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Can we explain environmental contamination by particular traits associated with patients?

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## ABSTRACT

### Background

Little is known about patient risk factors associated with environmental contamination. The aim of this study was to both evaluate the rate of environmental contamination and to investigate individual risk factors.

**Methods:** We conducted a prospective cohort study. Each day, 5 rooms occupied by patients were selected. Five critical surfaces were systematically swabbed twice a day before and after cleaning. For each included patients' clinical characteristics were collected. Logistic regression was performed to evaluate the association between environmental contamination and patients' characteristics.

**Results:** One hundred and seven consecutive patients were included and 1052 environmental samples were performed. Nineteen (18%) patients were known previously colonized/infected with a multidrug-resistant organism (MDRO). Respectively, 723 (69%) and 112 (11%) samples grew with  $\geq 1\text{cfu/cm}^2$  and  $>2.5\text{cfu/cm}^2$  bacteria, resulting in 62 (58%) contaminated rooms. Considering positive samples with at least one pathogenic bacterium, 16 (15%) rooms were contaminated.

By univariate and multivariate analysis, no variables analyzed were associated with the environmental contamination. Considering contaminated rooms with  $> 2.5\text{ cfu/cm}^2$ , 3 factors were protective for environmental contamination: known MDRO carriers/infected patients (OR=0.25, 95%CI 0.09-0.72,  $p=0.01$ ), patients with urinary catheter (OR=0.19, 95%CI 0.04-0.89,  $p=0.03$ ) and hospitalization in single room (OR=0.3, 95%CI 0.15-0.6,  $p<0.001$ ).

**Conclusions:** Our study conducted in a non-outbreak situation, show a low rate of environmental contamination with pathogenic bacteria. Only 11% of our environmental samples grew with more than  $2.5\text{cfu/cm}^2$ , and they were related to non-pathogenic bacteria. We were unable to identify risk factors associated with the environmental contamination.

**KEY WORDS :** environmental contamination, risk factors

**ABBREVIATIONS:**

GNB: Gram negative bacteria

HAI: Healthcare associated infections

MDRO: Multidrug resistant organisms

## INTRODUCTION

The prevalence of multidrug-resistant organisms (MDROs) continues to increase in healthcare settings all around the world. Contributory factors to this rise include antibiotic overuse and deficiencies in infection prevention and control. Healthcare workers and the hospital environment carry a high burden of MDROs [1–3], and can act as transmission vectors of MDROs to and between patients. Gram-negative bacilli such as *Escherichia coli*, *Klebsiella pneumoniae*, *Acinetobacter* spp. and *Pseudomonas aeruginosa*, can survive on surfaces for prolonged periods [4]. Several authors have suggested that environmental contamination is associated with a higher risk of colonization/infection [5]. Specifically Occupation of a room previously occupied by a colonized/infected patient is associated with a risk of acquisition of that specific pathogen [6]. Several authors have previously identified that near-patient sites are frequently contaminated. However, these studies have mainly been conducted during outbreaks [7], in specific hospital wards (usually intensive care units) [8,9] or have focused on specific microorganisms such as *Staphylococcus aureus* or *Enterobacterales* [10,11] or specific MDROs [12]. Various other factors have been implicated in environmental microbial contamination, including temperature and humidity [13]; the number of body sites colonized with vancomycin-resistant enterococci (VRE) [14]; and stool microbial load [15,16]. Related to this, patients with asymptomatic colonization may be less likely to contaminate their environment than patients with the higher infectious burden associated with symptomatic infections [17].

Considering the importance of cleaning to control the spread of microorganisms we considered that it was crucial to understand individual risk factors associated with environmental contamination. The purpose of our study was to evaluate the rate of environmental contamination in routine hospital practice and to identify any individual patient risk factors associated with greater environmental contamination.

## METHODS

We conducted a single centre study in Avicenne, A French 500 bed teaching hospital between November 2017 and January 2018. Each working day, 5 rooms occupied by patients were randomly selected. Five critical (i.e. frequently touched) surfaces were systematically swabbed: early in the morning before any cleaning process and a second time later in the day usually at around 16:00 (at least 8 hours after cleaning). The five selected surfaces were: bedrails, armchair, toilets seats, the overbed table and door handle.

During the study period routine standard hospital cleaning protocols were applied. Over-bed tables, bedrails. For the duration of the study, neither healthcare workers nor cleaning teams were aware of, the study and the selected rooms.

For each patient the following baseline characteristics were recorded: age, ward of admission, single/double room occupancy, time elapsed between hospitalization and date of sampling, recent surgery during hospitalization, known MDRO colonization and or infection, ongoing invasive devices (venous catheter, indwelling bladder catheter, mechanical ventilation), ongoing antibiotic therapy,

urinary and or faecal incontinence, Katz score [18], patient wearing diaper, and excreta management (toilets versus bedpan).

Environmental sampling was performed daily by the same member of the infection control team (MM). A 10x10cm<sup>2</sup> surface was systematically sampled using a pre-moistened nylon tipped flocked swab (Copan diagnostics, California, USA). Swabs were rotated to ensure full contact of all parts of the swab tip and the surface. Swabs were then vortexed for 1 min at maximum speed; 200 µL (from 500 µl) of the suspension was then spread onto brain heart infusion (BHI) agar and incubated at 37°C for 24 hours. Total colony counts were counted and the number of cfu per cm<sup>2</sup> was calculated.

Each different presumptive colony type was identified using matrix-assisted laser desorption-ionization mass spectrometry (Maldi-tof Microflex LT, Bruker Daltonics) and when pathogenic bacteria (e.g. *S. aureus* non-fermentative Gram-negative bacilli or *Enterobacterales*) were identified, antimicrobial susceptibility testing was performed according to Comité de l'antibiogramme de la Société Française de Microbiologie – European Committee on Antimicrobial Susceptibility Testing (CA-SFM – EUCAST) guidelines [10].

Ethical approval was not required as this was considered to be a service evaluation of our routine practice.

#### *Statistical analysis*

Two different statistical analyses were performed, defining contamination as growth of at least 1 cfu/cm<sup>2</sup> or >2.5 cfu/cm<sup>2</sup>.

Categorical variables were described with frequencies and percentages. Quantitative variables were described with the mean (Standard deviation (SD)) or median and [Q1 – Q3]. Parametric and non-parametric tests; using Chi<sup>2</sup> compared categorical variables or Fisher's exact tests and using Mann-Whitney test compared quantitative variables. In a first step, variables showing associations at a significance level of  $\alpha=0.20$  in a univariable analysis were selected for inclusion in the multivariable model.

We investigated the relation between contaminated and non-contaminated rooms and potential predictors by performing a multivariable logistic analysis. Statistical analysis was performed using the R 2.11.1 statistical package (R Development Core Team; R Foundation for Statistical Computing, Vienna, Austria [<http://www.R-project.org>]).

## RESULTS

Between November 1<sup>st</sup> 2017 and January 31<sup>st</sup> 2018 107 patients' environments were swabbed, yielding 1052 environmental samples (Figure 1). Seventy-three (68.2%) patients were nursed in a single room. The mean age was 60.2 ( $\pm$  20.1) years and the mean Katz score was 6 ( $\pm$  1.75). Nineteen (17.8%) patients were previously known to be colonized or infected with an MDRO. Respectively, 34 (31.8%), 54 (50.5%), 34 (31.8%) had a surgery, at least one invasive devices or an antibiotic course. 52 (48.6%) patients had a venous catheter, 12 (11.2%) a urinary catheter and none were mechanically ventilated. Seventeen (15.9%) patients were incontinent, mostly (12) of urine only. Nineteen (17.7%) patients were wearing diapers, and 23 (21.5%) used bedpans. Of the 1052 environmental samples, 555 (53%) were obtained in the morning (before cleaning), and 497 (47%) later in the day (after cleaning).

Seven hundred and twenty three (69%) environmental samples grew at least 1 cfu/cm<sup>2</sup>, representing 104 (97%) contaminated rooms. Only 64 (9%) of the culture-positive samples grew pathogenic bacteria, comprising *S. aureus* (23) and *Enterobacterales* (41). Environmental contamination according surface type is described in Table 1. 112 (11%) samples grew with >2.5 cfu/cm<sup>2</sup>, representing 54 (46.2%) contaminated rooms. 8 (12.9%) of these 54 rooms, 8 (12.9%) had positive samples at both swab times (morning and later during the day). 33 (30%) of the positive samples grew at least one pathogenic bacterium: *S. aureus* (12); *Enterobacterales* (21). The most frequent contaminated environment were bedrails (70.1%) and toilets seats (75.9%). Comparing early sampling to late sampling no differences in terms of positive samples was noted.

By univariate analysis environmental contamination with >2.5 cfu/cm<sup>2</sup> was associated with the absence of urinary catheter (20.7% vs 1.8%; p= 0.0019). However, only patients known to be carriers or infected with MDRO bacteria and hospitalization in single room were still significantly associated with environmental contamination by multivariate analysis. Taking into account environmental contamination with pathogens or none pathogens by at least 1 cfu/cm<sup>2</sup>, none factors were associated with a significantly higher risk.

## DISCUSSION

In our point prevalence study we were surprised to find a low rate of environmental contamination compared to previously-published studies. Indeed, fewer than 15% of environmental samples grew  $>2.5$  cfu/cm<sup>2</sup>, and the majority of these samples yielded only non-pathogenic bacteria. The most frequent contaminated sites with pathogenic bacteria, toilets and patient chairs, were as previously reported [19,20].

Several authors have suggested that hospital surfaces can be persistent reservoirs for health care associated infections [21]. Also, it is well described that patients hospitalized in rooms previously occupied by patients with MDROs have an increased risk of acquiring these pathogens. A recent prospective cohort study conducted in ICU [25] highlighted that positive environmental cultures were significantly associated with contamination of healthcare workers gloves and gowns, suggesting a major role of environmental contamination for transmission to health care workers gloves and gowns. However, most of these studies were conducted during outbreaks, and little is known about contamination in non-outbreak settings. Some recent studies that have focused on environmental contamination by extended-spectrum beta-lactamase producing *Enterobacteriales* (ESBL-E) suggested that as few as 5% of environmental samples were culture-positive [26]. As in our study, these studies have been performed outside epidemics, which may partly explain the low prevalence of contamination.

We tried to identify patient factors associated with environmental contamination. Identifying high-level disseminators would allow targeted environmental cleaning and protection of patients most at risk. Other authors have tried to correlate the environmental contamination to patient factors [16,27]. Regarding *Clostridioides difficile* environmental contamination it was found that patients with diarrhoea caused significantly more environmental contamination than asymptomatic carriers [27]. We were unable to identify any factor clearly correlated with the risk of environmental contamination. However, three factors seemed protective in multivariate analysis: urinary catheters, colonized/infected patients with MDRO and single room occupancy. Possibly this is because in the first two situations at least there is greater awareness of the need for good infection prevention practices. We cannot explain why single-room hospitalization reduced the risk of environmental contamination.

As suggested by others, colonized patients seem to contaminate their environment as well as the infected one [28].

Our study had several limitations. Firstly, it was conducted in a single teaching hospital in a low MDRO prevalence country. Also we believe that there was a high level of compliance with biocleaning recommendations that may not be applicable to other real-life hospital settings; it is also acknowledged that we did not audit compliance with cleaning practices during the study. Although our swabbing technique was carefully standardized, and equated with a widely-used standard, it may not be the optimal means of detecting microorganisms on surfaces. Finally, although we took steps to



ensure that the early morning samples were collected before cleaning, it is possible that some rooms may have been cleaned immediately before swabbing.

## **CONCLUSION**

Patient-related environmental contamination with pathogenic bacteria in our study was a rare event. As such, we could not identify patients most at risk of disseminating such bacteria. It is therefore important to maintain ensure that environmental cleaning is maintained to a univseally high standard.

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**CONFLICT OF INTEREST:** The authors report no conflicts of interest linked to this study.

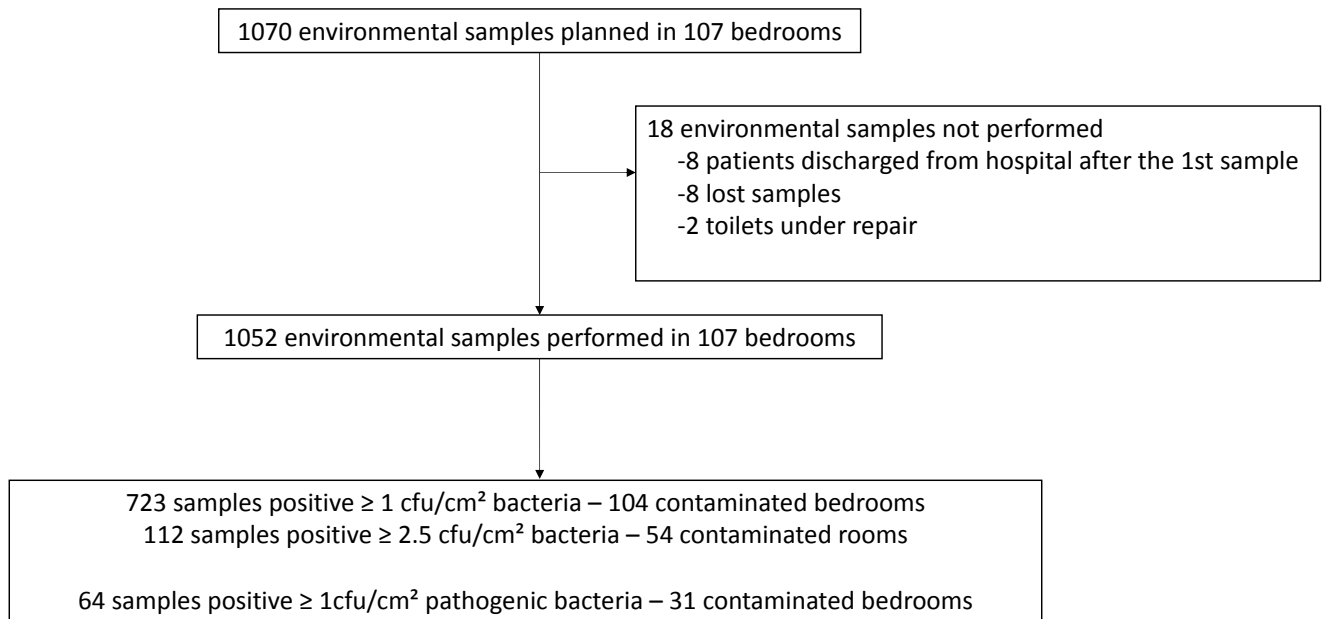
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**Figure 1.** Flow chart of the study

	<b>Any Bacteria <math>\geq</math> 1 cfu/cm<sup>2</sup></b>	<b><i>Staphylococcus aureus</i></b>	<b><i>Enterobacterales</i></b>
Over-bed Table	59.8%	1.4%	4.2%
Chair	69.1%	1.9%	2.8%
Bed rails	74.7%	3.7%	1%
Toilet seat	82.6%	2.6%	11.2%
Door and closet knobs	57.5%	1.4%	0%

**Table 1.** Environmental contamination according to selected surfaces

Variable	Contaminated rooms (n=54)	Non contaminated rooms (n=53)	Univariate analysis p-value	Multivariate analysis p-value	Odd ratio
Patients known carrier or infected with MDR, n (%)	6 (11.1)	13 (24,5)	0.08	<b>0.01</b>	0.25 [0.09-0.72]
Recent surgery, n (%)	14 (25.9)	20 (37,7)	0.21		
Comatose patients, n (%)	2 (3.7)	0 (0)	0.49		
Any invasive devices, n (%)	23 (42.6)	32 (60,4)	0.08	0.91	
Urinary catheter, n (%)	1 (1.85)	11 (20,7)	<b>0.002</b>	<b>0.03</b>	0.19 [0.04-0.89]
Venous catheter, n (%)	22 (40.7)	30 (56,6)	0.12	0.17	
Dependent patients, n (%)	14 (25.9)	17 (32)	0.52		
Antibiotic therapy, n (%)	12 (22.2)	19 (35,6)	0.13	0.12	
Single room, n (%)	30 (55.5)	43 (81,1)	0.13	<b>0.0005</b>	0.3 [0.15-0.6]
Time elapsed between admission and sampling (mean, day)	7.1	9.8	0.33		

**Table 2.** Comparative analysis of sites with positive and negative screening

Numerator corresponds to the number of chambers with at least one positive environmental sample. the denominator corresponds to the total number of chambers included in the study.