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Original article

A prospective multicentre surveillance study to investigate the risk associated with contaminated sinks in the intensive care unit

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ABSTRACT

Objectives: The aim was to assess the incidence of sink contamination by multidrug-resistant (MDR) *Pseudomonas aeruginosa* and Enterobacteriaceae, risk factors for sink contamination and splashing, and their association with clinical infections in the intensive care setting.
Methods: A prospective French multicentre study (1 January to 30 May 2020) including in each intensive care unit (ICU) a point-prevalence study of sink contamination, a questionnaire of risk factors for sink contamination (sink use, disinfection procedure) and splashing (visible plashes, distance and barrier between sink and bed), and a 3-month prospective infection survey.
Results: Seventy-three ICUs participated in the study. In total, 50.9% (606/1191) of the sinks were contaminated by MDR bacteria: 41.0% (110/268) of the sinks used only for handwashing, 55.3% (510/923) of those used for waste disposal, 23.0% (62/269) of sinks daily bleached, 59.1% (126/213) of those daily exposed to quaternary ammonium compounds (QACs) and 62.0% (285/460) of those untreated; 459 sinks (38.5%) showed visible splashes and 30.5% (363/1191) were close to the bed (<2 m) with no barrier around the sink. MDR-associated bloodstream infection incidence rates ≥0.70/1000 patient days were associated with ICUs meeting three or four of these conditions, i.e. a sink contamination rate ≥51%, prevalence of sinks with visible splashes ≥14%, prevalence of sinks close to the patient's bed ≥21% and no daily bleach disinfection (6/30 (20.0%) of the ICUs with none, one or two factors vs. 14/28 (50.0%) of the ICUs with three or four factors; p 0.016).
Discussion: Our data showed frequent and multifactorial infectious risks associated with contaminated sinks in ICUs. **Anne-Sophie Valentin, Clin Microbiol Infect 2021;27:1347.e9–1347.e14**

Introduction

Multidrug-resistant *Pseudomonas aeruginosa* (PA) and Enterobacteriaceae are involved in bloodstream infections (BSIs) and ventilator-associated pneumonia (VAP), leading to increased morbidity, mortality and hospital costs in intensive care units (ICUs) [1,2]. To reduce the risk of infections and to combat antimicrobial resistance, the WHO guidelines have established core components for infection prevention and control programmes [3].

P-shaped traps (i.e. P-traps), consisting of U-bends followed by 90-degree bends to the horizontal, are one of the sources of bacteria colonizing patients in ICUs [4]. Based on genetic association between bacteria found in P-traps and those found in patients, sink-associated outbreaks have been reported in ICU patients [5–14]. Using fluorescent marker testing and bacteria-containing biofilm, studies have helped to define the transmission of pathogens from a P-trap to patients [15–17]. The introduction of pathogens into the P-traps results from the use of

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sinks for handwashing and disposal of waste [18]. Some pathogens are able to survive and remain virulent in P-traps, where they develop rich and resilient biofilms [19,20]. When nutrients are added to the system, the biofilm extends upwards to reach the strainer of the sink. During faucet operation, aerosols and drain contents are dispersed to surrounding areas from the sink, and transfer of bacteria to the patient's bed may occur if there is no barrier between the sink and these surfaces [14,15,18,21]. Three lessons have been learned from investigations of sink-associated outbreaks: first, the ability to control most outbreaks with a series of measures including sink replacement, room design modifications to prevent splashing and repeated use of bleach to control outbreaks [12,14,18,22]; second, the impossibility of eradicating sink contamination; and, third, the prevention of outbreak recurrence by implementing routine disinfection of the sinks [23]. Prevention of infections being a major issue, a number of ICU teams may have implemented all, or part, of the above measures in their units. The extent of the implementation of such measures in ICUs, however, remains undocumented.

In the context of the nationwide infection survey, the study was conducted to investigate the current potential infectious risk associated with sinks in French ICUs. To achieve this, the sinks near the patients were tested for multidrug-resistant PA and *Enterobacteriaceae*, factors potentially contributing to the contamination of areas near to the sinks were searched, and the degree of implementation of the measures that could contribute to the prevention of sink-associated infections were investigated.

Materials and methods

Setting

The prospective multicentre study, managed with the local ICU and infection control teams between 1 January and 30 May 2020, included a point-prevalence study of sink contamination, a questionnaire of risk factors for sink contamination (sink use, disinfection procedure) and for splashing (visible plashes, distance and barrier between sink and bed), and a 3-month prospective infection surveillance study.

Study of sink contamination

A 1-day study was conducted in each patient room, at least 48 hr after any disinfection procedure. P-traps were sampled by personnel trained for this purpose. Sinks were cultured by rotating and swiping a cotton-tipped swab (Amies Transport Medium, Mast, Amiens, France) inserted to a depth of 5–7 cm through the drain so that visible debris was obtained on the cotton tip. Swabs were sent to the national centre, plated onto ORIENTATION, ESBL and mSuperCARBA plates (CHROMagar, Paris, France), and incubated at 37°C for 48 hr. PA and *Enterobacteriaceae* were identified using a *MALDI-TOF* Biotyper (*Bruker* Daltonics, Marne-la-Vallée). The presence of a bacterial culture on ORIENTATION plates was verified. Screening for third generation cephalosporin resistant Enterobacteriaceae (3GCRE), carbapenemase-producing Enterobacteriaceae (CPE) and imipenem-resistant *P. aeruginosa* (IRPA), i.e. target pathogens named MDR in the text, was performed on ESBL and mSuperCARBA plates. Susceptibility to ceftazidime, cefotaxime, imipenem, meropenem and ertapenem was assessed by the disc diffusion method [24]. Bacteria showing diminished susceptibility to carbapenems were tested for the presence of bla_{OXA48}, bla_{KPC}, bla_{VIM}, bla_{IMP} and bla_{NDM} genes using PCR and PCR products sequencing [25,26]. A sink was considered contaminated when one MDR was isolated from the swab.

Risk factors for sink contamination and splashing

The local infection control practitioners provided information on the use of each studied sink (use for waste disposal and/or for handwashing), on factors that may contribute to contamination of clinical areas near to the sinks (visible splashes during sink use, presence of a physical barrier and a distance <2 m between sink and bed) and on the sink disinfection procedure potentially implemented in the ICU (product used, disinfection frequency). The data were collected using a standardized questionnaire, centralized and analysed by the SPIADI team. Four potential risk factors for sink contamination and splashing were defined: a lack of daily (or three times a week) 2.6% bleach and, using the median values observed for the 73 ICUs, a local sink contamination rate exceeding the contamination median value, a prevalence of sinks with a distance <2 m and no barrier between sink and bed exceeding the prevalence median value, and a prevalence of sinks with visible splashes exceeding the prevalence median value.

Survey of infections

The ICUs were asked to survey infections over a 3-month period between 1 January and 15 June, using the HAI-Net ICU protocol (version 2.1). All details of patients, case definitions and descriptive results are available at https://ecdc.europa.eu/sites/portal/files/documents/HAI-Net-ICU-protocol-v2.2_0.pdf. In each ICU, the identified BSIs and VAP were documented. The incidence rates of BSIs were produced per 1000 patient-days (PDs), and those of VAP per 1000 ventilator-days (VDs).

Statistical analysis

All variables were examined by univariate analysis using the chi-square test or Fisher's exact test. All statistical tests were two-tailed. A p value < 0.05 was considered statistically significant.

The study was run in accordance with French guidelines and did not require ethical approval.

Results

Seventy-three ICUs participated the study. The study covered 996 beds (15.8% of French ICU beds) (Table S1, Fig. S1).

Sink contamination

Of the studied swabs, 50.9% (606/1191) were contaminated: 43.9% yielded at least one 3GCRE (523/1191), 2.5% at least one CPE (30/1191), and 7.6% an IRPA (91/1191) including 1.1% carbapenemase-producers (13/1191) (Table S2). The sink contamination rate in different ICUs ranged from 0 to 100.0% (median value 51.0%); 64.4% of the ICUs (47/73) yielded at least one sink contaminated with a CPE or an IRPA. One to four MDR were obtained from the 606 contaminated swabs: 833 3GCRE, 37 CPE and 91 IRPA were characterized (Table 1). Among the 37 CPE, the carbapenemase genes were diverse (17 bla_{NDM-1}, 16 bla_{OXA-48} and 4 bla_{VIM}). Among the 13 carbapenemase producers, PA with bla_{VIM} was in nine isolates and with bla_{IPM} in four.

Risk factors for sink contamination

Of the studied sinks, 22.5% (268/1191) were used only for handwashing and 77.5% (923/1191) for multiple tasks, including waste disposal (Table S2). The contamination rate was 41.0% (110/268) for the sinks used only for handwashing and 55.3% (510/923) for those used for waste disposal ($p < 0.001$). The 3GCRE were

Table 1
Distribution of the MDR Enterobacteriaceae and imipenem-resistant *P. aeruginosa* recovered from the 1191 sink samples

Distribution of the MDR enterobacteriaceae and PA isolated from sink samples						
	Ceftazidime and/or cefotaxime R	Carbapenemase producers				
		N	bla_{OXA48}	bla_{NDM-1}	bla_{VIM}	Bla_{IMP}
Enterobacteriaceae	833	37	16	17	4	
Klebsiella	254	17	6	9	2	
K. pneumoniae	161	13	5	8		
K. oxytoca	82	4	1	1	2	
other	11					
Enterobacter	315	6	2	4		
E. cloacae	197	3	1	2		
E. asburiae	101	3	1	2		
other	17					
Citrobacter	213	11	6	3	2	
C. freundii	183	10	6	2	2	
Other	30	1		1		
Serratia marcescens	26	2	2			
Escherichia coli	17	1		1		
other Enterobacteriaceae	8					
Imipenem resistant Pseudomonas aeruginosa (n=91)	37	13			9	4

similar regardless of sink use, with predominant *Enterobacter cloacae* (23.6%; 197/833), *Citrobacter freundii* (22.0%; 183/833) and *Klebsiella pneumoniae* (19.3%; 161/833). A lack of sink disinfection was reported for 38.4% of the ICUs (28/73). When implemented, disinfection was mostly performed daily (68.9%; 31/45), using bleach (57.8%; 26/45) or quaternary ammonium compounds (QACs) (42.2%; 19/45). Independently of the sink use, the sink contamination rates varied according to the treatment routine (Fig. 1): 23.0% (62/269) for sinks disinfected daily with 2.6% bleach, 59.1% (126/213) for those disinfected daily with QACs and 62.0% (285/460) for sinks with no disinfection ($p < 0.001$).

Risk factors for splashing

Visible splashing was observed in 38.5% of sinks (459/1191; median value 14.0%), and a distance of <2 m and no barrier

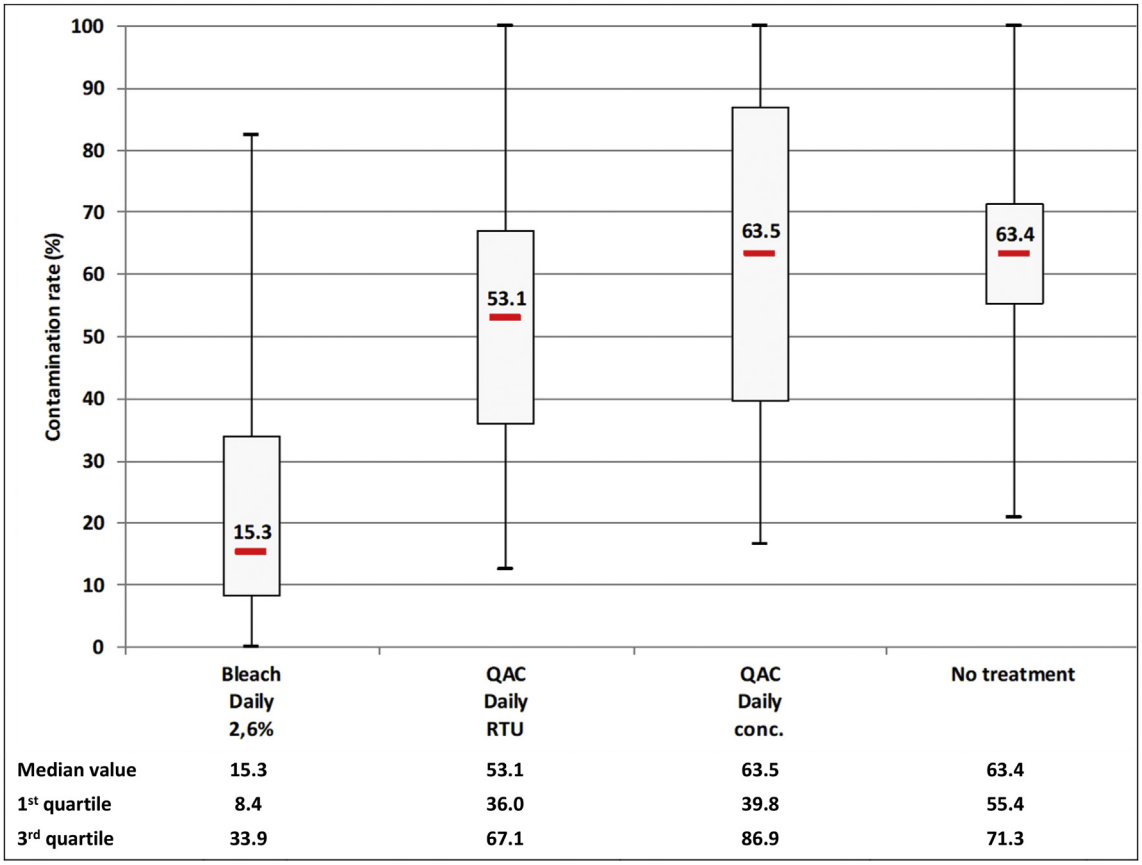

Fig. 1. Box plots representative of the sink contamination rates observed in the 73 ICUs, according to the daily sink treatment (2.6% bleach solution, ready-to-use (RTU) or (concentrated quaternary ammonium compound) QAC solution) and for sinks with no routine disinfection.

between the sink and the bed was noted in 30.5% of sinks surveyed (363/1191; median value 21.0%) (Table S2).

Upon looking at the four risk factors stated above, no risk factor was observed in 20 ICUs (27.4%), 14 (19.2%) had two, 28 (38.4%) had three and in 11 (15.1%) all four risk factors were observed (Table 2).

Survey of infections

In connection with the COVID-19 pandemic, 25 ICUs cancelled their survey. The BSI survey, conducted in 58 of the 73 ICUs (79.4%), covered 61 419 PDs (Table S1, Fig. S2). The MDR-BSI incidence rate varied between 0 and 6.20/1000 PDs (mean value 0.70) and was ≥0.70 for 20 ICUs (34.5%). The MDR-BSIs mostly involved *K. pneumoniae* (25.0%; 11/44), *E. cloacae* (25.0%; 11/44) and *Escherichia coli* (20.4%; 9/44). The VAP survey, conducted in 45 ICUs, covered 19 326 VDs. The MDR-VAP incidence rate varied between 0 and 11.50/1000 VDs (mean value 3.47) and was ≥3.47 for 16 ICUs (35.5%). The MDR-VAP mostly involved *E. cloacae* (20.9%; 14/67), IRPA (19.4%; 13/67) and *K. pneumoniae* (17.9%; 12/67). There was an association (a) between the prevalence of sinks with visible splashing ≥14.0% and a MDR-BSI incidence rate ≥0.70/1000 PDs (p 0.041), and (b) between a MDR-BSI incidence rate ≥0.70/1000 PDs and three or four risk factors (6/30 (20.0%) of the ICUs with none, one or two factors vs. 14/28 (50.0%) of the ICUs with three or four factors; p 0.016) (Table 2). There was no association between the ICUs yielding a MDR-VAP incidence rate ≥3.47/1000 PDs and those having three or four risk factors.

Discussion

Our nationwide study presented distinguishing features: first, unlike most studies related to the infectious risk associated with sinks, it was not conducted during an MDR-associated outbreak in included ICUs; second, we considered, beyond the study of sink contamination, additional factors that can be expected to contribute to the infectious risk associated with sinks: two factors possibly influencing the contamination of P-traps (sink use for waste disposal, routine sink disinfection), and three factors that may contribute to the contamination of the areas surrounding the sinks (visible splashes during sink use, sinks situated <2 m of the bed, lack of splash barriers). Third, a 3-month nosocomial infection survey was conducted in the participating ICUs, in order to search for association between infection incidence rates and the studied risk factors.

Concordant with a study conducted a decade ago at regional level [11], the analysis of a large number of samples revealed that sink contamination by MDR is a common event. Of serious concern, our results, obtained in a single-day point-prevalence study, and should thus be considered a minimum, revealed two-thirds of ICUs yielding at least one sink contaminated with a CPE or an IRPA.

The use of sinks for multiple tasks including disposal of the fluids from patient bathing is common in the ICU setting [10,13]. This practice, noted for three-quarters of the sinks in our study, is probably the source of contamination of the sinks by bacteria from the patient's flora [4,6,11,12]. PA, *Klebsiella* and *Enterobacter* species were mostly recovered from sinks, three species able to colonize humans and well recognized for their ability to establish themselves in P-traps and to cause sink-associated infections [12,14,15,18]. The frequent contamination we observed for sinks used *a priori* only for handwashing suggest no clear delineation, in practice, between handwashing sinks and sinks for other purposes. Discarded intravenous fluids and food supplements have been shown to promote the extension of initial and minimal P-trap contamination upwards, reaching the strainer [15,16]. This point was unfortunately not investigated.

Routine sink disinfection was implemented in half of the ICUs, and sink contamination was common whether or not a disinfection procedure was implemented. Concordant with previous studies [6,8], our data remind us that sink disinfection does not completely prevent the establishment of MDR in P-traps, and that MDR may escape exposure to disinfectant products. However, bleach treatment of the sinks has been shown to contain sink contamination at low levels, and, by this mechanism, to help prevent outbreak recurrences [6,9]. Concordant with these data, daily bleach was associated in our study with reduced detection of MDR from the swabs compared with untreated sinks. By contrast, the sinks treated with QACs showed the same contamination rates as untreated sinks.

Imperfect sink and patient room design may play a role in nosocomial transmission of pathogens in the ICU setting [14,19].

Table 2
Potential risk factors of sink-associated outbreaks and observed incidence rates (IR) of MDR-BSIs and MDR-VAP

Potential risk factors[a] of sink-associated outbreak		ICUs (*N*)	MDR-BSIs IR (/1000 PDs)[b]			MDR-VAP IR (/1000 VDs)[c]		
			<0.70	≥0.70	NK	<3.47	≥3.47	NK
Sink contamination rate ≥51.0%	Yes	42	18	14	10	19	9	14
	No	31	20	6	5	10	7	14
Prevalence of sinks with a distance	Yes	37	17	10	10	15	8	14
<2 m from the patient's bed and no physical barrier around the sink ≥21.0%	No	36	21	10	5	14	8	14
Prevalence of sinks with visible splashing ≥14.0%	Yes	37	14	13	10	13	9	15
	No	36	24	7	5	16	7	13
Daily (or three times a week)	Yes	16	9	4	3	8	1	7
disinfection of sinks with bleach 2.6%	No	57	29	16	12	21	15	21
Number of potential risk factors	0 or 1	20	13	4	3	8	2	10
	2	14	11	2	1	5	6	3
	3	28	12	10	6	13	5	10
	4	11	2	4	5	3	3	5
All ICUs		73	38	20	15	29	16	28

BSI, bloodstream infection; ICU, intensive care unit; MDR, multidrug resistant; PD, patient-days; VAP, ventilator-associated pneumonia.

[a] Potential risk factors included: a sink contamination rate exceeding the median value observed for the 73 ICUs (51.0%); a prevalence of sinks with a distance <2 m from the patient's bed and no physical barrier around the sink exceeding the median value observed for the 73 ICUs (21.0%); a prevalence of sinks with visible splashing exceeding the median value observed for the 73 ICUs (14.0%); no daily disinfection of the sinks (or three times a week) using bleach 2.6%.

[b] The observed MDR-BSIs incidence rates were distributed in two subpopulations separated by the median value observed for the 58 ICUs where the BSIs were surveyed (0.70/1000 PDs).

[c] The observed MDR-VAP incidence rates were distributed in two subpopulations separated by the median value observed for the 45 ICUs where the VAP were surveyed (3.47/1000 VDs).

Our study showed that the measures supposed to prevent splash-back contamination of the areas surrounding the sinks were not generally implemented, with excessive proximity between sinks and beds or visible splashes for a third of the studied sinks.

Based on the results of the BSIs and VAP survey, no link was found between high incidence rates and high sink contamination rates. An association was found, however, between ICUs with a high MDR-BSIs incidence rate and those with at least three risk factors out of failure to implement daily (or 3 times a week) bleach, a high sink contamination rate, a high prevalence of sinks with a distance <2 m and no barrier between sink and bed, and a high prevalence of sinks with visible splashing.

Designed to further the knowledge of infectious risk associated with sinks, this study had several limitations. The implementation of a single swab to document sink contamination may not have been capable of providing a representative picture of the MDR colonisation of the P-trap. Second, we did not investigate all the factors potentially involved in sink-to-patient transmission, i.e. the level of adherence to hand hygiene and standard precautions by healthcare workers, and the local infection control strategy. Third, failing any recognized threshold, we considered the median value of each studied factor as the point of increased risk. The establishment of such thresholds remained empirical, which is a matter of debate. Fourth, due to the shortness of the survey period, the number of detected BSIs and VAP was low, which weakened the analysis of association between infection incidence rates and the studied risk factors.

In conclusion, our data on MDR-contaminated sinks near patients may help to raise the ICU staff's awareness of the infectious risk associated with sinks [23], and provide a baseline for developing studies (a) to explore the mechanisms of sink contamination, and investigate the extent to which heavy contamination can be avoidable; (b) to clarify the potential of bleach for preventing heavy sink colonization, and, if so, to determine the amount of bleach to use and the exposure time to apply; (c) to evaluate the contribution of each studied risk factor to the occurrence of infections over longer monitoring periods, and to establish robust critical thresholds determining the conditions that may significantly contribute to the risk. Guidelines defining the measures to be taken to create a safe environment for the delivery of care should be made available to ICU teams (including sink and patient room design), so that they can improve their routine sink practices.

Transparency declaration

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Author contributions

N.V.D.M. designed the research. F.G. developed the tool used for survey (data collection and analysis). S.D.S. performed the microbiological analysis. The members of the SPIADI ICU group conducted the study in the ICUs (BSI and VAP 3-month survey, sink swabbing and data collection). R.G., C.D. and A.S.V. performed the statistical analysis. N.V.D.M., A.S.V. and M.D. conducted the research. N.V.D.M. wrote the paper. All authors contributed to the data interpretation, revised each draft for important intellectual content, and read and approved the final manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cmi.2021.02.018.

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