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Concise Communication

The impact of environmental cleaning protocol featuring PX-UV in reducing the incidence of multidrug-resistant gram-negative healthcare-associated infection and colonization in intensive care units in Thailand

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Abstract

In this quasi-experimental study, implementing PX-UV to the standard environmental cleaning protocol was associated with a reduction in the overall incidence of multidrug-resistant (MDR) gram-negative organisms ($P = .01$) and MDR *Acinetobacter baumannii* ($P = .001$) in intervention intensive care units. However, the intervention did not reduce patient length of stay and 30-day mortality.

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The emergence of multidrug-resistant gram-negative (MDR-GNB) bacilli poses a substantial public health threat in intensive care units (ICUs).[1] Effective infection prevention measures in ICUs are crucial to prevent healthcare-associated infections (HAIs).[2] However, despite cleaning protocols implemented in healthcare facilities, the manual cleaning remains suboptimal.[3]

Although some evidence supports the impact of ultraviolet light (UV) to reduce environmental contamination among GNB[4], limited data support the impact of UV in reducing the incidence of MDR-GNB HAIs and colonization. Moreover, most studies conducted in healthcare facilities have focused on the control of MDR gram-positive microorganisms,[5] leaving a knowledge gap regarding the effective prevention of MDR-GNB HAIs.[6,7] Given the high prevalence of MDR-GNB infections in Thailand,[8] we evaluated the impact of an environmental cleaning protocol featuring UV together with monitoring and feedback of environmental cleaning performance in reducing the incidence of MDR-GNB HAIs and colonization in Thai ICUs. Our findings may contribute to the development of evidence-based cleaning and disinfection protocols in resource-limited settings.

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Methods

From April 1, 2021, to March 31, 2023, we performed a quasi-experimental study with a control group to evaluate the impact of the addition of pulsed xenon UV (PX-UV) terminal disinfection to an ongoing environmental cleaning protocol that included monitoring and feedback of environmental cleaning performance using environmental cultures on the incidence of MDR-GNB in 4 ICUs at Thammasat University Hospital, a 795-bed tertiary-care academic hospital. The study units included 2 medical ICUs (units A and D) and 2 surgical ICUs (units B and C), totaling 38 patient rooms. The intervention included units A and B, and the controls included units C and D. In addition to standard environmental cleaning protocol, pulsed xenon UV (PX-UV) terminal disinfection was implemented in the intervention units. Similar routine daily and terminal cleaning protocols were applied to all 4 study units.[9] Environmental cleaning involved regular cleaning practices that were tailored to the risk level of the patient and were performed in accordance with hospital IP policies. These practices included daily cleaning and terminal manual cleaning, plus chemical disinfection. Cleaning was performed by separate groups of housekeepers. Auditing and feedback mechanisms using postterminal cleaning environmental cultures, without housekeepers' awareness, were employed every week.[4] The study periods consisted of a 1-year preimplementation period (period 1: April 1, 2021, through March 31, 2022) and a 1-year postimplementation period (period 2: April 1, 2022, through March 31, 2023).

Table 1. Demographics and Baseline Characteristics of Participants Among Intervention and Control Units

	Preimplementation Period (Period 1)[a]				Postimplementation Period (Period 2)[a]			
Variables	Total (N=691)	Intervention (N=345)	Control (N=346)	*P* Value	Total (N=699)	Intervention (N=350)	Control (N=349)	*P* Value
Age, mean y (±SD)	62±20.4	63±18.9	62±19.8	.42	60±20.2	61±18.6	60±19.9	.36
Sex, male	377 (54.6)	189 (54.8)	188 (54.3)	.91	376 (53.8)	187 (53.4)	189 (54.2)	.85
Underlying diseases								
Diabetes mellitus	242 (35)	117 (33.9)	125 (36.1)	.54	253 (36.2)	126 (36)	127 (36.4)	.91
Hypertension	374 (54.1)	180 (52.2)	194 (56.1)	.30	370 (52.9)	189 (54)	181 (51.9)	.57
Heart diseases	163 (23.6)	83 (24)	80 (23.1)	.77	167 (23.9)	80 (22.9)	87 (24.9)	.52
Other[b]	135 (19.5)	69 (20)	66 (19.1)	.76	125 (17.9)	63 (25.2)	62 (17.8)	.94
Site of infection and colonization								
Respiratory tract	327 (47.3)	161 (46.7)	166 (47.9)	.73	326 (47.7)	162 (46.3)	164 (47)	.85
Urinary tract	88 (12.7)	45 (13)	43 (12.4)	.81	79 (11.3)	40 (11.4)	39 (11.2)	.92
Bacteremia	92 (13.3)	46 (13.3)	46 (13.3)	.99	81 (11.6)	39 (11.1)	42 (12)	.71
Other[c]	136 (19.7)	69 (20)	67 (19.4)	.79	126 (18)	63 (18)	63 (18)	.99
LOS, mean d ±SD	9±10.4	9.8±11.9	8.2±9.4	.63	9±11.4	9.7±12.4	8.3±10.3	.59
30-d mortality	128 (18.5)	62 (17.9)	66 (19.1)	.71	144 (20.6)	71 (20.3)	73 (21)	.84

Note. SD, standard deviation; LOS, length of stay.
[a]Data are no. (%) unless otherwise indicated.
[b]Other underlying diseases were malignancies, kidney diseases, lung diseases, liver diseases and neurological diseases.
[c]Other sources of infection were bone and joint, skin and soft tissue, central nervous system, intra-abdomen and unidentified sources.

During the entire study, all ICU beds from which a patient had been discharged or transferred after occupying the room for a minimum of 48 hours were cleaned by housekeepers according to the hospital terminal cleaning protocol. Rooms with patients that had MDR-GNB HAI or colonization on admission were excluded. The protocol included using a chlorine disinfectant solution (Aurora Chemical, Thailand) at a concentration of 200 ppm to disinfect the floor with cotton-string mops. High-touch surfaces (eg, infusion pump, medical chart, bedside table) and other room surfaces (eg, chair, light switch, ventilator) were disinfected with quaternary compounds (DUAL QUATS) disinfectant wipes (Pose Health Care, Thailand). We collected one surface sample for each site, including infusion pump, overbed table, bedside table, medication cart, vital signs screen, before and after terminal cleaning in all units and after PX-UV implementation in intervention units using the MacConkey contact plates (Redipor, Cherwell Laboratories, UK) incubated at 36±1°C for 48 hours.[4]

During period 2, PX-UV (Xenex, San Antonio, TX) was implemented in the intervention units in addition to the standard terminal cleaning protocol that utilized a PX-UV device, which emits broad-spectrum irradiation covering the UV-C spectrum of 200–280 nm. The device was positioned within 2 m of high-touch surfaces and was operated for 5–7 minutes at each of 2 distinct locations within the patient's room (1 cycle per location, n = 2 cycles per room). The disinfection process, including setup, irradiation cycles, and repositioning, took ~15–20 minutes. Compliance with the protocol was monitored by the PX-UV device.

Data collected included patient characteristics, underlying diseases, length of stay and 30-day all-cause mortality, and the incidence of MDR-GNB in 4 ICUs during period 1 and 2. The targeted MDR-GNB included MDR *A. baumannii*, extended-spectrum β-lactamase (ESBL)–producing Enterobacterales, carbapenem-resistant Enterobacterales, MDR *Pseudomonas aeruginosa*. MDR-GNB were defined as resistance to ≥3 antimicrobial classes.[10] The primary outcome was the incidence of MDR-GNB HAI and colonization in the 4 ICUs. The Centers for Disease Control and Prevention/National Healthcare Safety Network Patient Safety Component Manual 2022 was used to define infection and colonization.[11] Active surveillance for colonization was not performed. Colonization status was defined based on clinical cultures.[11] The secondary outcomes were length of stay and 30-day all-cause mortality.

All analyses were performed using Stata version 16 software (StatCorp, College Station, TX). The primary outcomes were the incidence of MDR-GNB HAIs and colonization. We used χ^2 tests to compare categorical variables and independent t-tests for continuous data. Trend analyses were performed to evaluate the overall pattern of changes on outcomes of interest over time using segmented regression analysis of interrupted time series. All *P* values were 2-tailed; $P < .05$ was considered statistically significant. This study was approved by the Ethics Committee of Thammasat University.

Results

We enrolled 691 patients in period 1 (intervention units, 6,840 patient days; control units, 6,800 patient days) and 699 patients in period 2 (intervention units, 6,790 patient days; control units, 6,820 patient days). The mean patient ages in period 1 and period 2 participants were 62 years (SD, ±20.4) and 60 years (SD, ±20.2). The most common underlying diseases were hypertension (744 of 1,390, 53.5%) and diabetes mellitus (495 of 1,390, 35.6%). Baseline characteristics are presented in Table 1. The rate of UV device use was 100% (350 of 350) in intervention units with 81% protocol compliance (284 of 350). Environmental culture results are shown in Supplementary Tables 1 and 2.

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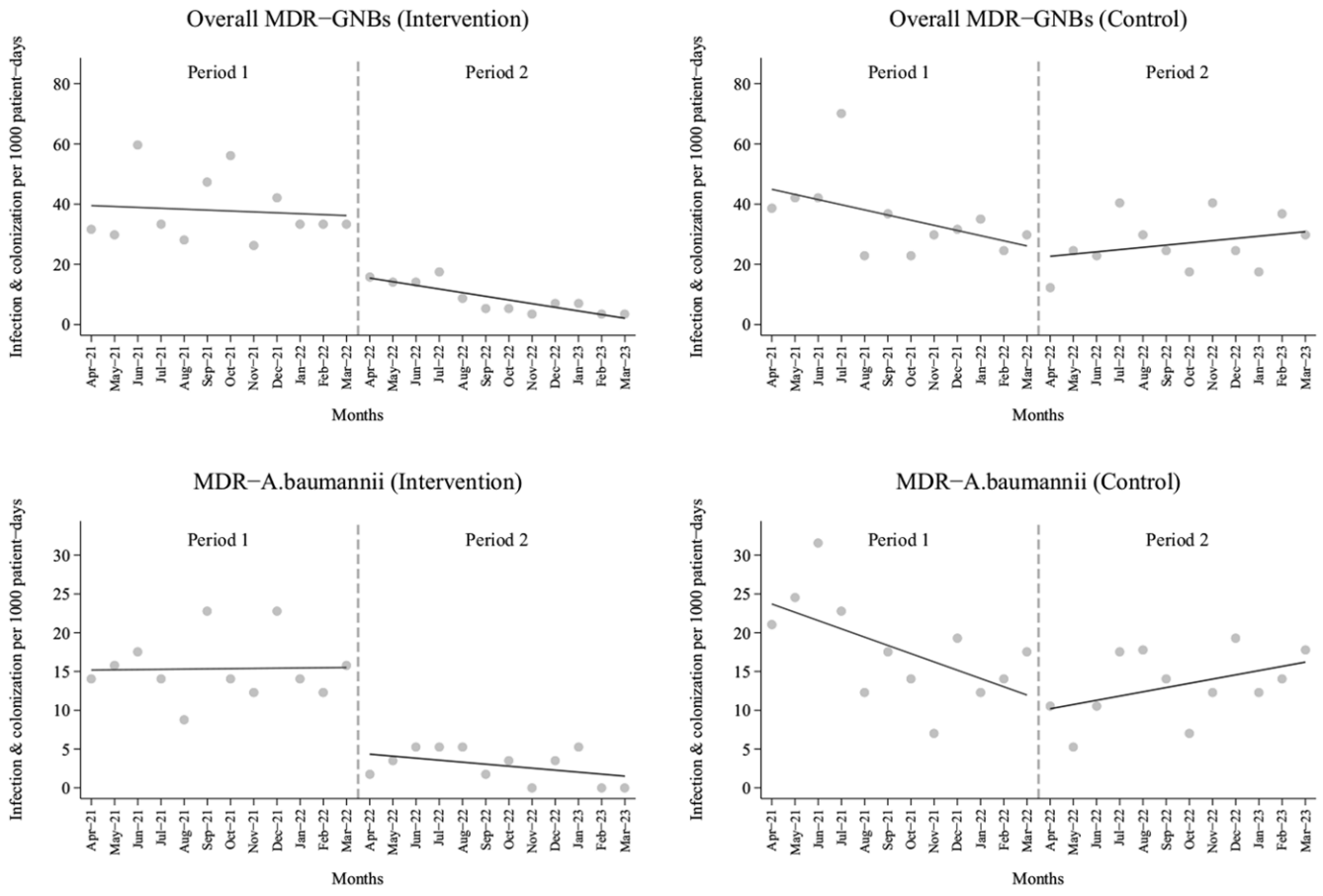

Organisms in ICU	PX-UV				Control			
	Change in level		Change in trend		Change in level		Change in trend	
	Mean (95% CI)	*P*-value	Mean (95% CI)	*P*-value	Mean (95% CI)	*P*-value	Mean (95% CI)	*P*-value
Overall MDR-GNBs	-19.5 (-33.9 to -5.20)	0.010	-0.91 (-2.98 to 1.15)	0.367	-4.18 (-22.2 to 13.9)	0.634	2.45 (-0.15 to 5.06)	0.063
MDR-*A. baumannii*	-10.9 (-16.7 to -5.16)	0.001	-0.29 (-1.12 to 0.54)	0.478	-2.32 (-10.8 to 6.16)	0.574	1.61 (0.39 to 2.84)	0.012

Figure 1. Overall multidrug-resistant gram-negative microorganisms and multidrug-resistant *Acinetobacter baumannii* infection and colonization among intervention and control units.

Through time-series analysis, compared to control units, we detected an immediate significant reduction in the total incidence of MDR-GNB HAI and colonization in the intervention units during period 2 compared to period 1:8.8 per 1,000 patient days (n = 60) versus 37.8 per 1,000 patient days (n = 259; $P = .010$) without significant change from month to month in the postimplementation period. We detected a significant reduction in the incidence of MDR *A. baumannii* HAIs and colonization in the intervention units: 2.9 per 1,000 patient days (n = 20) versus 15.3 per 1,000 patient days (n = 105; $P = .001$) (Fig. 1). However, we did not observe any significant change in the level or trend of the incidence of other MDR-GNB or other secondary outcomes (Table 1 and Supplementary Table 3 online).

Discussion

Our study has yielded some key findings. First, we observed a substantial decrease in the incidence of overall MDR-GNB HAIs and colonization following the implementation of PX-UV. Second, prespecified subgroup analysis did not demonstrate a significant reduction in the incidence of other MDR-GNB except for MDR *A. baumannii*. The overall significant reduction in MDR-GNB incidence was driven by MDR *A. baumannii*, likely due to its high prevalence, representing 39% of all positive cultures (infection and colonization). Third, fewer intervention rooms had positive baseline environmental culture during the postimplementation period, which may represent the overall MDR-GNB reduction after PX-UV implementation.

Previous studies have suggested that PX-UV implementation can help reduce the contamination of MDR-GNB on high touch surfaces in the United Kingdom and Thailand.[4,12] A study in Japan showed that PX-UV implementation decreased the incidence of MDR *A. baumannii* by 63% in an ICU after 6 months.[13] Likewise, we found significant reductions in the incidences of overall MDR-GNB and MDR *A. baumannii* by 76.8% and 81% in 12 months. However, there were no changes in the incidences of other MDR-GNBs, likely due to the relatively lower incidence of other MDR-GNBs in our ICUs.

This study had several limitations. The study was performed in a single center. We only measured the impact of PX-UV on the incidence of MDR-GNBs. Because our institution used a standard environmental cleaning protocol featuring monitoring and feedback

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using environmental cultures, and most of the environmental sites were relatively cleaned before the implementation of PX-UV. Thus, the additional impact of PX-UV to disinfect environmental surface in settings where monitoring and feedback were not available should be further studied. We did not separate the proportion of HAIs and colonization. Misclassification bias may have occurred with MDR *A. baumannii* because it is more likely to be environmentally acquired than other MDR-GNB. We did not assess genetic relatedness to confirm transmission between patients. Lastly, we acknowledge the small sample size in detecting changes in other MDR-GNB other than MDR *A. baumannii*.

In conclusion, the addition of PX-UV to the standard environmental cleaning protocol together with monitoring and feedback of environmental cleaning was associated with a reduction in the overall incidence of MDR-GNB and MDR *A. baumannii* HAIs and colonization in ICUs in Thailand.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/ice.2023.255

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Competing interests. All authors report no conflicts of interest relevant to this article.

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