EFFECT OF PLAN-DO-CHECK-ACT CYCLE ON CONTROLLING RISK OF MULTIDRUG-RESISTANT ORGANISM INFECTIONS AMONG PATIENTS IN INTENSIVE CARE UNIT, THE SECOND XIANGYA HOSPITAL, CENTRAL SOUTH UNIVERSITY, HUNAN, PR CHINA

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Abstract. Patients in the intensive care unit (ICU) are at a high risk of developing multidrug-resistant organism (MDRO) infections because of their critical condition, frequent invasive procedures and inappropriate use of broad-spectrum antibiotics. This study evaluated the effect of the Plan-Do-Check-Act (PDCA) cycle system on controlling the risk of MDRO infections in ICU patients. Patients who tested negative for bacterial infection upon hospital admission were randomly assigned to control and PDCA groups (n = 64 per group) for routine MDRO prevention and control measures (the former group) and routine measures together with the PDCA cycle-based management (the latter group) during their ICU stay. Patients' MDRO infection rate, antimicrobial use density, ICU length of stay, total hospitalization stay and ICU MDRO contamination were significantly reduced in the PDCA group compared to the control (p-value <0.050). However, the 28-day mortality was not different between the two groups. In addition, nurses' hand hygiene behavior was significantly improved in the PDCA group compared to the control (n = 30 per group). The results confirmed the utility of the PDCA cycle system for bacterial infection prevention and control in ICUs. However, its long-term benefits need to be determined through expanding the cohort size and extending the intervention duration.

Keywords: antimicrobial use density, infection control, intensive care unit, plan-do-check-act, multidrug-resistant organism

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INTRODUCTION

The intensive care unit (ICU), the core unit for centralized treatment of critically ill patients in hospitals, has become a high-risk area for infections by multidrug-resistant organism (MDRO) due to patients' complicated conditions and compromised immune status, frequent invasive procedures, and extensive use of broad-spectrum antibiotics (Ramachandran *et al*, 2024). In recent years, MDRO infection rate in ICUs worldwide has been on the rise, with the detection rate of pathogens such as *Acinetobacter baumannii* and methicillin-resistant *Staphylococcus aureus* (MRSA) exceeding 30%, prolonging patients' dependence on mechanical ventilation, extending ICU length of stay and increasing mortality, while at the same expanding the use of medical resources and elevating the risk of MDRO transmission (Golli *et al*, 2022). To effectively curb MDRO infections in ICUs has become a key challenge in the field of hospital infection prevention and control (Yuan and Peng, 2021).

A Plan-Do-Check-Act (PDCA) cycle was proposed as a quantifiable and standardized quality improvement tool (Lu *et al*, 2022). Through a closed-loop management mode, utilizing the "Plan-Do-Check-Act" approach, the system has enabled remarkable improvements in the fields of medical quality control and hospital infection prevention (Meehan *et al*, 1993). Studies have validated the efficacy of the PDCA cycle in reducing catheter-related bloodstream infections and surgical site infections (Kong *et al*, 2021; Lai *et al*, 2022). However, its employment in the systematic

intervention of MDRO infections in ICUs is poorly documented. The existing MDRO prevention and control in ICUs primarily rely on empirical measures, such as hand hygiene supervision and environment disinfection (Çağlayan *et al*, 2022). This strategy lacks the dynamic evaluation and continuous improvement mechanism of the PDCA approach. Thus, there is low compliance in the implementation of improvement measures and significant fluctuations in their effectiveness (Honarmand *et al*, 2024). Exploring the precise application path of the PDCA cycle in the prevention and control of MDRO infections in ICUs has practical significance.

Our study developed a PDCA-based MDRO infection prevention and control system to evaluate its impact on MDRO infection rate, quantitative detection of MDROs, hospitalization time, and mortality frequency among ICU inpatients, as well as on the hand hygiene practices of ICU nurses. The insights obtained are expected to provide valuable evidence for reducing infection-related complications, patients' mortality rate and MDRO contamination in ICUs.

MATERIALS AND METHODS

Participants enrollment and study location

Participants were selected from ICU inpatients at the Second Xiangya Hospital, Central South University, Hunan, PR China, who were admitted between April 2024 and June 2025. Using the MDRO infection rate as the primary endpoint and assuming an MDRO infection rate of ~30% in the control group and a reduction of 20% in the intervention group (Huang *et al*, 2019), the sample size ($\alpha = 0.05$) was estimated to be 56 per group using a G-Power software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, North Rhine-Westphalia, Germany).

Inclusion criteria were (i) ≥18 years of age, (ii) continuous ICU stay ≥48 hours, and (iii) expected stay ≥28 days. Exclusion criteria were (i) confirmed MDRO colonization/ infection before admission (based on the initial pathogen identification

upon admission), (ii) diagnosis of severe immunodeficiency, and (iii) discharge/death before the end of the study (15 days). Factoring in a 10% loss in the follow-up, 64 cases were finally enrolled in each group (Fig 1). Cluster randomization was used for assignment to the PDCA group (PDCA cycle management) or the control group (routine MDRO prevention and control procedures) (Ji and Ye, 2024).

Participants' management procedure

Case screening, MDRO test results recording, hand hygiene compliance spot check, and environment sampling were carried out by research assistants who had undergone training (conducted by non-ICU healthcare staff). Research assistants were only informed of the patient enrollment procedures, but were unaware of the group (intervention or control) to which the patients were assigned.

In the control group, patients underwent the standard prevention and control plan of Second Xiangya Hospital, namely i) MDRO screening of patients upon admission, ii) nurse hand hygiene supervision (once a month), iii) environment cleaning (performed once daily) and iv) upon detection of nosocomial infection, patient treatment with antibacterial drug according to the Guiding Principles for Clinical Application of Antibacterials (Joynt *et al*, 2023).

In the PDCA group, the aforementioned protocol was managed using the PDCA cycle as follows.

Plan: An MDRO prevention and control team responsible for baseline investigation and scheme formulation was established, consisting of the ICU director, infection control nurses, clinical pharmacists, and microbiologists. A retrospective analysis was conducted on the MDRO infection rate, nurse hand hygiene compliance, antimicrobial use density (AUD), and environmental cleanliness compliance rate in the ICU over the past year. This required identifying the following core issues: improper nurse hand

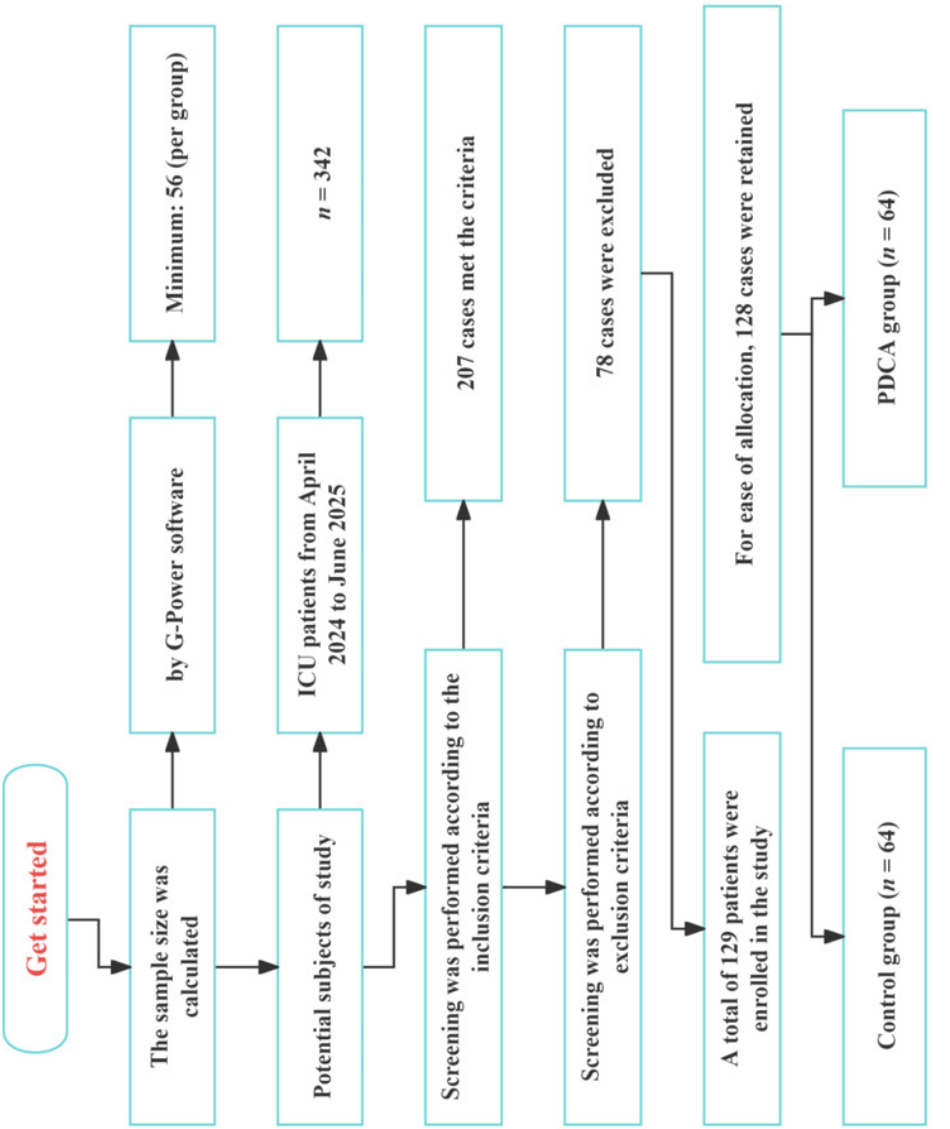

Fig 1 - Screening process of study subjects

ICU: intensive care unit; PDCA: Plan-Do-Check-Act

hygiene, excessive antibiotic use, and insufficient frequency of environmental disinfection. Then, the following management objectives were established: post-intervention MDRO infection rate <20%, nurse hand hygiene compliance rate ≥90% and an AUD ≤90 defined daily dose (DDD)/100 patient-days.

Do: Every month, ICU nurses were trained in MDRO identification, proper hand hygiene procedure, and contact isolation procedures; only those who passed the assessment (theory + practice) were allowed to participate in the program (passing score ≥95). The management process optimization was as follows: (i) for high-risk patients (*eg,* recently prescribed carbapenem antibiotics), clearly marked single-room isolation was implemented in advance; (ii) surfaces of frequently touched items were wiped with chlorine disinfectant (500 mg/l) twice a day, and ultraviolet irradiation was conducted three times a week (30 minutes each time); (iii) a tiered prescribing system was adopted, with mandatory infectious disease/ critical care consultation prior to prescribing restricted-spectrum antibiotics; (iv) de-escalation therapy was promoted, with therapy re-evaluated after 48 hours based on clinical response. Suspected cases of MDRO were registered daily. Nurse hand hygiene compliance (through video surveillance) and environment cleanliness compliance (using an ATP bioluminescence assay) (Mart *et al*, 2021) were determined weekly. A prevention and control summary report was issued monthly.

Check: MDRO infection, hand hygiene compliance, environmental cleanliness compliance rate, and AUD were compared before and after the intervention program.

Act: Hand hygiene training and environment disinfection processes were incorporated into the standard operating procedure (SOP) of the ICU. Regarding the problems identified during the management process, the prevention and control team sought appropriate

and applicable solutions, which were implemented in the next management cycle.

The main differences between the conventional and PDCA management systems are summarized in Table 1.

Data collection

MDRO infection rate during a patient's ICU stay was determined. Diagnosis was undertaken according to the Hospital Infection Diagnosis Criteria and the Centers for Disease Control and Prevention (CDC) definition of MDRO (Ziegler *et al*, 2019). AUD during the ICU stay was measured and expressed as the daily drug dose (DDD) consumed per 100 patient.days. Samples were collected from frequently touched surfaces, *eg*, bed sheets, bed rails and the ward (three corners randomly selected, and the average value recorded) upon a patient's admission to the ICU, and again upon discharge. MDROs (carbapenem-resistant Enterobacteriaceae bacteria, MRSA, and other pertinent MDROs) were cultured, isolated and the number of colonies determined (Zhou *et al*, 2021). ICU length of stay, total hospitalization length of stay and 28-day all-cause mortality following hospital admission were recorded.

After two weeks of management, a random check was conducted on the hand hygiene practices of the nurses in the two groups (n = 30 nurses in each group). Hand disinfection operation procedure and rating scale were adopted for scoring (total score = 100) as follows (Jiang *et al*, 2025).

$$\text{Percent hand hygiene compliance rate} = \frac{\text{number of hand hygiene performed}}{\text{number of hand hygiene opportunities}} \times 100$$

$$\text{Percent hand hygiene effectiveness rate} = \frac{\text{number of staff performing correct procedure}}{\text{number of staff performing hand hygiene}} \times 100$$

Table 1

Differences between PDCA and conventional management

Method	Management	
	Conventional	PDCA
Supervision of hand hygiene	Once a month	Weekly video spot check + real-time feedback
Frequency of environmental disinfection	Once daily	Areas of high-risk patients administered twice daily
Management of antibiotics use	Refer to guide manual for use of medication	Hierarchical management + 48-hour efficacy evaluation
MDRO screening	Single screening at admission	Admission screening + weekly dynamic monitoring

MDRO: multidrug-resistant organism; PDCA: Plan-Do-Check-Act

Data analysis

For subjects with data missing values ≤5%, the mean imputation method was used (Austin *et al*, 2021); subjects with >5% missing data were excluded from the study. Comparison of counting data [*n* (%)] employed the chi-square test. Measured data first underwent the Shapiro-Wilk test, and if there was a normal distribution, the data were presented in the form of mean ± standard deviation (SD and analyzed by the independent sample *t*-test (between groups) and the paired *t*-test (within groups). Comparison of non-normally distributed data employed the Mann-Whitney U test (between groups) and the Wilcoxon test (within groups). Statistical significance is accepted if *p*-value <0.050. For calculation, data were entered independently by two researchers into the Statistical Package for the Social Sciences (SPSS) version 30.0 (IBM Corp, Armonk, NY).

Ethical considerations

This study protocol was approved by the Ethics Committee of The Second Xiangya Hospital of Central South University (no. 24YA022). Prior written consent was received from each participant.

RESULTS

The PDCA group consisted of 30 females and 34 males , average (mean ± SD) age of 65 ± 5 years (range = 49-75 years), while the control group consisted of 25 females and 39 males, average age of 63 ± 6 years (range = 53-77 years) (Table 2). The inter-group comparison of the clinical baseline data showed no statistically significant difference, confirming that the health status of the two groups was comparable.

The MDRO infection rate was significantly lower in the PDCA group compared to the control group (9% *vs* 23%, respectively; *p*-value <0.05) (Table 3). In the PDCA group, of the 6 bacterial isolates, 3 were *Acinetobacter baumannii*, 2 methicillin-resistant *Staphylococcus aureus* (MRSA), and 1 each of carbapenem-resistant *Enterobacter* (CRE) and unidentified MDRO, while in the control group of the 15 bacterial isolates, 8 were *A. baumannii*, 4 MRSA, 2 CRE, and 1 unidentified MDRO. AUD (mean ± SD) of the PDCA group was 84 ± 5 DDD/100 patient.hour, significantly lower than that of the control group (102 ± 14 DDD/100 patient.hour, *p*-value <0.050) (Table 3).

Before the introduction of the PDCA system, quantification of MDRO among the patients' bed sheets, bed rails and ward is not significantly different between the PDCA and control group (bed sheet: 84 ± 10 (mean ± SD) *vs* 84 ± 13 colony forming units per square centimeter (CFU/cm^2); bed rail: 85 ± 9 *vs* 84 ± 14 CFU/cm^2; and ward: 125 ± 16 *vs* 123 ± 16 CFU/cm^2) (Fig 2). Following application of the PDCA system to the standard patient's management procedure of the Hospital, MDRO contamination at the three test sites is significantly lower in the PDCA group compared to control (bed sheet: 38 ± 8 *vs* 61 ± 12 CFU/cm^2; bed rail: 42 ± 9 *vs* 59 ± 12 CFU/cm^2; and ward: 58 ± 13 *vs* 89 ± 19

Table 2

Details of articles chosen for scoping review

Characteristic	Control group (N = 64)	PDCA group (N = 64)	Statistics	*p*-value*
Sex, *n* (%)				
Male	39 (61)	34 (53)	$X^2 = 0.797$	0.372
Female	25 (39)	30 (47)		
Mean (± SD) age, years	65 (± 5)	63 (± 6)	t = 1.178	0.241
Reason for ICU admission, *n* (%)			$X^2 = 2.207$	0.820
Severe respiratory disease	24 (38)	20 (31)		
Circulatory critical illness	13 (20)	15 (24)		
Nervous system emergency	17 (27)	14 (22)		
Multiple organ dysfunction syndrome	1 (2)	2 (4)		
After major surgery or trauma	6 (8)	7 (11)		
Others	3 (5)	6 (8)		
Combined with diabetes mellitus, *n* (%)			$X^2 = 0.554$	0.457
Yes	24 (38)	20 (31)		
No	40 (62)	44 (69)		

Table 2 (cont)

Characteristic	Control group (N = 64)	PDCA group (N = 64)	Statistics	*p*-value*
Combined with hypertension, *n* (%)			$X^2 = 0.518$	0.472
Yes	24 (38)	28 (31)		
No	40 (62)	44 (69)		
Combined with hyperlipidemia, *n* (%)			$X^2 = 0.422$	0.516
Yes	12 (19)	15 (24)		
No	52 (81)	49 (76)		
Smoking history, *n* (%)			$X^2 = 0.582$	0.446
Yes	42 (66)	46 (72)		
No	22 (34)	18 (28)		
Alcohol use *n* (%)			$X^2 = 1.222$	0.269
Yes	26 (41)	20 (31)		
No	38 (59)	44 (69)		

*Statistically significant when *p*-value <0.050

ICU: intensive care unit; PDCA: Plan-Do-Check-Act; t: independent sample t test; X^2: chi-square test

Fig 2 - MDRO evaluation before and after management

A: bed; B: bedrail; C: ward

*p-value <0.050 comparing between same group; †p-value <0.050 between Control and PDCA group

CFU/cm^2: colony forming units per square centimeter; MDRO: multidrug-resistant organism; PDCA: Plan-Do-Check-Act

Table 3

Comparison of MDRO infection risk

Characteristic	Control group (N = 64)	PDCA group (N = 64)	Statistics	*p*-value*
MDRO infection, *n* (%)	15 (23)	6 (9)	$X^2 = 4.614$	0.032
Mean (± SD) DDD of AUD	102 (± 14)	84 (± 5)	t = 9.948	<0.001

*Statistically significant when *p*-value <0.050

AUD: antimicrobial use density; DDD: defined daily dose; MDRO: multidrug-resistant organism; PDCA: Plan-Do-Check-Act; SD: standard deviation; t: independent sample t test; X^2: chi-square test

CFU/cm^2 (*p*-value <0.050) (Fig 2). Of note, MDRO contamination at the test sites in the control group is also significantly reduced following the standard management procedure.

ICU length of stay (mean ± SD) was 6 ± 2 days in the PDCA group compared to 7 ± 2 days in the control group (*p*-value <0.05) (Table 4). A similar trend was observed in the total length of hospitalization (14 ± 3 *vs* 15 ± 3 days, *p*-value <0.05). However, the 28-day all-cause mortality is not significantly different between the two groups (Table 4). ICU patients typically have severe underlying conditions. Mortality is affected by multiple factors such as multi-organ failure rather than just MDRO infections. The PDCA cycle reduced infection-related complications to shorten hospital stays, but it could not reverse the poor prognosis of critically ill patients.

In terms of nurse hand hygiene compliance, the rate in the PDCA and control group was 93 and 73% respectively (*p*-value <0.05) (Table 5). In addition, the hand hygiene effectiveness rate was similarly higher in the PDCA group compared to the control (97% *vs* 73%; *p*-value <0.05) (Table 5).

Table 4

Comparison of hospital stay and mortality rate

Characteristic	Control group (N = 64)	PDCA group (N = 64)	Statistics	*p*-value*
Mean (± SD) days	15 (23)	6 (9)	$X^2 = 4.614$	0.032
of ICU stay	7 (± 2)	6 (± 2)	t = 2.380	0.019
Mean (± SD) days of hospital stay	15 (± 3)	14 (± 3)	t = 2.492	0.014
28-day all-cause mortality, *n* (%)	7 (11)	5 (8)	$X^2 = 0.368$	0.544

*Statistically significant when *p*-value <0.050

ICU: intensive care unit; PDCA: Plan-Do-Check-Act; SD: standard deviation; t: independent sample t test; X^2: chi-square test

Table 5

Comparison of hand hygiene results between two nurse groups

Group	Control group (N = 30)	PDCA group (N = 30)	X^2	*p*-value*
Hand hygiene compliance rate, *n* (%)	22 (73)	28 (93)	4.320	0.038
Hand hygiene accuracy rate, *n* (%)	22 (73)	29 (97)	6.405	0.011

*Statistically significant when *p*-value <0.050

PDCA: Plan-Do-Check-Act; X^2: chi-square test

DISCUSSION

Our study demonstrated that the introduction of PDCA into the hospital's regular patients' management program was conducive to reducing MDRO infection among ICU patients and MDRO contamination in the ward.

The lower MDRO infection rate in the PDCA group compared to the control was consistent with previous studies on the role of the PDCA cycle system in reducing infections at surgical sites (Bao *et al*, 2024) and in catheter-related bloodstream infections (Fan and Zhou, 2025). However, the MDRO infection rate in our case series remained above 10%, which might be related to the higher complexity of underlying diseases in the ICU patients and the concealed transmission routes of MDROs. Additionally, the decreased MDRO colonization rate in the PDCA group suggested that the PDCA cycle had effectively disrupted the "colonization-infection" chain of MDROs through measures such as environment disinfection and contact isolation, as reported by Sun *et al* (2021). In our study, the frequency of environmental disinfection (twice daily with chlorine-based disinfectant) might be a critical reinforcing factor. The AUD in the PDCA group was decreased, highlighting the effect of the PDCA cycle system in promoting rational drug use. Other previous studies have validated the role of the PDCA cycle system in reducing AUD through measures such as hierarchical management of antibacterial drugs and the optimization of consultation systems (Huang *et al*, 2023). However, Yin *et al* (2025) have achieved a greater reduction in AUD by integrating real-time monitoring technologies, such as an electronic prescribing system and rapid microbial test. In contrast, our reliance on manual verification could have limited the PDCA effectiveness.

The ICU length of stay and total hospitalization time were shortened in the PDCA group compared to the control group, suggesting that PDCA implementation was instrumental in accelerating patient rehabilitation. Shi and Xu (2025) reported that shortened ICU stays following PDCA intervention, which was consistent with the trend observed in our study. The underlying reason is related to infection control, which indirectly shortens hospital stay by reducing complications (sepsis and

ventilator-associated pneumonia), in line with the core logic of infection prevention and control (Kern, 2025). It is worth noting that although the infection rate decreased, there was no difference in mortality between the PDCA and control groups. Several factors may underlie this observation: i) the high severity of underlying diseases in ICU patients limited the improvement effect of infection control on prognosis, and ii) mortality, as a long-term outcome measure, was dependent on various factors, *eg*, multiple organ failure, progression of underlying diseases, other than on MDRO infections alone. These results indicated that when implementing the PDCA cycle system in ICUs, integrating comprehensive measures, such as early pathogen diagnosis and precise anti-infection treatment, was crucial in achieving comprehensive improvement in patients' prognosis.

The improvement of nurses' hand hygiene compliance and effectiveness in the PDCA group confirmed the superiority of the "people-environment" dual-track prevention and control strategy (Chen, 2025). Wei *et al* (2022) pointed out that hand hygiene training alone improves compliance, while PDCA intervention combined with environmental disinfection further enhances compliance. Through the installation of touch-free hand sanitizer dispensers and the implementation of the "hand hygiene supervisor" program, a more significant improvement was achieved in our study. This suggested a synergy between hardware input and behavioral intervention.

However, our investigation was subject to several limitations. Firstly, the management of both patient groups was initiated upon admission and continued until ICU discharge or the patient's death. Considering the active implementation of the intervention measures, such as training and process optimization, as well as the need for ICU medical staff to be directly involved in the execution of prevention and control measures, researchers and participants were unable to achieve complete blinding of the group assignment (open-label

design). Nonetheless, assessor- and statistician-blinded approaches were adopted to reduce outcome assessment biases. Secondly, despite an *a priori* sample size calculation, the small cohort size might restrict the broader applicability of the results. Thirdly, participants were all from a single center, lacking regional and population representation. Fourthly, absence of some data on environment cleanliness compliance rates, such as the failure to report specific test values, might have compromised the reliability of the results. Fifthly, the short study duration (3 months) made it difficult to assess the long-term impact of the PDCA cycle system. Therefore, in future studies, we need to verify the universality of the PDCA cycle across hospitals of different levels and locations in various regions. The follow-up time should also be extended to observe the long-term effect of the PDCA cycle on reducing MDRO colonization/infection. Sixthly, integrating molecular epidemiology to track the transmission trajectory of drug resistance genes, such as *mecA* and $bla_{\text{NDM-1}}$, should help to clarify the impact of intervention measures on the evolution of drug resistance. Finally, it is advisable to develop an AI monitoring system, which utilizes Internet of Things technology (Yang *et al*, 2024) to collect real-time data on hand hygiene compliance and environment disinfection, thereby achieving optimization of the PDCA cycle system.

In conclusion, the implementation of the "Plan-Do-Check-Act" (PDCA) cycle system into the prevention and control of MDROs in ICUs reduced multidrug-resistant organism (MDRO) infection and colonization rates, and improved the compliance rate of ICU nurse hand hygiene and environment cleanliness. Although the patient's mortality rate did not improve, our study confirmed the core value of the PDCA cycle system in optimizing the infection control process and promoting the implementation of multi-dimensional prevention measures. In the future, it will be necessary to expand the sample size,

extend the intervention period and introduce an upgrade of the PDCA cycle system using AI technology, to provide a scientific basis for the development of more precise MDRO prevention and control in ICUs in PR China.

ACKNOWLEDGEMENTS

The study was supported by the General Program of Natural Science Foundation of Guangxi Zhuang Autonomous Region (project no. 2025GXNSFAA069028) and Hunan Provincial Social Science Fund Project (project no. 23YBA022).

CONFLICT OF INTEREST DISCLOSURE

The authors declare no conflict of interest.

AVAILABILITY OF DATA AND MATERIALS

The datasets analyzed in the current study are available from the corresponding author upon reasonable request.

REFERENCES

Austin PC, White IR, Lee DS, van Buuren S. Missing data in clinical research: a tutorial on multiple imputation. *Can J Cardiol* 2021; 37(9): 1322-31.

Bao WJ, Wang C, Zhang LL, Yu HX. Impact of combined cluster nursing and Plan-Do-Check-Act cycle on postoperative infection risk and clinical outcomes in patients with open fractures and multidrug resistance. *Asian J Surg* 2024; 47(10): 4613-4.

Çağlayan C, Barnes SL, Pineles LL, Harris AD, Klein EY. A data-driven framework for identifying intensive care unit admissions colonized with multidrug-resistant organisms. *Front Public Health* 2022; 10: 853757.

Chen X. PDCA cycle and safety culture in nursing safety management of Day Ward chemotherapy. *World J Surg Oncol* 2025; 23(1): 99.

Fan Y, Zhou X. Application of the Plan-Do-Check-Action cycle in reducing the incidence of forearm hematoma in patients after transradial artery percutaneous coronary interventions. *J Multidiscip Healthc* 2025; 18: 1183-9.

Golli AL, Cristea OM, Zlatian O, *et al*. Prevalence of multidrug-resistant pathogens causing bloodstream infections in an intensive care unit. *Infect Drug Resist* 2022; 15: 5981-92.

Honarmand K, Wax RS, Penoyer D, *et al*. Society of critical care medicine guidelines on recognizing and responding to clinical deterioration outside the ICU: 2023. *Crit Care Med* 2024; 52(2): 314-30.

Huang SS, Septimus E, Kleinman K, *et al*. Chlorhexidine versus routine bathing to prevent multidrug-resistant organisms and all-cause bloodstream infections in general medical and surgical units (ABATE Infection trial): a cluster-randomised trial. *Lancet* 2019; 393(10177): 1205-15.

Huang Y, Huang Y, Yi L, Pan W, Chen Y. A FOCUS-PDCA quality improvement model for reducing the distribution defect rate of sterile packages. *Sci Rep* 2023; 13(1): 15016.

Ji B, Ye W. Prevention and control of hospital-acquired infections with multidrug-resistant organism: a review. *Medicine (Baltimore)* 2024; 103(4): e37018.

Jiang P, Liu Y, Gu HY, Li QX, Xue LB. Implementation of six sigma management to standardize surgical hand disinfection practices. *BMC Surg* 2025; 25(1): 118.

Joynt GM, Ling L, Wong WT, Lipman J. Therapeutic drug monitoring of carbapenem antibiotics in critically ill patients: an overview of principles, recommended dosing regimens, and clinical outcomes. *Expert Rev Clin Pharmacol* 2023; 16(8): 703-14.

Kern BK. Implementation of a unit-specific quality improvement process for prevention of hospital-acquired pressure injuries. *BMJ Open Qual* 2025; 14(4): e003379.

Kong X, Zhu X, Zhang Y, Wu J. The application of plan, do, check, act (PDCA) quality management in reducing nosocomial infections in endoscopy rooms: it does work. *Int J Clin Pract* 2021; 75(8): e14351.

Lai F, Xie D, Weng Y, *et al*. Application of plan-do-check-act management to improve first-attempt insertion success rates of internal jugular vein catheterization for standardized training residents in an intensive

care unit. *BMC Med Educ* 2022; 22(1): 420.

Lu MN, Zhang BL, Dai QH, Fu XH. Application of the Plan-Do-Check-Act cycle in shortening the decision to delivery interval time. *Risk Manag Healthc Policy* 2022; 15: 1315-23.

Mart MF, Williams Roberson S, Salas B, Pandharipande PP, Ely EW. Prevention and management of delirium in the Intensive Care Unit. *Semin Respir Crit Care Med* 2021; 42(1): 112-26.

Meehan CD, Silvestri A, Street ED. Improving blood glucose monitoring in a hospital setting using the PDCA approach. Plan, do, check, act cycle. *J Nurs Care Qual* 1993; 7(4): 56-63.

Ramachandran MS, Sandaradura I, Nayyar V. Prevalence of multidrug-resistant organisms in intensive care unit patients and rate of subsequent bacteraemia: a 5-year study. *Anaesthesiol Intensive Ther* 2024; 56(5): 277-84.

Shi Y, Xu Y. The effect of Plan Do Check Act cycle management mode on patients with severe pneumonia complicated with respiratory failure: a retrospective study. *Pak J Med Sci* 2025; 41(8): 2273-8.

Sun J, Cao W, Song Y, Yuan C. Plan, Do, Check, Act (PDCA) cycle nursing model reduces the risk of hemangioma in hemodialysis patients. *Iran J Public Health* 2021; 50(12): 2560-6.

Wei Y, Xu M, Wang W, *et al*. Effect analysis of Plan-do-check-act cycle method applied in nursing management of disinfection supply room. *Panminerva Med* 2022; 64(1): 127-9.

Yin D, Tang Y, Wang S, Wang S, Hou R, Duan J. Use of multiple metrics and clustering analysis to assess antimicrobial use in Shanxi hospitals, China: a cross-sectional study based on 25 general hospitals. *Front Public Health* 2025; 13: 1464613.

Yang X, Li YM, Wang Q, Li R, Zhang P. Machine learning model based on RCA-PDCA nursing methods and differentiating factors to predict hypotension during cesarean section surgery. *Comput Biol Med* 2024; 174: 108395.

Yuan ZQ, Peng YZ. Multidrug resistant organisms in burn intensive care unit: strategies and opinions. *Zhonghua Shao Shang Za Zhi* 2021;

37(6): 524-9. [in Chinese]

Zhou Y, Yu F, Yu Y, Zhang Y, Jiang Y. Clinical significance of MDRO screening and infection risk factor analysis in the ICU. *Am J Transl Res* 2021; 13(4): 3717-23.

Ziegler KM, Haywood JD, Sontag MK, Mourani PM. Application of the new Centers for Disease Control and Prevention surveillance criteria for ventilator-associated events to a cohort of PICU patients identifies different patients compared with the previous definition and physician diagnosis. *Crit Care Med* 2019; 47(7): e547-54.