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RESEARCH ARTICLE

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Impact of multimodal strategies to reduce multidrug-resistant organisms in surgical intensive care units: Knowledge, practices and transmission: A quasi-experimental study

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Abstract

Aim: This study examined the effects of multimodal strategies on knowledge and practices in preventing multidrug-resistant organism (MDRO) transmission among healthcare personnel (HCP), and to investigate MDRO transmission in two surgical intensive care units (SICUs).

Design: A quasi-experimental study with a one-group pretest–posttest design.

Methods: We recruited 62 HCP. Data were collected during 2017–2019. Multimodal strategies, including training, educational and reminder posters, an educational YouTube channel, champions and feedback, were used to enhance knowledge and practices. Data were analysed using Wilcoxon signed-rank test and chi-square test.

Results: After the intervention, median knowledge scores increased from 16.0 to 17.0 ($p = .001$), and overall correct MDRO prevention practices increased from 76.6% to 94.0% ($p < .001$). The MDRO transmission rate decreased from 25% to 0% ($p < .001$).

Conclusion: The findings indicate that multimodal strategies could enhance knowledge and practices for preventing MDRO transmission among HCP and could reduce the MDRO transmission rate in SICUs.

KEYWORDS

knowledge, multidrug-resistant organisms, multimodal strategies, practices, transmission

1 | INTRODUCTION

The emergence of multidrug-resistant organisms (MDROs) is the greatest current threat to public health worldwide (World Health Organization [WHO], 2014). Recently, carbapenem-resistant Enterobacteriaceae (CRE), *Acinetobacter baumannii* (CRAB), *Pseudomonas aeruginosa* (CRPsA) and vancomycin-resistant Enterococcus (VRE) are an emerging or serious cause of healthcare-associated infection (HAI), particularly among critically ill patients admitted to intensive care units (ICUs) (Gomez-Simmonds et al., 2016;

Tzouvelekis et al., 2012). In Thailand, a national surveillance study reported that the prevalence of imipenem-resistant *Acinetobacter baumannii* (IRAB) in ICUs increased from 14.2% in 2000 to 80.2% in 2019 (National Antimicrobial Resistance Surveillance Center Thailand [NARST], 2020). MDROs cause an estimated 700,000 deaths worldwide each year and are projected to cause 10 million deaths per year by 2050. MDROs could potentially reduce the world's GDP up to 100.2 trillion USD between 2014 and 2050 (O'Neill, 2014). In Thailand, MDROs cause approximately 38,000 deaths annually at a cost of 84.6 to 202.8 million USD to patients and healthcare systems (Phumart et al., 2012). WHO, therefore, aims to encourage best practices among healthcare personnel (HCP) to avoid the further spread of MDROs. This requires action across all sectors using multimodal strategies and One Health approaches (WHO, 2016).

2 | BACKGROUND

Several studies have reported that implementing clinical practice guidelines can reduce the incidence and spread of MDROs (Borer et al., 2011; D'Agata et al., 2012; DalBen et al., 2016; Kim et al., 2014; Viale et al., 2015). However, some studies have reported negative findings after implementing contact precautions (Furuya et al., 2018; Simmons & Larson, 2015). Several factors may lie behind these reports of success and failure in reducing the incidence of MDROs. However, correct knowledge and practices to prevent MDROs among HCP remain key factors.

Previous studies reported that multimodal interventions are effective in reducing MDRO infections and transmission, and especially enhance the compliance of hand hygiene (Alshehari et al., 2018; Backman et al., 2011; Centers for Disease Control & Prevention [CDC], 2006; Mathai et al., 2011; Oliveira et al., 2018; Shen et al., 2017; WHO, 2018) and environmental hygiene (Allen et al., 2018; Mitchell et al., 2019). However, hand and environmental hygiene represent only two categories of MDRO prevention out of the seven recommended by the US CDC. Furthermore, the majority of studies were performed in medical ICUs. This study aimed to examine the effects of a multimodal MDRO transmission prevention strategy on knowledge and practices among HCP and the incidence of MDRO infections and transmissions in surgical ICUs (SICUs). Seven core categories of practices in MDRO transmission prevention, including patient placement, hand hygiene, personal protective equipment (PPE), environmental cleaning and disinfection, linen and waste management, patient transfer, and patient and family education, were examined. Research hypotheses were: (a) knowledge of MDRO transmission prevention among HCP after receiving multimodal strategies was higher than before receiving multimodal strategies; (b) correct practices of MDRO transmission prevention among HCP after receiving multimodal strategies were higher than before receiving the multimodal strategies; (c) incidences of MDRO infection among SICU patients after the multimodal strategy interventions were lower than before receiving the multimodal strategy interventions; and (d) MDRO transmission rates among SICU patients after the multimodal strategy interventions were lower than before receiving the multimodal strategy interventions.

3 | THE STUDY

3.1 | Design and setting

A quasi-experimental study with a one-group pretest–posttest design was conducted. The participants received multimodal interventions between tests. Two SICUs in a 1,400-bed university hospital in northern Thailand were selected due to a high incidence of MDROs at that hospital. Each SICU had seven to eight beds, with a median number of monthly admissions of 38, and an interquartile range (IQR) of 35 to 40 admissions monthly. The mean nurse-to-patient ratio was 1:2 per SICU.

3.2 | Sample size calculation

A power calculation using G*Power version 3.1.9.7 to estimate sample size requirements was conducted for this study. We used a medium effect size in this study (d = 0.5) as determined by previous similar studies (Mathai et al., 2011; Shen et al., 2017) examining differences between two dependent means (matched pairs), the required sample size to achieve a power of 0.95 with an alpha of 0.05 was 45 (Faul, 2020). To anticipate losses to follow-up, about 35% was added in this long-term study, for a total of 61 participants.

3.3 | Participants

Participants were recruited from two SICUs for sufficient numbers of samples including those lost to follow-up. The inclusion criteria were as follows: (a) HCP with at least 1 year of work experience in the SICU and (b) all participants agreed to participate in the study. Members of the research team and SICU head nurses were excluded. A total of 62 HCP participated including 10 physicians, 35 registered nurses, 11 practical nurses and 6 nurse aides (Figure 1). None of the participants were lost to follow-up in this study.

3.4 | Definition of MDRO infection and transmission

MDRO infection was defined as SICU patients diagnosed as having bacterial isolates that are resistant to one or more agents in three or more different classes of antimicrobials including CRE, CRAB, CRPsA, IRAB and VRE.

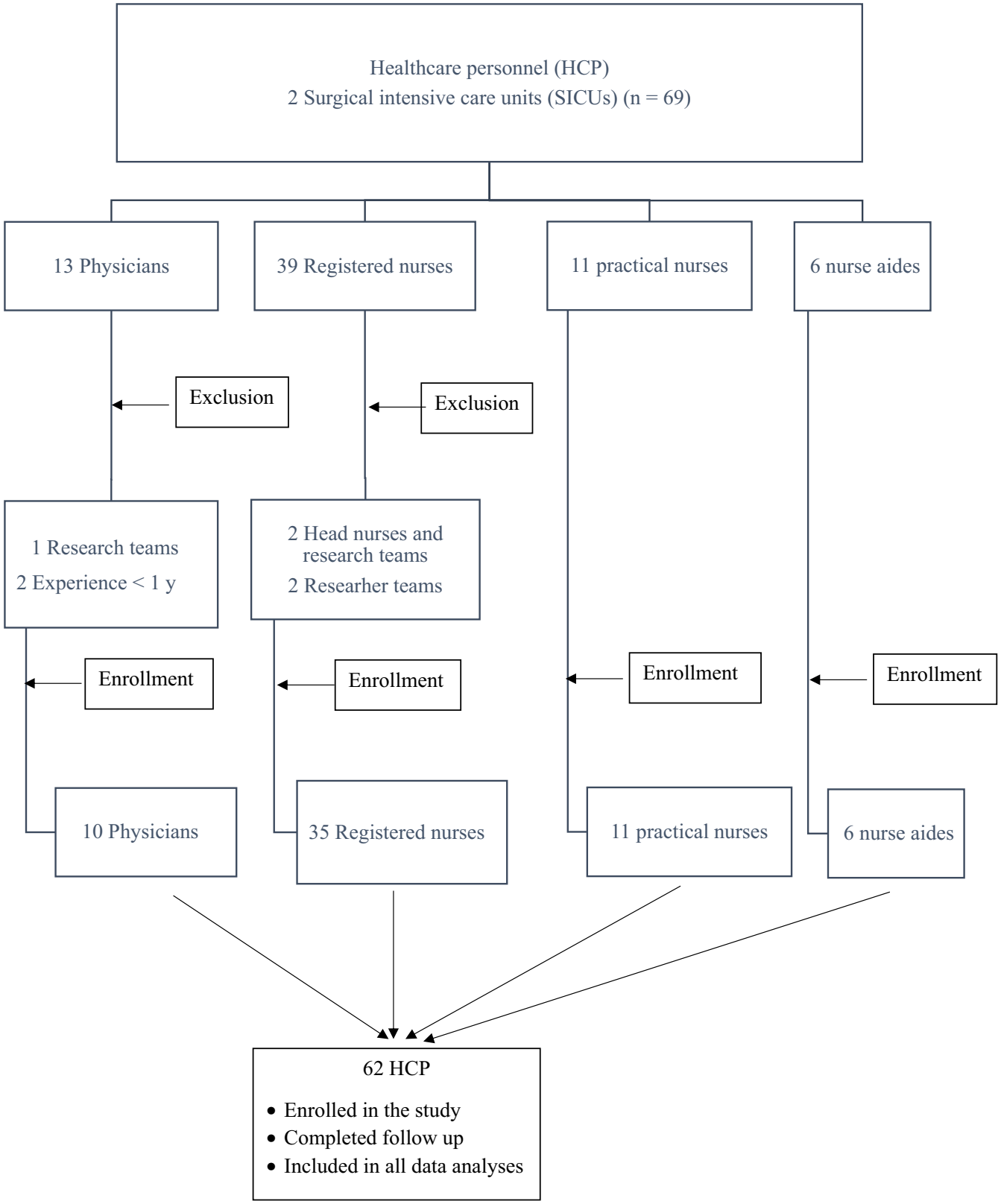

FIGURE 1 Study flow diagram

MDRO transmission was defined as when patients, environmental surfaces and HCP that had once tested negative for CRE, CRAB, CRPsA, IRAB or VRE, then tested positive with the same genus, species and antibiotic susceptibility of one of these strains as an MDRO patient.

3.5 | Intervention

Multimodal strategies were used to promote knowledge and practices, consisting of a training, educational and reminder poster, an educational YouTube channel, MDRO prevention champions and

feedback. Each HCP professional group received one training session which were conducted by the researchers and included presentation, discussion, demonstration and return-demonstration. The key concepts included epidemiology, incidence and burden of MDROs, the Thai National Strategic Plan on Antimicrobial Resistance for 2017 to 2021, One Health concepts, and clinical practice guidelines to prevent MDRO transmission. The media and materials used for training were Microsoft PowerPoint presentations, two existing videos (on the same Thai national strategic plan and the One Health concept) and a video on clinical practice guidelines to prevent and control MDRO transmission. The latter was developed by researchers and uploaded to a YouTube channel at https://www.youtube.com/watch?v=Ms5gcyD6P-k. HCP could, therefore, access the video anytime and anywhere to review or increase their knowledge. The training sessions lasted 75 min on average (range: 55–90 min). Two educational posters related to seven categories of preventing and controlling MDRO transmission were also developed by the researchers and placed in designated areas near entry doors. The reminder poster came from the winning motto of an MDRO prevention motto contest. These posters were also placed near a sink, a nurse station and in treatment rooms. MDRO prevention champions were selected by the subjects, one champion for each profession. The researchers gave a small gift of appreciation to each champion. Weekly group feedback sessions on the percentage of correct practices to prevent and control MDRO transmission were conducted using bar graphs and line graphs in a Microsoft PowerPoint presentation. Line graphs were used in trend presentations of correct practices to prevent and control MDRO transmission. During the study period, key hospital policies regarding MDRO infection and transmission such as the antimicrobial stewardship program and hand hygiene campaign did not change.

3.6 | Instruments

Research instruments were developed by the researchers included a demographic data questionnaire, a knowledge test, an observational record form, a satisfaction questionnaire and an MDRO surveillance form. The knowledge test measured knowledge of practices related to preventing and controlling MDRO transmission. Twenty items were included in each subject with multiple-choice questions (four choices) for physicians, nurses, and practical nurses and true/false questions for nurse aides. An observational checklist (correct or incorrect) was used to record actual practices. Five-point rating scales were used to assess satisfaction with multimodal strategies. All research instruments were validated by six experts. The content validity indexes of the knowledge test, the observational record form and the satisfaction questionnaire were 0.93, 0.96 and 0.96, respectively, and reliability was 0.70, 1.0, and 0.78, respectively. Clinical practice guidelines to prevent and control MDRO transmission were developed by the researchers, modified from the Centers for Disease Control and Prevention (CDC) guidelines to manage MDROs in healthcare settings, 2006 (CDC, 2006). The guidelines included seven categories: Category 1: patient placement (isolation in single room/cohorting patients, patient-dedicated equipment, and contact precautions signs); Category 2: hand hygiene (WHO five moments for hand hygiene, including: before touching a patient, before clean/aseptic procedures, after body fluid exposure/risk, after touching a patient and after touching patient surroundings); Category 3: use of personal protective equipment (wearing, changing and disposing of PPE); Category 4: environmental cleaning and disinfection (frequency, method, and process of environmental cleaning; and disinfection medical instruments); Category 5: linen and waste management (collecting, placing, labelling MDRO, and waste management); Category 6: patient transfer (notifying prior to transfer, wearing appropriate PPE and covering of wounds prior to transfer); and Category 7: patient and family education (WHO five moments for hand hygiene and patient-dedicated equipment).

3.7 | Data collection

Participant observation of MDRO prevention practices was employed during two periods of the study, the pre-intervention period, from 1 August 2017 through 30 September 2017, and the post-intervention period, from 1 November 2017 through 31 July 2019. The researchers randomly selected participants for observation five days a week during the pre- and post-intervention periods by participatory observation. The demographic questionnaire and knowledge test were distributed to all participants following the initial observation. During the intervention period, multimodal strategies were implemented for 1 month. The knowledge test and satisfaction questionnaire were administered to all participants following this period. Additionally, the researchers conducted surveillance of MDROs and MDRO transmission rates throughout the pre- and post-intervention periods. Before collecting data, six researchers (N.K., N.N., D.K., N.D., C.R. and U.S) were trained to use all data collection tools and underwent a three-hour training program and collected data over a five-day observational period. All observational occasions were randomly assigned. All observers participated in working with the participants and observing their practices without recording data for 2 weeks prior to actual data collection, in order to prevent the Hawthorne effect.

3.8 | Data analysis

R version 3.5.1 was used to analyse the data. Demographic data for the participants were recorded as frequency and percentage, mean and standard deviation, and median and range/interquartile range (IQR), as appropriate. The knowledge scores of HCP pre- and post-intervention were tested for normality of the distribution using the Kolmogorov–Smirnov test ($N \geq 50$) or the Shapiro-Wilks test ($N < 50$). Wilcoxon signed-rank test was used to compare the differences between the pre- and post-intervention data sets that deviated from

the normal distribution. Comparison of correct practices between the pre- and the post-intervention was undertaken using the chi-square test or Fisher's exact test. The chi-square test was used when the cell sizes were expected to be large. When expected cell sizes were <5, Fisher's Exact test was used. All analyses were performed with a significance level of $p < .05$ ($\alpha = 0.05$).

4 | RESULTS

The majority of HCP were female (82.3%) and their median age was 29.0 years (IQR = 24.0–40.5 years). Most HCP held a bachelor's degree or commensurate (56.4%). More than one half of HCP were registered nurses (55.0%), followed by practical nurses (17.7%) and physicians (16.1%). The median work experience in the SICU was 3.5 years (IQR = 1.0–15.0 years). Almost all participants did not have over the last year on the prevention of MDRO transmission (91.9%), but 77.4% had pursued self-study on the topic. The three most common sources of MDRO prevention knowledge were physical copies of the hospital guidelines/manuals (42.0%), educational posters (27.3%) and internet/intranet (18.2%) (Table 1).

After implementation of the multimodal intervention, the overall median MDRO transmission prevention knowledge scores increased significantly from 16.0 (IQR = 15.75–18.0) to 17.0 (IQR = 16.0–19.0) (p =.001) (Table 2), and overall, MDRO transmission prevention measures increased from 76.6% to 94.0% (p <.001). The proportion of MDRO transmission prevention measures, before and after multimodal intervention, were stratified by category and activity (Table 3). Overall, the proportion of correct hand hygiene practices among nurses highest significantly increased following the intervention (77.2% versus. 97.0%, p <.001). The proportions of correct hand hygiene practices before and after the intervention stratified by job position are provided in Appendix S1. The incidence of MDROs reduced from 3.97/1,000 patient days to 3.87/1,000 patient days (p = .964) and the MDRO transmission rate reduced from 25% to 0% (p <.001) (Appendix S2).

The participants rated extremely satisfied and highly satisfied with multimodal strategies (mean 4.27, SD = 0.45); the educational YouTube channel (mean 4.27, SD = 0.63), MDRO prevention champions (mean 4.21, SD = 0.63), feedback (mean 4.19, SD = 0.60), educational posters (mean 4.19, SD = 0.51) and a reminder poster (mean 4.13, SD = 0.50) (Appendix S3).

5 | DISCUSSION

Multimodal strategies can improve knowledge of MDRO transmission prevention among HCP leading to improvements in practice which in turn could reduce MDRO transmission rates in SICUs. Median knowledge scores among all professions increased following the intervention and this increase was larger and more significant among physicians and registered nurses. Overall, the findings demonstrated that a multimodal intervention could play a vital role in

TABLE 1 Demographic data for surgical intensive care unit personnel (N = 62)

Characteristic	Number	Percent
Gender		
Male	11	17.7
Female	51	82.3
Age (years)		
<30	32	51.6
30–39	14	22.6
40–49	8	12.9
≥50	8	12.9
$\bar{X} \pm SD$ =33.2 ± 10.8		
Median 29.0, Range = 20–58		
Educational level		
Senior high school	5	8.1
Certificate or commensurate	9	14.5
Bachelor degree or commensurate	35	56.4
Master degree or commensurate	13	21.0
Ward		
Surgical intensive care unit	33	53.2
Surgical critical care unit	29	46.8
Job position		
Physician	10	16.1
Registered nurse	35	56.5
Practical nurse	11	17.7
Nurse aide	6	9.7
Work experience in intensive care unit (years)		
1–5	34	54.8
6–10	8	12.9
11–15	6	9.7
16–20	6	9.7
>20	8	12.9
$\bar{X} \pm SD$ =8.5 ± 9.1		
Median = 3.5, Range = 1–36		
Training for prevention of MDROs in past year		
No	57	91.9
Yes	5	8.1
Self-study for prevention of MDROs in past year		
No	14	22.6
Yes	48	77.4
Sources of knowledge access (n = 88) (more than one answer acceptable)		
Printed hospital guidelines/manuals	37	42.0
Printed educational posters	24	27.3
Internet/intranet	16	18.2
Hospital annual academic meeting	11	12.5

Abbreviation: MDROs, Multidrug-resistant organisms.

TABLE 2 Comparison of knowledge scores before and after multimodal strategies intervention among healthcare personnel in surgical intensive care units

	Knowledge scores[a]						Wilcoxon signed ranks test	
Study period	Min	Max	Median	IQR	$\bar{X}$	S.D.	Z	*p*-value
Physician (*N* = 10)								
Pre-intervention	14.00	17.00	16.00	14.00–16.25	15.50	1.18	2.687	0.007
Post-intervention	16.00	18.00	17.50	17.00–18.00	17.40	0.70		
Registered nurse (*N* = 35)								
Pre-intervention	11.00	20.00	16.00	16.00–19.00	16.71	1.87	3.477	0.001
Post-intervention	15.00	20.00	17.00	17.00–19.00	17.74	1.48		
Practical nurse (*N* = 11)								
Pre-intervention	10.00	19.00	15.00	13.00–18.00	16.00	2.79	0.155	0.877
Post-intervention	13.00	20.00	17.00	15.00–20.00	16.18	2.48		
Nurse aide (*N* = 6)								
Pre-intervention	16.00	16.00	16.00	16.00–18.50	16.83	1.33	1.342	0.180
Post-intervention	19.00	19.00	17.50	16.00–19.00	17.50	1.38		
Overall (*n* = 62)								
Pre-intervention	10.00	20.00	16.00	15.75–18.00	16.44	1.87	3.374	0.001
Post-intervention	13.00	20.00	17.00	16.00–19.00	17.35	1.78		

[a]Maximum scores = 20 points.

increasing knowledge among a sample that had not been trained in MDRO prevention in the past year. Training may also allow HCP to create networks and learning communities to share knowledge or post questions and answers related to preventing MDROs (Aguinis & Kraiger, 2009). In addition, HCP can access presentation slides and training materials using the intranet and they could watch videos developed by the researchers on the YouTube channel anytime and anywhere (Ventola, 2014).

Gains in knowledge may have played a key role in improving prevention practices. In fact, training, in addition to the educational posters and the reminder poster used in this study, increased not only knowledge but also proficiency in skills and practices. The posters engaged HCP in the learning process and facilitated understanding because HCP were able to visualize the key points that may help them to improve their retention and recall of events and facts (WHO, 2019).

The MDRO prevention champion as role model and providing feedback were also effective interventions to enhance correct practices. Champions may have helped to accelerate connections between HCP leading to a social environment fostering the improvement of skills and correct practices. The champions may have provided support and boosted the skills and confidence of HCP in preventing MDRO transmissions (N'Guyen et al., 2019). However, after implementation of the intervention, the rate of correct prevention practices remained 80% in some areas including performing hand hygiene before touching a patient; wearing eye protection or face shields to prevent splashes; changing gloves between dirty and clean tasks on the same patient; and disinfecting the overbed table before and after use. Perhaps, the HCP considered these acts as lower risk and did not prioritize them the same way they did with other prevention measures. A previous study showed that after providing education and feedback to HCP, the overall compliance of hand hygiene improved significantly from 41.9% to 46.8% (p =.004), and the compliance of proper glove or gown use increased from 56.8% to 65.5% (p =.001). However, hand hygiene compliance after touching patient surroundings was not observed in the previous study (Baccolini et al., 2019).

The stratified data for hand hygiene performance by profession showed that nurses had the highest compliance rates of hand hygiene, while physicians exhibited the lowest hand hygiene compliance, especially before touching a patient and before performing clean/aseptic procedures. One study found that a heavy workload, rushing, attitudes, beliefs and skin rashes from repetitive hand washing explained poor hand hygiene adherence among physicians (Squires et al., 2013). Environmental factors should not be key factors in this study because the hospital provided plenty of opportunities to practice hand hygiene in both SICUs: a sufficient number of sinks that are easy to access, adequate hand hygiene products and plenty of alcohol-based hand rub. The overall hand hygiene compliance among other professions was above 95%. The barriers to low hand hygiene compliance among physicians in this study should be explored to develop appropriate interventions. These findings were consistent with several other studies indicating that nurses had the highest hand hygiene compliance and the

TABLE 3 Comparison of the proportions of correct practices before and after multimodal strategies intervention among healthcare personnel in surgical intensive care units

	Pre-intervention period Direct observation occasions			Post-intervention period Direct observation occasions			
	Number			Number			
Activity	Correct	Total	Percent	Correct	Total	Percent	*p*-value
Patient placement							
Isolation in single room/ cohorting patients	64	64	100.0	541	541	100.0	–
Patient-dedicated equipment	64	64	100.0	541	541	100.0	–
Contact precautions signs	64	64	100.0	541	541	100.0	–
Total	192	192	100.0	1,623	1,623	100.0	–
Hand hygiene							
Before touching a patient	102	184	55.4	1,429	1,804	79.2	<0.001
Before clean/aseptic procedures	83	117	70.9	1,279	1,492	85.7	<0.001
After body fluid exposure/risk	101	117	86.3	1,562	1,595	97.9	<0.001
After touching a patient	110	134	82.1	1,710	1,804	94.8	<0.001
After touching patient surroundings	86	167	51.5	1,716	1,804	95.1	<0.001
Total	482	719	67.0	7,696	8,499	90.6	<0.001
Personal protective equipment (PPE)							
Wearing PPE appropriately	330	422	78.2	5,049	5,294	95.4	<0.001
Changing PPE appropriately	129	222	58.1	507	644	78.7	<0.001
Disposing PPE appropriately	348	435	80.0	5,019	5,100	98.4	<0.001
Total	807	1,079	74.8	10,575	11,037	95.8	<0.001
Environmental (ENV) cleaning and disinfection							
Frequency of ENV cleaning	698	903	77.3	3,570	3,787	94.3	<0.001
Method of ENV cleaning	104	129	80.6	521	541	96.4	<0.001
Process of ENV cleaning	129	129	100.0	541	541	100.0	<0.001
Stethoscope disinfection	67	121	55.4	748	884	84.6	<0.001
Thermometer disinfection	115	115	100.0	580	580	100.0	<0.001
Overbed table disinfection	87	129	67.4	704	884	79.6	<0.001
Total	1,200	1,526	78.6	6,664	7,217	92.3	<0.001
Linen and waste management							
Collecting contaminated linen	102	129	79.1	477	541	88.2	<0.001
Placing in plastic bag and labelling MDRO	129	129	100.0	541	541	100.0	<0.001
Waste management	115	115	100.0	541	541	100.0	<0.001
Total	346	373	92.8	1,559	1,623	96.1	<0.001
Patient transfer							
Notifying prior to transfer	9	9	100.0	242	242	100.0	–
Wearing appropriate PPE	9	9	100.0	242	242	100.0	–
Covering wound prior to transfer	9	9	100.0	242	242	100.0	–
Total	27	27	100.0	726	726	100.0	–
Patient and family education							
Hand hygiene (five moments)	67	129	51.9	531	541	98.2	<0.001
Patient-dedicated equipment	78	129	60.5	528	541	97.6	<0.001
Total	145	258	56.2	1,059	1,082	97.9	<0.001
Grand total	3,199	4,174	76.6	29,901	31,807	94.0	<0.001

compliance rates were different among healthcare professionals (Baccolini et al., 2019; Costers et al., 2012; Erasmus et al., 2010). However, a previous study documented that the compliance rate of hand hygiene among physicians was lower than nurses but higher than healthcare assistants and other HCP categories (Baccolini et al., 2019).

This study also demonstrated that increased knowledge of MDRO prevention and an increase in correct MDRO transmission prevention practices among HCP reduced MDRO transmission rates. However, the incidence of MDRO in these SICUs did not significantly decrease. This could be explained by several factors. Firstly, all ICU patients were critically ill and antibiotic use was common. In addition, several MDRO pathogens are commonly found among SICU patients and in the environment. These factors can create an epidemic of MDROs in several SICUs. Reducing MDRO infection requires additional interventions such as screening of asymptomatic carriers and antibiotic stewardship (Lemmen & Lewalter, 2018). Although the implementation of any intervention in surgical settings is a challenge and more efforts are needed, this study highlighted that a multimodal strategy was successful in reducing MDRO transmission in SICUs. This may be because all participants, including the surgeons, agreed to participate in this project. This should be considered a key strategy for further infection control programs in surgical settings. To our knowledge, this is the first study to examine seven core activities to prevent MDRO transmission in the SICU including patient placement, hand hygiene, personal protective equipment (PPE), environmental cleaning and disinfection, linen and waste management, patient transfer and patient and family education. Previous studies have examined certain aspects of these activities such as hand hygiene compliance (Baccolini et al., 2019; Bird et al., 2010; Hoffmann et al., 2020), use of gloves (Bearman et al., 2010), use of gloves and gown (Baccolini et al., 2019) and environmental cleaning and disinfection (Chemaly et al., 2014), but did not examine the seven core activities as a whole.

These findings will guide policymakers and healthcare providers to enhance knowledge and practices of HCP, and reduce MDRO transmission. For combating MDRO spread, HCP should implement the seven core activities for preventing MDRO transmission. Multidisciplinary involvement is another key success factor for preventing MDRO transmission. Surgeons should be a part of IPC improvement programs in surgical settings. Nurses may be key to reducing the transmission of MDROs because they have the most frequent encounters with patients for care, and thus more occasions to practice MDRO transmission prevention when providing nursing care. The nursing role is also extended to include educating patients and families. However, the MDRO infection rate should also be examined in further studies.

The strengths of this study included the use of observation to increase the accuracy and reliability of the data. In addition, this study involved a large number of observation occasions resulting in a small variation in the findings.

5.1 | Limitations

This study had some limitations regarding the study unit and design. The findings from this study may be limited only to SICUs only. It is plausible that the participants may have modified their practices based on being observed. In addition, the post-test scores may have regressed towards the mean without any intervention based on the pre- and post-test design; maturation effects may have occurred from increased education and experience. Finally, this was an uncontrolled quasi-experimental study. Further studies should be conducted using a control group design or randomized-controlled trial to eliminate this limitation.

6 | CONCLUSIONS

Multimodal strategies including training, educational posters, a reminder poster, an educational YouTube channel, MDRO prevention champions, and feedback could enhance knowledge and practices in preventing MDRO transmission among HCP, and could reduce the MDRO transmission rate in SICUs in a university hospital in Thailand. The application of these multimodal strategies may improve knowledge and practices in preventing MDRO among HCP and reduce the spread of MDRO in other SICUs. Nurses may be key to preventing MDRO transmission.

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CONFLICT OF INTERESTS

None declared.

AUTHOR CONTRIBUTIONS

Study design: N.K. conceptualized the study, but all authors were involved in study design. Data collection: N.K., N.N., D.K., N.D., C.R. and U.S. Data analysis: N.K. Manuscript writing: N.K. wrote the first draft. All authors contributed to revising subsequent versions of the manuscript, and to approving the final manuscript.

ETHICAL CONSIDERATIONS

This study was approved by the Research Ethics Committee at the Faculty of Nursing, Chiang Mai University (reference no. 072–2017) and Research Ethics Committee 4 at the Faculty of Medicine, Chiang Mai University (reference no. 4918–2017). The participants learned about the study aims, procedures and benefits prior to written informed consent procedures. Data collection occurred post-consent and preserved the participant confidentially, and we protected their rights throughout the study.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

Aguinis, H., & Kraiger, K. (2009). Benefits of training and development for individuals and teams, organizations, and society. *Annual Review of Psychology*, *60*, 451–474. https://doi.org/10.1146/annurev.psych.60.110707.163505

Allen, M., Hall, L., Halton, K., & Graves, N. (2018). Improving hospital environmental hygiene with the use of a targeted multi-modal bundle strategy. *Infection, Disease and Health*, *23*(2), 107–113. https://doi.org/10.1016/j.idh.2018.01.003

Alshehari, A. A., Park, S., & Rashid, H. (2018). Strategies to improve hand hygiene compliance among healthcare workers in adult intensive care units: A mini systematic review. *Journal of Hospital Infection*, *100*(2), 152–158. https://doi.org/10.1016/j.jhin.2018.03.013

Baccolini, V., D'Egidio, V., de Soccio, P., Migliara, G., Massimi, A., Alessandri, F., Tellan, G., Marzuillo, C., De Vito, C., Ranieri, M. V., & Villari, P. (2019). Effectiveness over time of a multimodal intervention to improve compliance with standard hygiene precautions in an intensive care unit of a large teaching hospital. *Antimicrobial Resistance and Infection Control*, *8*, 92. https://doi.org/10.1186/s13756-019-0544-0

Backman, C., Taylor, G., Sales, A., & Marck, P. B. (2011). An integrative review of infection prevention and control programs for multidrug-resistant organisms in acute care hospitals: A socio-ecological perspective. *American Journal of Infection Control*, *39*(5), 368–378. https://doi.org/10.1016/j.ajic.2010.07.017

Bearman, G., Rosato, A. E., Duane, T. M., Elam, K., Sanogo, K., Haner, C., Kazlova, V., & Edmond, M. B. (2010). Trial of universal gloving with emollient-impregnated gloves to promote skin health and prevent the transmission of multidrug-resistant organisms in a surgical intensive care unit. *Infection Control and Hospital Epidemiology*, *31*(5), 491–497. https://doi.org/10.1086/651671

Bird, D. W., Sulis, C., Burke, P., & Agarwal, S. (2010). Hand hygiene compliance and multidrug-resistant organism infection in the surgical intensive care unit. *Chest*, *138*(4), 525A. https://doi.org/10.1378/chest.10980

Borer, A., Eskira, S., Nativ, R., Saidel-Odes, L., Riesenberg, K., Livshiz-Riven, I., & Peled, N. (2011). A multifaceted intervention strategy for eradication of a hospital-wide outbreak caused by carbapenem-resistant *Klebsiella pneumoniae* in Southern Israel. *Infection Control and Hospital Epidemiology*, *32*(12), 1158–1165. https://doi.org/10.1086/662620

Centers for Disease Control and Prevention (2006). *Management of multidrug-resistant organisms in healthcare setting 2006*. Retrieved from https://www.cdc.gov/mrsa/pdf/mdroGuideline2006.pdf

Chemaly, R. F., Simmons, S., Dale, C., Ghantoji, S. S., Rodriguez, M., Gubb, J., Stachowiak, J., & Stibich, M. (2014). The role of the healthcare environment in the spread of multidrug-resistant organisms: Update on current best practices for containment. *Therapeutic Advances in Infectious Disease*, *2*(3–4), 79–90. https://doi.org/10.1177/2049936114543287

Costers, M., Viseur, N., Catry, B., & Simon, A. (2012). Four multifaceted countrywide campaigns to promote hand hygiene in Belgian hospitals between 2005 and 2011: Impact on compliance to hand hygiene. *European Communicable Disease Bulletin*, *17*(18), 20161. https://doi.org/10.2807/ese.17.18.20161-en

D'Agata, E. M., Horn, M. A., Ruan, S., Webb, G. F., & Wares, J. R. (2012). Efficacy of infection control interventions in reducing the spread of multidrug-resistant organisms in the hospital setting. *PLoS One*, *7*(2), e30170. https://doi.org/10.1371/journal.pone.0030170

DalBen, M. D. F., Teixeira Mendes, E., Moura, M. L., Abdel Rahman, D., Peixoto, D., Alves dos Santos, S., Barcelos de Figueiredo, W., Vitale Mendes, P., Utino Taniguchi, L., Bezerra Coutinho, F. A., Massad, E., & Levin, A. S. (2016). A model-based strategy to control the spread of carbapenem-resistant enterobacteriaceae: Simulate and implement. *Infection Control and Hospital Epidemiology*, *37*(11), 1315–1322. https://doi.org/10.1017/ice.2016.168

Erasmus, V., Daha, T. J., Brug, H., Richardus, J. H., Behrendt, M. D., Vos, M. C., & van Beeck, E. F. (2010). Systematic review of studies on compliance with hand hygiene guidelines in hospital care. *Infection Control and Hospital Epidemiology*, *31*(3), 283–294. https://doi.org/10.1086/650451

Faul, F. (2020). *G*Power version 3.1.9.7*. Retrieved from https://www.psychologie.hhu.de/arbeitsgruppen/allgemeine-psychologie-und-arbeitspsychologie/gpower.html

Furuya, E. Y., Cohen, B., Jia, H., & Larson, E. L. (2018). Long-term impact of universal contact precautions on rates of multidrug-resistant organisms in ICUs: A comparative effectiveness study. *Infection Control and Hospital Epidemiology*, *39*(5), 534–540. https://doi.org/10.1017/ice.2018.35

Gomez-Simmonds, A., Hu, Y., Sullivan, S. B., Wang, Z., Whittier, S., & Uhlemann, A. C. (2016). Evidence from a New York City hospital of rising incidence of genetically diverse carbapenem-resistant *Enterobacter cloacae* and dominance of ST171, 2007–14. *Journal of Antimicrobial Chemotherapy*, *71*(8), 2351–2353. https://doi.org/10.1093/jac/dkw132

Hoffmann, M., Sendlhofer, G., Gombotz, V., Pregartner, G., Zierler, R., Schwarz, C., Tax, C., & Brunner, G. (2020). Hand hygiene compliance in intensive care units: An observational study. *International Journal of Nursing Practice*, *26*(2), e12789. https://doi.org/10.1111/ijn.12789

Kim, N.-H., Han, W.-D., Song, K.-H., Seo, H.-K., Shin, M.-J., Kim, T. S., Park, K. U., Ahn, S., Yoo, J. S., Kim, E. S., & Kim, H. B. (2014). Successful containment of carbapenem-resistant Enterobacteriaceae by strict contact precautions without active surveillance. *American Journal of Infection Control*, *42*(12), 1270–1273. https://doi.org/10.1016/j.ajic.2014.09.004

Lemmen, S. W., & Lewalter, K. (2018). Antibiotic stewardship and horizontal infection control are more effective than screening, isolation and eradication. *Infection*, *46*(5), 581–590. https://doi.org/10.1007/s15010-018-1137-1

Mathai, A. S., George, S. E., & Abraham, J. (2011). Efficacy of a multimodal intervention strategy in improving hand hygiene compliance in a tertiary level intensive care unit. *Indian Journal of Critical Care Medicine*, *15*(1), 6–15. https://doi.org/10.4103/0972-5229.78215

Mitchell, B. G., Hall, L., White, N., Barnett, A. G., Halton, K., Paterson, D. L., Riley, T. V., Gardner, A., Page, K., Farrington, A., Gericke, C. A., & Graves, N. (2019). An environmental cleaning bundle and healthcare-associated infections in hospitals (REACH): A multicentre, randomised trial. *The Lancet. Infectious Diseases*, *19*(4), 410–418. https://doi.org/10.1016/S1473-3099(18)30714-X

National Antimicrobial Resistance Surveillance Center Thailand (NARST) (2020). *Antimicrobial Resistance 2000–2019*. Retrieved from http://narst.dmsc.moph.go.th/data/AMR%202000-2019-06M.pdf

N'Guyen, T., Bourigault, C., Guillet, V., Buttes, A.-C., Montassier, E., Batard, E., Birgand, G., & Lepelletier, D. (2019). Association between excreta management and incidence of extended-spectrum β-lactamase-producing Enterobacteriaceae: Role of healthcare workers' knowledge and practices. *Journal of Hospital Infection*, *102*(1), 31–36. https://doi.org/10.1016/j.jhin.2018.12.006

O'Neill, J. (2014). *Review on antimicrobial resistance. Antimicrobial resistance: Tackling a crisis for the health and wealth of nations 2014*. Wellcome Trust.

Oliveira, A. C., Gama, C. S., & Paula, A. O. (2018). Multimodal strategy to improve the adherence to hand hygiene and self-assessment of the institution for the promotion and practice of hand hygiene. *Journal of Public Health*, *40*(1), 163–168. https://doi.org/10.1093/pubmed/fdx035

Phumart, P., Phodha, T., Thamlikitkul, V., Riewpaiboon, A., Prakongsai, P., & Limwattananon, S. (2012). Health and economic impacts of antimicrobial resistant infections in Thailand: A preliminary study. *Journal of Health Systems Research*, *6*(3), 353–360. https://doi.org/10.1093/pubmed/fdx035

Shen, L. I., Wang, X., An, J., An, J., Zhou, N., Sun, L. U., Chen, H., Feng, L., Han, J., & Liu, X. (2017). Implementation of WHO multimodal strategy for improvement of hand hygiene: a quasi-experimental study in a Traditional Chinese Medicine hospital in Xi'an, China. *Antimicrobial Resistance and Infection Control*, *6*, 98. https://doi.org/10.1186/s13756-017-0254-4

Simmons, B. P., & Larson, E. L. (2015). Multiple drug resistant organisms in healthcare: The failure of contact precautions. *Journal of Infection Prevention*, *16*(4), 178–181. https://doi.org/10.1177/1757177415570104

Squires, J. E., Suh, K. N., Linklater, S., Bruce, N., Gartke, K., Graham, I. D., Karovitch, A., Read, J., Roth, V., Stockton, K., Tibbo, E., Woodhall, K., Worthington, J., & Grimshaw, J. M. (2013). Improving physician hand hygiene compliance using behavioural theories: A study protocol. *Implementation Science*, *4*(8), 16. https://doi.org/10.1186/1748-5908-8-16

Tzouvelekis, L. S., Markogiannakis, A., Psichogiou, M., Tassios, P. T., & Daikos, G. L. (2012). Carbapenemases in *Klebsiella pneumoniae* and other Enterobacteriaceae: An evolving crisis of global dimensions. *Clinical Microbiology Reviews*, *25*(4), 682–707. https://doi.org/10.1128/CMR.05035-11

Ventola, C. L. (2014). Social media and health care professionals: Benefits, risks, and best practices. *Pharmacy and Therapeutics*, *39*(7), 491–520. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4103576/pdf/ptj3907491.pdf

Viale, P., Tumietto, F., Giannella, M., Bartoletti, M., Tedeschi, S., Ambretti, S., Cristini, F., Gibertoni, C., Venturi, S., Cavalli, M., De Palma, A., Puggioli, M. C., Mosci, D., Callea, E., Masina, R., Moro, M. L., & Lewis, R. E. (2015). Impact of a hospital-wide multifaceted programme for reducing carbapenem-resistant Enterobacteriaceae infections in a large teaching hospital in northern Italy. *Clinical Microbiology and Infection*, *21*(3), 242–247. https://doi.org/10.1016/j.cmi.2014.10.020

World Health Organization (2014). *Antimicrobial resistance global report on surveillance*. World Health Organization.

World Health Organization (2016). *Guidelines on core components of infection prevention programmes at the national and acute health care facility level*. World Health Organization.

World Health Organization (2018). *WHO competency framework for health worker education and training on antimicrobial resistance*. World Health Organization.

World Health Organization (2019). *Implementation manual to prevent and control the spread of carbapenem-resistant organisms at the national and health care facility level*. World Health Organization.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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