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Original article

Impact of sink removal from intensive care unit rooms on the consumption of antibiotics and on results of Zero Resistance Project

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A B S T R A C T

Introduction: Due to the favourable impact of removing the sinks on isolations in bronchoaspirate samples of patients with mechanical ventilation, we now evaluate the impact on the consumption of antibiotics as well as on the results of the Zero Resistance Project (ZRP).
Patients and methods: All the patients admitted to the unit in a quasi-experimental before–after study with a pre-intervention period between 2014 and 2016 and a post-intervention period from 2016 to 2017, to evaluate antibiotic consumption in defined daily doses, and until 2018, to evaluate the ZRP indicators. The intervention was the removal of the sinks from the rooms of the ICU. We evaluated antibiotic consumption densities and their ratios, grouped as Enterobacteriaceae and non-fermenting gram-negative bacilli (NFGNB) according to their antibiograms; the absolute number of 'antibiotic days', 'hospitalised days', 'isolation days', and 'multi-resistant bacteria (MRB) days'; as well as their incidence densities per 1000 hospitalised days and the ratio between the two years prior to and the two years after the intervention.
Results: Post-intervention antibiotic use was 1.61-fold (1.60–1.62) and 2.24-fold (2.10–2.37) lower for antibiotics used against Enterobacteriaceae and NFGNB, respectively. There were also reductions in the number of days of antibiotic use by 1.29-fold (1.22–1.36), number of MRB days by 1.84-fold (1.63–2.08), and number of patient isolation days by 1.51-fold (1.38–1.66).
Discussion: The results suggest that the intervention had a favourable impact on the consumption of antibiotics, as well as on the number of days on antibiotics, MRB, and isolation.

Impacto de la retirada de los lavabos en una unidad de cuidados intensivos sobre el consumo de antibióticos y en los resultados del Proyecto Resistencia Zero

Palabras clave:
Bacterias multirresistentes
Consumo de antibióticos
Lavamanos
Bacilos gramnegativos no fermentadores
Enterobacterias
Aislamiento del paciente

R E S U M E N

Introducción: Debido al impacto favorable de la retirada de los lavabos sobre los aislamientos por bacilos gramnegativos no fermentadores (BGNNF) en muestras de broncoaspirado de pacientes con ventilación mecánica, ahora evaluamos el impacto en el consumo de antibióticos, así como en los resultados del Proyecto Resistencia Zero.
Participantes y métodos: Todos los pacientes ingresados en la unidad en un estudio cuasi-experimental antes-después, con período preintervención entre 2014-2016 y postintervención, desde 2016 hasta 2017 para la evaluación del consumo de antibióticos a través de dosis diarias definidas y hasta 2018 para

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evaluación de indicadores del Proyecto Resistencia Zero. La intervención consistió en la retirada de los lavamanos de los boxes de las UCI. Se evaluaron las densidades de consumo y sus razones, agrupando según los antibiogramas informados para enterobacterias y BGNNF; del Proyecto Resistencia Zero: los «días de antibiótico», «días de estancia», «días de aislamiento» y «días de bacterias multirresistentes (BMR)» de forma absoluta y mediante sus densidades de incidencia por 1.000 días de estancia, y su razón entre los 2 años previos a la intervención y los 2 posteriores.

Resultados: Los consumos postintervención resultaron 1,61 (1,60-1,62) y 2,24 (2,10-2,37) veces inferiores, para antibióticos frente a enterobacterias y BGNNF, respectivamente. Se redujeron 1,29 (1,22-1,36) veces los días de antibiótico, 1,84 (1,63-2,08) los días de BMR y 1,51 (1,38-1,66) los días de aislamiento.

Discusión: Los resultados sugieren un impacto favorable de la intervención tanto sobre el consumo de antibióticos, como en los días de antibiótico, de BMR y de aislamiento.

Introduction

As stated in the multidisciplinary consensus document on bacterial resistance sponsored by various scientific societies (including SEIMC, SEFH, and SEMPSPH),[1] the levels of human antibiotic consumption in Spain without a justified epidemiological reason is the highest in the world. Moreover, the number of infections with antimicrobial resistant bacteria (including healthcare-related infections) in Spain are among the highest in Europe. In addition to the unjustified or inappropriate use of antimicrobials, some of the reasons for this are the poor application of hygienic measures in health centres, insufficient training on the prevention, diagnosis, and treatment of infectious diseases, a lack of teamwork, and a deficit in human and material resources to adequately deal with this problem.

Water infrastructure is an important reservoir for microorganisms which can generate colonisations and infections in hospitals by gram-negative bacilli (including carbapenem-resistant strains), atypical mycobacteria, and *Legionella* spp., among others.[2–4] However, beyond the cleanliness criteria for water quality[5] and for the prevention and control of legionellosis,[6] there are no official recommendations in Spain to help mitigate this problem except a recently decalogue on the safe use of sinks in augmented care units made by SEMPSPH.[7] Some international exceptions are the water safety guidelines in place in Ireland[4] and the United Kingdom,[8] which are good examples of how to tackle as a team specific hygiene measures as a complement to infection control guidelines.

During the period 2014–2016 an increase in isolations for non-fermenting gram-negative bacilli (NFGNB) in bronchial aspirate (BAS) samples from patients receiving invasive mechanical ventilation (IMV) in our Intensive Care Units (ICUs) led us to intensify their surveillance as part of our collaboration with the ICU National Zero Resistance Project,[9] a national initiative with 280 participant units – 40 from the Community of Madrid – that aims the adequate use of antibiotics, the early detection and prevention of multi-resistant bacteria (MRB) dissemination and the eradication of their reservoirs. We created a specific working group to review structural and infection control measures in our ICU that concluded that sinks should be removed from the rooms because of their under use for hand hygiene and other inappropriate uses.[10] Despite the quasi-experimental nature of this work, we found that this measure contributed to a decrease the incidence density (ID) per 1000 days of IMV of these isolates from 11.28 to 1.91 the following year, representing a 5.90-fold reduction (95% CI [1.49, 51.05], $p = 0.003$).[11] Although most of the isolates generated were due to colonisations, we hypothetisized that the sink removal may have impacted on the consumption of antimicrobials in the same year and the Zero Resistance Project results of our ICU. We present this additional evaluation.

Methods

Design, period, intervention and setting

This was a quasi-experimental before–after study with the following study phases: a pre-intervention period from April 2014 to April 2016, being this the month in which the sinks were removed; a post-intervention period from April 2016 to April 2017, the most similar to the above in all other conditions except the removal of the sinks and the same used to assess the impact over NFGNB in BAS, during which the antibiotic consumption was evaluated through defined daily doses (DDDs); and an evaluation period until April 2018 in which we evaluated the indicators used in the National Zero Resistance Project [9]adding an extra year to get more consistency in the Regional and National trends. This work was carried out in a multipurpose ICU at a second-tier hospital in the Region of Madrid with eight individual rooms, each with a sink. The sinks were previously located more than 1 m from the foot of the patient's bed and were under-utilized for hand hygiene although some improper uses occurred related to the patient's hygiene, devices cleaning and fluids disposal.[10]

Outcomes

Antimicrobial consumption was evaluated through the consumption density (CD), as the quotient of the DDD per 100 stays (S) per individual year, and in also for the pre-intervention period. The Pharmacy Service provided the consumption data in grams of each antibiotic used in the ICU and the DDDs were calculated according to the methodology set out by the World Health Organization.[12] The patient hospitalisation times were obtained from the Hospital Information System and the other indicators were derived from the ICU database via the ENVIN-HELICS application.[13] The Zero Resistance Project indicators included in the study were 'antibiotic days', 'hospitalised days', 'isolation days', and 'multi-resistant bacteria (MRB) days'.

Statistical analysis

The CD (DDD/100S) were studied for each antibiotic and totals were grouped and calculated in accordance to the antibiogram reports provided by the Microbiology Service in isolation cases for Enterobacteriaceae and NFGNB. The magnitude of the effect was studied using the interannual variation percentage (%) and the consumption density ratio (CDR) between pre-intervention years and the post-intervention year for each year, and as a total. We studied the absolute number of 'antibiotic days', 'hospitalised days', 'isolation days', and 'MRB days', as well as their incidence densities per 1000 hospitalised days and estimated incident density ratio (IDR) between the two years prior to and the two years after the intervention. The association was assessed by bilateral contrast using the exact method (based on a binomial distribution) with the EPIDAT 4.2 application parameter-inference module.[14] All the estimates were calculated with a 95% confidence level for their intervals.

Multi-resistant bacteria information

The MRB included in the Zero Resistance Project were: methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus* spp., extended-spectrum β-lactamase (ESBL) and carbapenem-resistant *Enterobacteriaceae*, multidrug-resistant *Pseudomonas aeruginosa* and carbapenem-resistant *Acinetobacter baumannii*.

Results

Table 1 shows the annual distribution of patients, hospitalised stays, stays with IMV, and the consumption of antibiotics according to antibiograms for Enterobacteriaceae and NFGNB, with their interannual variations. In the pre-intervention years (2014–2016) the consumption of antibiotics was reduced both for those with activity against Enterobacteriaceae (−16.27%) and against NFGNB (−4.55%). These reductions intensified during the post-intervention year (2016–2017), although the drop in consumption was more intense for those with action against NFGNB (−54.25%) compared to those against enterobacteria (−32.19%). The total pre-intervention consumption was 113.06 DDD/100S for antibiotics against Enterobacteriaceae and 136.35 DDD/100S for those against NFGNB, with post-intervention reductions of 37.9% and 55.3%, respectively.

Table 2 describes the DDD, hospital stays, and CD for each year and period, according to each antibiotic grouping. Comparisons using pre-intervention CDRs reflect the same trends as year-to-year variations, although the fact there was no association for the NFGNB group during the pre-intervention years suggests that consumption was similar. Taking the post-intervention year (2016–2017) as a reference, we observed that the CD of each year and the overall pre-intervention CD was higher in both groups of antibiotics. It was also observed that all the comparisons were significant and that their magnitude was higher in those for NFGNB compared to Enterobacteriaceae. During the period prior to the removal of the sinks from the ICU rooms, the consumption of antibiotics against Enterobacteriaceae and NFGNB were 1.61 and 2.24 times higher, respectively.

Table 3 shows the data from April 2014 to April 2018 based on the Zero Resistance Project indicators. An increase in the number of admissions, in patients with MRB, and in the incidence density of MRB was observed in the post-intervention period. However, the number of days of antibiotic for patients with an MRB and in isolation, decreased both in absolute terms and in their incidence densities. In the period prior to the removal of the sinks, the number of days of antibiotics, the number of days of isolation, and the number of days with MRB were 29%, 51%, and 84% higher, respectively, than those for the period during which the sinks had been removed.

Fig. 1 shows the evolution of our Zero Resistance indicators (ID per 1000 hospitalised days) in the context of those in the Community of Madrid and in Spain as a whole for the same periods studied (year-to-year since April). The regional and national trends show some parallels and a similar degree of downward fluctuation, with national values being lower. However, in our unit, although the number of hospitalised days increased (ID of patients with MRB), there was an improvement post-intervention in the number of antibiotic days, isolation days, and MRB days, of which the last two (number of isolation days and MRB days) decreased below the national average, and the former (number of antibiotic days) decreased below the regional average.

Discussion

Compared with the period prior to the removal of the sinks (2014–2016), a 1.61-fold and 2.24-fold reduction in the consumption of antibiotics with activity against Enterobacteriaceae and NFGNBs, respectively, in the post-intervention year (2016–2017) was observed. In relation to the Zero Resistance indicators, in the two post-intervention years (2016–2018) a reduction in the days on the antibiotic (by 1.29-fold), days of MRB (by 1.84-fold), and days of isolation (by 1.51-fold) was observed, thus improving upon the regional average of the former case, and the regional and national averages in the latter two cases. These data are in addition to the 5.90-fold reduction in NFGNB isolates from BAS samples obtained from patients with IMV, documented in our previous work for the same period.[11]

Clear limitations to our quasi-experimental experience reported here were found, including its open, single-centre nature. Also, other possible explanations for the observed reductions other than the removal of the sinks are possible, such as the implementation of the Zero Resistance Project itself, the early detection of MBR by surveillance cultures would decrease their dissemination by time. However, our staff did not detect any relevant change in the implementation of the Project during post-intervention period and the surveillance data had not been analysed prior to this article and so, if the Zero Resistance Project had generated benefits, it was because of the additional training and awareness of our staff working in the project and not due to feedback of the data.

In addition, an indication to reduce inhaled nebulisation in our unit (with disposal of the nebulisation vessel after one use, without reprocessing) was in place, although this had already been implemented a year earlier with no apparent impact on the data related to antibiotic use. The removal of the sinks also forced the staff to disposal all fluids thorough the sluice room. Furthermore, the general use of water-free wipes, mitts, and scalp caps was commenced in the second post-intervention year to replace the system of bottles and dishes with soap and water, regardless of whether chlorhexidine-impregnated wipes had been used during both periods of the study on the patients that were infected or had a colonisation by MRB, so this did not impact in the immediate post-intervention year (2016–2017) in which the main effect is the sinks removal.

Only one sink remained in the unit and this has not generated outbreaks of *Clostridium difficile* in patients, consistent with indications by staff that hydroalcoholic solution was been used for hand hygiene rather than the sinks. Furthermore, no changes were made in the unit's hand hygiene compliance in the post-intervention period.

An epidemic, endemic, or endemoepidemic situation is usually the starting point for other quasi-experimental academic publications found related to water safety.[15,16] However, it would be unethical to randomise patients in these studies when the data suggests that the same microorganisms isolated in these patients are also found on the entry[17] and exit[18] points (faucets and drains, respectively) of the unit's sinks and when inappropriate uses have been identified for these.[10,19]

To the best of our knowledge, this work is the first time a relationship between water safety and the impact on the consumption of antibiotics has been studied in a quantified way, although it is true that such quantification is implicit in work done to evaluate the impact on microbiological isolates. The reduction in antibiotic consumption we found in this work cannot be attributed entirely to the intervention to remove the sinks. Although most of the isolates

Table 1
Patients, hospitalised stays, and the CDs of antibiotics and their year-to-year (2014–2017) variations (Δ).

	Pre-intervention			Post-intervention	
	2014–2015	2015–2016		2016–2017	
			Δ (%)		Δ (%)
Number of patients	300	301		350	
Number of days hospitalised	1932	2174		2092	
Number of days in ICU on IMV	1197	1375		1047	
Antibiotics reported for Enterobacte-riaceae (DDD/100S)					
Amikacin	18.97	15.50	−18.29	8.37	−46.00
Amoxicillin/Clavulanic acid	12.45	8.15	−34.54	11.19	37.30
Ampicillin	1.84	2.48	34.78	1.36	−45.16
Cefepime	5.33	6.49	21.76	1.67	−74.27
Cefotaxime	7.38	1.81	−75.47	2.32	28.18
Cefuroxime	0.22	0.20	−9.09	0.96	380.00
Ciprofloxacin	16.38	21.93	33.88	10.61	−51.62
Gentamicin	3.15	2.74	−13.02	0.76	−72.26
Imipenem	30.15	26.35	−12.60	11.71	−55.56
Meropenem	11.89	6.65	−44.07	13.09	96.84
Piperacillin/Tazobactam	15.97	11.29	−29.30	8.21	−27.28
Total	123.72	103.59	−16.27	70.24	−32.19
Antibiotics reported for NFGNB (DDD/100S)					
Amikacin	18.97	15.50	−18.29	8.37	−46.00
Aztreonam	1.32	0.28	−78.79	0	−100.00
Cefepime	5.33	6.49	21.76	1.67	−74.27
Ceftazidime	4.17	3.88	−6.95	0.32	−91.75
Ciprofloxacin	16.38	21.93	33.88	10.61	−51.62
Colistimethate Sodium	6.95	6.95	0.00	0	−100.00
Gentamicin	3.15	2.74	−13.02	0.76	−72.26
Imipenem	30.15	26.35	−12.60	11.71	−55.56
Meropenem	11.89	6.65	−44.07	13.09	96.84
Piperacillin/Tazobactam	15.97	11.29	−29.30	8.21	−27.28
Tobramycin	0	1.34	–	0	−100.00
Trimethoprim/Sulfamethoxazole	25.43	29.96	17.81	6.27	−79.07
Total	139.71	133.36	−4.55	61.01	−54.25

CD: consumption density (DDD/100S).

Table 2
Distribution of DDD, hospitalised stays, and CD by period and comparison of the CDR (2014–2017).

Periods	DDD	Hospitalised stays	CD	CDR	95% CI	*p*
Antibiotics reported for Enterobacteriaceae						
Pre: 2015–2016	2251.98	2174	103.59	1		
Pre: 2014–2015	2390.31	1932	123.72	1.19	1.18–1.20	<0.001
Post: 2016–2017	1469.46	2092	70.24	1		
Pre: 2015–2016	2251.98	2174	103.59	1.48	1.47–1.48	<0.001
Pre: 2014–2015	2390.31	1932	123.72	1.76	1.75–1.77	<0.001
Total Pre: 2014–2016	4642.28	4106	113.06	1.61	1.60–1.62	<0.001
Antibiotics reported for NFGNB						
Pre: 2015–2016	2899.25	2174	133.36	1		
Pre: 2014–2015	2699.20	1932	139.71	1.05	0.99–1.10	<0.082
Post: 2016–2017	1276.33	2092	61.01	1		
Pre: 2015–2016	2899.25	2174	133.36	2.19	2.05–2.34	<0.001
Pre: 2014–2015	2699.20	1932	139.71	2.29	2.14–2.45	<0.001
Total Pre: 2014–2016	5598.45	4106	136.35	2.24	2.10–2.37	<0.001

DDD: defined daily dose; CD: consumption density (DDD/100S); CDR: consumption density ratio; 95% CI: 95% confidence interval; *p*: exact method based on binomial distribution; Pre: pre-intervention; Post: post-intervention.

Table 3
Zero Resistance Project indicators and their IDR comparisons pre/post intervention (2014–2018).

	Pre-intervention		Post-intervention		IDR	95% CI	*p*
Year	2014–2015	2015–2016	2016–2017	2017–2018			
Number of patients admitted	300	301	350	340			
Number of patients with MRB	9	15	19	28			
Hospitalised stays	1932	2174	2092	1853			
Number of antibiotic days	1571	1795	1331	1180			
Number of MRB days	288	477	218	181			
Number of isolation days	605	619	392	384			
Number of patients with MRB[a]	4.66	4.98	9.08	15.11	0.49	0.28–0.82	0.004
Number of antibiotic days[a]	813.15	825.67	636.23	636.81	1.29	1.22–1.36	<0.001
Number of MRB days[a]	149.07	219.41	104.21	97.68	1.84	1.63–2.08	<0.001
Number of isolation days[a]	313.15	284.73	187.38	207.23	1.51	1.38–1.66	<0.001

[a] Incidence density (ID) per 1000 hospitalised days; IDR: incidence density ratio; 95% CI: 95% confidence interval; *p*: exact method based on binomial distribution.

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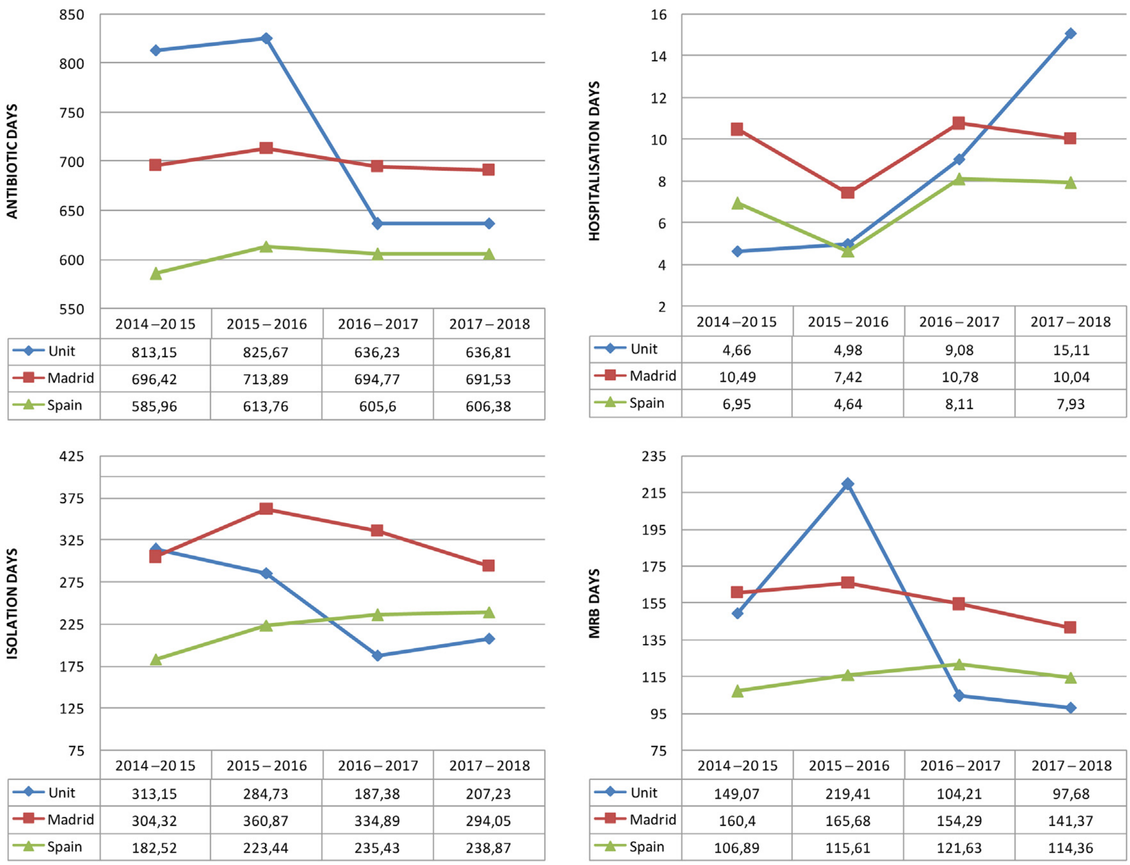

Fig. 1. Evolution of antibiotic days, hospitalisation days, isolation days, and MRB days in our unit, in Madrid and in Spain (2014–2018).

detected in epidemiological samples are colonisations, in reality, clinicians must weigh-up risk-benefit balance of the use of empirical antibiotic therapy in critically ill patients on a daily basis. The signs and symptoms of infection in these patients are often diffuse and changeable and so the isolation of these microorganisms from patient samples (e.g., BAS samples) can be decisive in cases of a suspected respiratory infection. In addition to the Zero Resistance Project itself, one measure that could have affected the consumption of antibiotics is the work done in hospitals by the Antibiotic Use Optimization Program (PROA)[20] since 2014. However, the impact of PROA on antimicrobials with action against gram-negative bacilli was limited only to the restricted use of carbapenems, which did not decisively change the trend in consumption density variations.

A review of patients with MRB showed that the progressive increase had occurred mainly at the expense of isolates detected upon admission to the unit and not during it. This may be because of methodological changes and greater consistency in the collection of exudates over time, as well as a progressive increase in type AmpC extended-spectrum beta-lactamase (ESBL) bacteria and carbapenemase producers detected in the health area. This type of multidrug-resistance has the highest clinical and epidemiological impact in hospitals because it complicates the management and evolution of patients.[21]

Given all the above, we believe that the most relevant results that could justify the removal of sinks in order to reduce the consumption of antibiotics would be the following: (1) the parallel reduction in the pre-existing NFGNB problem[11]; (2) that before the intervention there was already a statistically significant reduction in the consumption of antibiotics for treating Enterobacteriaceae but not for those against NFGNBs; (3) that the use of antibiotics suitable for treating NFGNBs, especially trimethoprim/sulfamethoxazole, was reduced after the removal of sinks, and that the magnitude of the reduction was higher than for Enterobacteriaceae antibiotics, which is consistent with the fact that the highest ratio of NFGNBs are found in wet reservoirs[2] and is also in line with the higher incidence of *Stenotrophomonas maltophilia* isolates pre-intervention[11]; and (4) that the reduction in Zero Resistance indicators whose distribution in the previous years was similar was statistically significant post-intervention, while a similar reduction was not seen at the regional and national levels, although data disaggregated by hospital size is not available for comparison.

Therefore, this is the first study to quantitatively suggest the favourable impact of removing ICU sinks on antibiotic consumption. This work reinforces the importance of managing risks related to water safety because it likely contributes to colonisation and infections and, therefore, encourages the prudent use of antimicrobials and a lower pressure in ICUs. This work can serve as a basis for further research on water safety. Such future studies should include the consumption of antibiotics as a metric for the efficiency of such interventions and should also clarify the cost of not performing them. New paths are also being opened to achieve the aims set out in the 'Zero tolerance' projects regarding ICU infections and in the fight against multidrug-resistant bacteria, which will go hand-in-hand with standard infection-control measures, water safety, specific care bundles for each infection location, and surveillance with data feedback.

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Conflicts of interest

None.

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