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Title

Association between excreta management and extended-spectrum β -lactamase producing *Enterobacteriaceae* incidence rate: Role of health-care worker's 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 ESBL-PE incidence.

Methods: 800 HCWs and 74 nurse-supervisors were questioned through 2 self-report questionnaires in order to assess their knowledge and practices, and to determine the equipment utilized for excreta management in 74 healthcare departments. The performance on equipment utilized, knowledge and practices were scored as good (score 1), intermediate (score 2) or bad (score 3) on the basis of pre-established thresholds. Linear regression was performed for evaluating the association between HCWs knowledge/practices and ESBL-PE incidence.

Findings: 688 HCWs (86%) and all nurse-supervisors participated to the survey. Proportions of scores 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. The single regression mathematic model highlighted that bad practices (score 3) from HCWs were significantly associated with increased ESBL-PE incidence ($p=0.002$).

Conclusions: HCWs' practices for managing excreta positively correlated with ESBL-PE incidence, especially in surgical units. Public health efforts to enhance knowledge and practices of HCWs urgently need to be developed and integrated, within infection control programs, to better control the spread of multidrug-resistant bacteria.

Key-words: ESBL-PE; excreta; hospital practices; infection control.

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]. Patients' colonization by *Escherichia coli* or *Klebsiella pneumoniae* within their digestive tract [3] can be sustainable over several months after hospital discharge, which may facilitate spread in the general population [4]. The ESBL-PE prevalence varies worldwide but their presence is now relatively common in healthcare settings [5] and in animals [6]. In France, since 2006, multidrug-resistant organisms surveillance programs have been focused on ESBL-PE, highlighting an increase in ESBL-PE incidence rate in French healthcare settings despite the implementation of infection control (IC) 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 feces (around 10^8 ESBL per gram wet weight), particularly in patients exposed to antibiotics [12]. These multidrug-resistant organisms can spread in hospital from the gut through different ways: from patient to patient, by hands of healthcare workers (HCWs) or patient room contamination [13,14]. This risk may be related to the quality of the equipment and materials in the hospital settings and to the level of knowledge and practices of HCWs regarding excreta management. Lepointeur *et al.* showed that only 19% of HCWs directly disinfected bedpans in bedpan washer-disinfectors, and the majority (71%) rinsed bedpans, often in patient restrooms (62%) before disinfection in washer-disinfector [15]. In the context of a local endemic ESBL-PE situation, we performed a quantitative study to assess hospital equipment, and

HCWs knowledge and practices related to excreta management; and its possible association with ESBL-PE incidence rate in a large university hospital.

MATERIAL AND METHODS

Study design, inclusion of healthcare Departments and HCWs

The survey was conducted at Nantes University Hospital during a 3-month period from January to March, 2014. We used the institutional infection control referent network to include HCWs. This network includes about 280 nurses and assistant-nurses working through 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 units had to complete a single questionnaire related to the excreta equipment.

Data collection

Questions related to healthcare units' equipment, knowledge, and practices of HCWs included 13, 7 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:

- Healthcare units' equipment: Score 1 (Well-equipped units: 11 to 13 points), score 2 (Intermediate: 7 to 10 points) and score 3 (Bad-equipped units: 0 to 6 points),
- HCWs' knowledge: Score 1 (HCW with high level of knowledge: 7 points), score 2 (HCW with intermediate level of knowledge: 5 to 6 points), score 3 (HCW with low level of knowledge: 0 to 4 points),
- HCWs' practices: Score 1 (HCWs with high level of practice: 10 to 13 points), score 2 (HCWs with intermediate level of practice: 6 to 9 points), score 3 (HCWs with low level of practice: 0

to 5 points). One point was scored when the answer was “always” or “never” according to the question.

Data related to ESBL-PE incidence were collected from the laboratory database with an automatic daily alert. Incidence rate was stratified by type of healthcare units 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 1,000. ESBL-PE incidence rate was coded 1 if it was higher than or equal to the global hospital median ESBL-PE incidence rate (0.47/ 1,000 patient-days [0.03-0.97]) and coded 0 if it was lower. The alcohol hand rub variable was coded as 1 if it was higher than or equal to the global hospital median consumption (36.67/ 1,000 patient-days [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 interquartile ranges 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 scores of performance (predictor continuous variable) and the ESBL-PE incidence rate or alcohol hand rub consumption. Correlation coefficients R were tested and all P values were two sided. P values <0.05 were considered significant.

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 were reported to be sufficient by 80% of nurse supervisors.

Only 13% and 25% of HCWs used covers to transport bedpans and urine bottles from the patient room 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 1), 8/74 healthcare units (10.8%) had a performance score of 1 (Good equipment), 53 (71.6 %) had a score 2 (Intermediate) and 13 (17.6%) had a score 3 (bad equipment).

Participants (HCWs)

Eight hundred questionnaires were distributed through 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%), in surgical units (39%), in physical medicine and rehabilitation units (15%) and in long term care facilities (5%).

HCWs knowledge evaluation

595 HCWs (86.4%) reported to know that excreta disposal in patients' rooms was forbidden and environment contamination from gut flora and may contribute to the spread of multidrug-resistant microorganisms. Most of HCWs (80.9%) reported to understand that using the hand shower available in patients' rooms to clean urine bottles and bedpans was a major risk factor associated with environment contamination particularly in patient colonized with multidrug-resistant microorganisms. Only 12% of HCWs reported to have been trained on the topic within the last 10 years; 63% of HCWs reported the need to be better trained, to understand excreta management and environmental contamination. All the other reporting related to HCWs' knowledge are summarized in table 2. According to the 7 evaluation items, 207 HCWs (30.1%) had a score 1 (good knowledge), 279 HCWs (40.6 %) had a score 2 (intermediate knowledge) and 202 HCWs (29.3%) had a score 3 (bad knowledge). Bad knowledge level (score 3) distribution increased from long term care facilities (0%), to physical medicine and rehabilitation department (30.0%), medical units (27.9%) and surgical units (41.3%).

HCWs practice evaluation

357 HCWs (51.9%) reported to always or often empty excreta (urine and feces) in patients' bathrooms; 35% (240/688) HCWs reported to the hand shower for equipment rinsing (urine bottle and bedpans) in the patient's bathroom. The evaluation of the main practices related to excreta collection and elimination are summarized in Table 3. According to the 13 evaluation items, 14 HCWs (2.0%) had a score 1 (good practices), 495 HCWs (71.9 %) had a score 2 (intermediate level) and 179 HCWs (26.1%) had a score 3 (bad practices). Bad practice level (score 3) distribution 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 4).

ESBL-PE incidence rates and alcohol hand rub consumption

ESBL-PE incidence rates per 1000 patient-days were 0.97 (0.45-1.12) in surgical units, 0.54 (0.41-0.64) in medical units, 0.31 (0.21-0.44) in physical medicine and rehabilitation units and 0.03 (0.01-0.05) in long-term care facilities (Table 5). Using single linear regression, bad practice for excreta management (score 3) was significantly associated with a high ESBL-PE incidence rate with a coefficient of -0.15 and a P value of 0.002 (Table 6). Scores related to healthcare units' equipment and HCWs knowledge did not show significant association with ESBL-PE incidence rate. The alcoholic hand rub consumption rate per 1,000 liter was calculated for the different units, with a higher rate for surgical units (Table 5), and showed no significant association with excreta management performance.

DISCUSSION

Numerous previous studies identified different risk factors associated with ESBL-PE acquisition in hospital settings [16]. But environmental factors or HCWs practices for excreta management are rarely assessed or 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. Little data were found from surveys on excreta management in the literature to compare our results.

The major interest of this study was to score the level of equipment in healthcare units, of HCWs knowledge and practices of nurses and assistant-nurses related to excreta management (collection/transport/elimination). Linear regression suggests that bad practice in excreta management could be associated with a high rate of ESBL-PE in healthcare units through environment contamination. This association is debated in the literature, as the link between patient's admission to a room previously occupied by a patient with multidrug-resistant microorganisms seems to be an independent risk factor for acquisition of these bacteria by subsequent room occupants. But 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 restroom is probably a key factor for controlling multidrug-resistant microorganisms spread [20,21].

Our results can potentially be explained by the high proportion of bad performance in managing excreta: 29% of healthcare units were bad-equipped, 30% of HCWs had low level of knowledge and only 2% of HCWs had a high level of practices. The two major bad practices were the elimination of

the excreta and equipment rinsing using a hand shower in the patient's restroom. The first bad practice is due to the lack (or breakdown) of washer disinfectors, or a long distance to the washer disinfector in healthcare units associated with additional bad HCW knowledge. In our study, 57% of the healthcare units had at least 1 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 bad practice is due to the old and historic presence of hand showers in French hospitals and their misuse with an unknown high risk of aerosolization by HCWs. This aerosolization of excreta can contaminate the restroom surfaces and HCW hands and gowns. ESBL-PE can also persist in the environment when HCWs leave patients' rooms and touch doorknobs with gloved hands after excreta collection [22].

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

There is considerable evidence showing that the environment in health care settings serves as a reservoir for infectious microorganisms. Therefore, strict adherence to basic cleaning and disinfection practices for healthcare settings is essential to prevent cross-transmission of multidrug-resistant microorganisms [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 most of ESBL-PE positive patients are unknown [16], strict

compliance with standard precaution is also essential: hand hygiene, personal protective equipment (glove, gown) when necessary and good excreta management.

Our study highlights a need for specific training on this topic for HCWs. Indeed, most of HCWs reported that they had never been trained on excreta management prior to this survey, and 63% of HCWs requested better training in order to further understand excreta management. These findings may suggest that 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.

Our study has several limitations. Firstly, we performed a quantitative evaluation and questionnaires were sent to the infection control referent nurses and assistant-nurses in healthcare units. This population can represent a selection bias as it could select participants who had 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 reading the questions through the study design. Furthermore, participants' responses may have also varied based on their interpretation of a particular statement in the questionnaire: they could not ask the study managers for clarifying the meaning of the questions. Furthermore, assistant-nurses have less initial training in infections and microbiological risks than nurses.

In conclusion, we found that the lack of proper practices on excreta management could be linked to a high ESBL-PE incidence rate 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 programs to control the spread of multidrug-resistant microorganisms 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, 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 multidrug-resistant microorganisms from feces.

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CONFLIT OF INTEREST STATEMENT

None declared

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Table 1. Evaluation of equipment for excreta management in a large university hospital, France

Items 1 to 13	Healthcare departments N = 74 (100%)
1. Bedpan washer-disinfector (WD) equipment	69 (93)
2. Sharing bedpan WD room with other activities and materials	37 (50)
3. Presence of restrooms in patient room	58 (78)
4. Presence of hand shower in patient room	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's room	59 (80)
12. Presence of water for hand hygiene in the WD room	56 (76)
13. Package protective bag for elimination (including gloves and apron)	56 (76)

Table 2. Knowledge evaluation of 688 HCWs related to excreta management in healthcare units

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

HCWs: Healthcare workers; WD: washer-disinfector; MDRO: multidrug resistant organisms

Table 3. Practice evaluation of 688 HCWs related to excreta management in healthcare units

Items 1 to 15		N = 688 (100%)			
		Yes, n (%)			
		Always	Often	Sometimes	Never
In the patient's bathroom					
1.	Elimination of urine and feces	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 restroom	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's discharge	337 (49)	165 (24)	76 (11)	110 (16)
Use of personal protective equipment 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	76 (11)	130 (19)	241 (35)	241 (35)

after excreta management

HCUs: Healthcare units

Table 4: Knowledge and practices evaluation of 688 HCWs related to excreta management stratified by type of healthcare units

Healthcare units (N=74)	Knowlegde			Practices		
	Score*			Score*		
	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

*Score 1: high level of performance; score 2: intermediate level; score 3 : bad level.

Table 5: Incidence rate of ESBL-PE and consumption of alcohol hand rub per 1000 patient-days

Healthcare Units (N=74)	ESBL-PE Incidence rate / 1000 patient-days (Confidence interval)	Alcohol hand rub consumption / litre/ 1000 patient-days (median, Interquartile ranges)
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)

Table 6: Simple linear regression model to predict the possible association between performance of equipment, knowledge and practice related to excreta management from 688 healthcare workers and ESBL-PE incidence rate and consumption of alcohol hand rub per 1000 patient-days in 74 healthcare units.

Variable	ESBL-PE incidence rate				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