven points), score of 2 (HCWs with intermediate level of knowledge: five or six points), score of 3 (HCWs with low level of knowledge: zero to four points),
- HCWs' practices: score of 1 (HCWs with high level of practice: 10–13 points), score of 2 (HCWs with intermediate level of practice: six to nine points), score of 3 (HCWs with low level of practice: zero to five points). One point was scored when the answer was 'always' or 'never' according to the question.

Data related to the incidence of ESBL-PE were collected from the laboratory database with an automatic daily alert. Incidence rate was stratified by type of healthcare unit included in the study. Incidence rate was the ratio between the number of patients with ESBL-PE hospitalized in 2015 (numerator) and the cumulated number of patient-days (denominator) x 1000. The incidence of ESBL-PE was coded 1 if it was higher than or equal to the global hospital median ESBL-PE incidence rate {0.47/1000 patient-days [interquartile range (IQR) 0.03–0.97]} and coded 0 if it was lower. The alcohol hand rub variable was coded 1 if it was higher than or equal to the global hospital median consumption [36.67/1000 patient-days (IQR 7.37–41.39)] and coded 0 if it was lower.

Data management and analysis

Data were collected using Sphinx Plus-V5 software (Chavanod, France). Data were described using the median and IQR for continuous variables, and proportions (%) for categorical variables. A simple linear regression was performed using STATA V15 software (StataCorp LP, Texas, USA) to examine the relation between performance scores (predictor continuous variable) and the incidence of ESBL-PE or alcohol hand rub consumption. Correlation coefficients (R) were tested, and all P-values were two sided. $P < 0.05$ was considered to indicate significance.

Results

Equipment of healthcare units

All nurse-supervisors participated in the study. Sixty-six of them (93%) reported that each healthcare unit was equipped with at least one washer-disinfector for every 21 beds. The washer-disinfector room was shared between disinfection of bedpans or urine bottles and other medical devices in half of the cases (37/74). Approximately 32% of patient rooms in healthcare units (24/74) were equipped with a hand shower for cleaning bedpans and urine bottles. The number of available bedpans and urine bottles was reported to be sufficient by 80% of nurse-supervisors.

Only 13% and 25% of HCWs used covers to transport bedpans and urine bottles from patient rooms to the washer-disinfector

room, respectively. Alcohol hand rub was not available in the washer-disinfector room in 24% of healthcare units. Individual protection for collecting excreta was used by assistant nurses in 93% of healthcare units. According to the 13 evaluation items (Table I), eight of 74 healthcare units (10.8%) had a performance score of 1 (good equipment), 53 (71.6%) had a score of 2 (intermediate equipment) and 13 (17.6%) had a score of 3 (poor equipment).

Participants (HCWs)

Eight hundred questionnaires were distributed to the 74 healthcare units. Six hundred and eighty-eight HCWs completed the questionnaire, with a participation rate of 86% (688/800). Participants were assistant nurses (332/688, 48%), nurses (311/688, 45%) or other staff members (46/688, 7%). HCWs were working in medical units (41%), surgical units (39%), physical medicine and rehabilitation units (15%) and long-term care facilities (5%).

Evaluation of HCWs' knowledge

Five hundred and ninety-five HCWs (86.4%) reported that they knew that excreta disposal in patient rooms was forbidden, and environment contamination from gut flora may contribute to the spread of MDROs. Most HCWs (80.9%) stated that they knew that using the hand shower available in patient rooms to clean urine bottles and bedpans was a major risk factor associated with environment contamination, particularly in patients colonized with MDROs. Only 12% of HCWs reported that they had received training on this topic within the last 10 years, and 63% of HCWs reported the need for further training in order to understand excreta management and environmental contamination. Table II shows the survey responses related to HCWs' knowledge. According to the seven evaluation items, 207 HCWs (30.1%) had a score of 1 (good knowledge), 279 HCWs (40.6 %) had a score of 2 (intermediate knowledge) and 202 HCWs (29.3%) had a score of 3 (poor knowledge). The distribution of poor knowledge (score of 3) increased from long-term care facilities (0%) to physical medicine and rehabilitation departments (30.0%), medical units (27.9%) and surgical units (41.3%).

Table I
Evaluation of equipment for excreta management in a large university hospital, France

Items 1–13	Healthcare departments $N = 74$ (100%)
1. Bedpan WD equipment	69 (93)
2. Sharing bedpan WD room with other activities and materials	37 (50)
3. Presence of bathroom in patient rooms	58 (78)
4. Presence of hand shower in patient rooms	24 (32)
5. Sufficient quantity of bedpans	59 (80)
6. Sufficient quantity of urine bottles	59 (80)
7. Excreta transport with covered bedpans	10 (13)
8. Urine transport with covered bottle	19 (25)
9. Dedicated bedpan for each patient	38 (52)
10. Dedicated urine bottle for each patient	38 (52)
11. Presence of alcohol hand rub for hand hygiene in patient rooms	59 (80)
12. Presence of water for hand hygiene in WD room	56 (76)
13. Package protective bag for elimination (including gloves and apron)	56 (76)

WD, washer-disinfector.

Table II
Knowledge evaluation of 688 healthcare workers related to excreta management in healthcare units

Items 1–7	$N = 688$ (100%) Yes, *N* (%)
1. Excreta rinsing in patient rooms is a risk factor for environmental contamination	595 (86.4)
2. Use of hand shower to clean urine bottles and basins is a major risk factor for environmental contamination	557 (80.9)
3. Transportation of excreta from patient rooms to bedpan washer-disinfector room across public areas needs specific hygiene precautions	461 (67.0)
4. Use of sealed pockets for urine and faecal collection reduces the risks	390 (56.7)
5. Environmental contamination increases the risk of MDRO outbreak	535 (77.8)
6. Use of single-use materials for excreta collection decreases the risks	458 (79.7)
7. Participation in at least one training programme related to excreta management within the last 10 years	83 (12.1)

MDRO, multi-drug-resistant organisms.

Evaluation of HCWs' practice s

Three hundred and fifty-seven HCWs (51.9%) reported that they always or often emptied excreta (urine and faeces) in patient bathrooms, and 35% (240/688) of HCWs reported that they used the hand shower in patient bathrooms to rinse equipment (urine bottle and bedpans). Table III summarizes the main practices related to excreta collection and elimination. According to the 13 evaluation items, 14 HCWs (2.0%) had a score of 1 (good practice), 495 HCWs (71.9%) had a score of 2 (intermediate practice) and 179 HCWs (26.1%) had a score of 3 (poor practice). The distribution of poor practice (score of 3) increased from long-term care facilities (0%) to physical medicine and rehabilitation units (18.5%), medical units (21.2%) and surgical units (41.8%) (Table IV).

Incidence of ESBL-PE and alcohol hand rub consumption

The incidence of ESBL-PE per 1000 patient-days was 0.97 [95% confidence interval (CI) 0.45–1.12] in surgical units, 0.54 (95% CI 0.41–0.64) in medical units, 0.31 (95% CI 0.21–0.44) in physical medicine and rehabilitation units, and 0.03 (95% CI 0.01–0.05) in long-term care facilities (Table V). Using single linear regression, poor practice for excreta management (score of 3) was significantly associated with a high incidence of ESBL-PE, with $R = -0.15$ and $P = 0.002$ (Table VI). Scores related to healthcare units'

Table III
Practice evaluation of 688 healthcare workers related to excreta management in healthcare units

Items 1–13	*N*=688 (100%) Yes, *N* (%)			
	Always	Often	Sometimes	Never
In patient bathrooms				
1. Elimination of urine and faeces	158 (23)	199 (29)	186 (27)	145 (21)
2. Use of hand shower to rinse equipment	96 (14)	144 (21)	110 (16)	338 (49)
3. Disinfection of equipment in the bathroom	28 (4)	83 (12)	124 (18)	453 (66)
4. Use of cover to transport excreta across HCUs	83 (12)	138 (20)	206 (30)	261 (38)
In the washer-disinfector room				
5. Equipment disinfection	158 (23)	206 (30)	158 (23)	166 (24)
6. Daily disinfection	144 (21)	213 (31)	151 (22)	180 (26)
7. Disinfection of materials only at patient discharge	337 (49)	165 (24)	76 (11)	110 (16)
Use of PPE for excreta management				
8. Gloves	616 (90)	66 (9)	6 (1)	0 (0)
9. Apron	34 (5)	48 (7)	179 (26)	427 (62)
10. Gown	14 (2)	14 (2)	220 (32)	440 (64)
11. Mask	28 (4)	21 (3)	179 (26)	460 (67)
12. No protection	14 (2)	21 (3)	75 (11)	578 (84)
13. Opening the doorknobs with gloved hand after excreta management	76 (11)	130 (19)	241 (35)	241 (35)

HCUs, healthcare units; PPE, personal protective equipment.

equipment and HCWs' knowledge were not significantly associated with the incidence of ESBL-PE. Alcohol hand rub consumption rate per 1000 L was calculated for the different units (Table V). No significant association was found between excreta management and alcohol hand rub consumption.

Discussion

Numerous previous studies have identified different risk factors associated with the acquisition of ESBL-PE in hospital settings [16]. However, environmental factors or HCWs' practices for excreta management are rarely assessed or are neglected for commensal bacteria hosted within the gut microbiota [15]. Although there are many national and international guidelines on the management of healthcare waste for preventing environmental health diseases, there are limited global data and information on equipment and excreta management for HCWs. A literature search found few data from surveys on excreta management for comparison with the results of this study.

Table IV
Evaluation of knowledge and practices of 688 healthcare workers related to excreta management, stratified by type of healthcare unit

Healthcare units ($N = 74$)	Knowledge score[a]			Practices score[a]		
	1	2	3	1	2	3
Medical ($N = 33$) (%)	27.9	44.2	27.9	3.8	75.0	21.2
Surgical ($N = 31$) (%)	27.3	31.4	41.3	0.0	58.2	41.8
Rehabilitation ($N = 5$) (%)	23.3	46.7	30.0	0.0	81.5	18.5
Long-term care ($N = 5$) (%)	20.0	80.0	0.0	0.0	100	0.0

[a] 1, high level; 2, intermediate level; 3, poor level.

The major interest of this study was to score the level of equipment in healthcare units, and the knowledge and practices of nurses and assistant nurses related to excreta management (collection/transport/elimination). Linear regression suggests that poor practice in excreta management could be associated with a high rate of ESBL-PE in healthcare units due to environment contamination. This association is debated in the literature, as the link between patient admission to a room previously occupied by a patient with MDROs seems to be an independent risk factor for acquisition of these bacteria by subsequent room occupants. However, this link is unclear for EBLE-PE in comparison with other Gram-negative bacteria [17–19]. The compliance of HCWs with standard precautions and the quality of room disinfection, including the bathroom, is probably a key factor for controlling the spread of MDROs [20,21].

These results can potentially be explained by the high proportion of poor performance in managing excreta: 29% of healthcare units were poorly equipped, 30% of HCWs had a low level of knowledge, and only 2% of HCWs had a high level of practice. The two main poor practices were elimination of the excreta, and rinsing equipment using a hand shower in patient bathrooms. The first issue is due to the lack (or breakdown) of washer-disinfectors, or a long distance to the washer-disinfector in healthcare units, associated with poor HCW knowledge. In this study, 57% of the healthcare units had at least one washer-disinfector per 21 beds. This rate was slightly lower than that (61%) observed in a large group of university hospitals in Paris [15]. The second poor practice is due to the historic presence of hand showers in French hospitals and their misuse, and the lack of knowledge about the high risk of aerosolization among HCWs. The aerosolization of excreta can contaminate bathroom surfaces and HCWs' hands and gowns.

Table V
Incidence of extended-spectrum β-lactamase-producing Enterobacteriaceae (ESBL-PE) and consumption of alcohol hand rub per 1000 patient-days

Healthcare units ($N = 74$)	Incidence of ESBL-PE/1000 patient-days (95% CI)	Alcohol hand rub consumption/ L/1000 patient-days, median (interquartile range)
Medical ($N = 33$)	0.54 (0.41–0.64)	41.39 (30.05–54.23)
Surgical ($N = 31$)	0.97 (0.45–1.12)	25.47 (19.23–32.47)
Rehabilitation ($N = 5$)	0.31 (0.21–0.44)	20.14 (10.20–25.63)
Long-term care ($N = 5$)	0.03 (0.01–0.05)	7.37 (3.22–7.95)

CI, confidence interval.

Table VI
Simple linear regression model to predict the possible association between performance of equipment, knowledge and practices related to excreta management from 688 healthcare workers and incidence of extended-spectrum β-lactamase-producing Enterobacteriaceae (ESBL-PE) and consumption of alcohol hand rub per 1000 patient-days in 74 healthcare units

Variable	Incidence of ESBL-PE				Alcohol hand rub consumption			
	Coefficient	*P*-value	95% CI		Coefficient	*P*-value	95% CI	
Equipment	0.07	0.48	-0.12	0.25	-4.69	0.16	-11.3	1.99
Knowledge	0.32	0.28	-0.26	0.91	-1.33	0.23	-3.56	0.88
Practices	-0.15	**0.002**	-0.24	-0.06	2.68	0.12	-0.75	6.12

CI, confidence interval.

ESBLE-PE can also persist in the environment when HCWs leave patient rooms and touch doorknobs with gloved hands after collection of excreta [22].

The incidence of ESBL-PE was 0.97 and 0.54 per 1000 patient-days in surgical and medical units, respectively. These rates were higher than the French national hospital incidence rate (0.60 per 1000 patient-days) [7]. In parallel, a higher proportion of HCWs with a low level of knowledge and poor practices (score of 3) was observed in surgical and medical units. The alcohol hand rub consumption rate was low in surgical units compared with medical units. All these factors may explain the significant association between poor practices by HCWs and the high incidence of ESBL-PE.

There is considerable evidence showing that the environment in healthcare settings serves as a reservoir for infectious micro-organisms. Therefore, strict adherence to basic cleaning and disinfection practices for healthcare settings is essential to prevent cross-transmission of MDROs [10]. In recent decades, requirements regarding the disinfection of the environment and medical equipment surfaces have been defined in various European standards and guidelines [23]. Moreover, as the ESBL-PE status of most ESBL-PE-positive patients is not identified [16], strict compliance with standard precautions is also essential: hand hygiene, personal protective equipment (glove, gown) when necessary, and good excreta management.

This study highlights a need for specific training on this topic for HCWs. Indeed, most HCWs reported that they had never been trained on excreta management prior to this survey, and 63% of HCWs requested additional training in order to further understand excreta management. These findings may suggest that the low level of knowledge could be attributed to poor training of HCWs. In the same way, poor practices may be attributed to the fact that HCWs are unaware of the risk factors for environment contamination during excreta disposal (collection, transport) and the use (disinfection) of equipment for the prevention of environment contamination.

This study has several limitations. Firstly, a quantitative evaluation was performed, and questionnaires were sent to the infection control referent nurses and assistant nurses in healthcare units. This population may represent selection bias, as it could select participants who had a high level of health education. Secondly, interpretation bias can occur with the quality and veracity of the HCWs' answers, according to their knowledge and practices. Effectively, HCWs may have overestimated their knowledge and practices when reading the questions. Furthermore, participants' responses may have varied based on their interpretation of a particular statement in the questionnaire (they were not allowed to ask the study managers to clarify the meaning of the questions). Furthermore, assistant nurses have less initial training in infections and microbiological risks than nurses.

In conclusion, this study found that the lack of proper practices for excreta management could be linked to a high incidence of ESBL-PE in healthcare settings, especially in surgical units. Public health efforts to enhance knowledge and practices of HCWs need to be developed and integrated in infection control programmes to control the spread of MDROs through the hospital environment. These findings suggest the following recommendations: (i) facilities should disseminate policies for appropriate excreta management; (ii) strict adherence to these rules is compulsory and must be evaluated; and (iii) education on excreta management should be provided to nurses and assistant nurses. Further research is needed to clarify the role of the contaminated hospital environment in the transmission of MDROs from faeces.

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