Application of the PDCA Cycle Combined with Predictive Nursing for Error Prevention and Control in Pharmacy Intravenous Admixture Services

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Abstract [**Objectives**] To assess the effectiveness of integrating the PDCA cycle with predictive nursing for error prevention and control in pharmacy intravenous admixture services. [**Methods**] A before-and-after control design was employed to compare the error rate, recheck pass rate, timely delivery rate, and risk prevention awareness scores among staff ($n=28$) during the conventional management period (January to December 2024, encompassing 124 680 medical orders) and the PDCA cycle combined predictive nursing management period (January to December 2025, encompassing 128 420 medical orders). [**Results**] Following the intervention, the error rate significantly decreased from 0.122% to 0.053% ($P<0.001$). Concurrently, the recheck pass rate increased from 99.38% to 99.82% ($P<0.001$), and the timely delivery rate improved from 96.10% to 98.72% ($P<0.001$). Additionally, risk prevention awareness scores among staff rose significantly from (82.45 ± 5.36) to (93.26 ± 4.18) points ($P<0.001$). [**Conclusions**] The integration of the PDCA cycle with predictive nursing substantially enhances the quality of medication safety management in pharmacy intravenous admixture services.

Key words PDCA, Predictive nursing, Pharmacy intravenous admixture service, Error prevention and control, Medication safety

1 Introduction

The pharmacy intravenous admixture service is a critical hospital department responsible for the centralized review, dispensing, recheck, and delivery of intravenous medications. The quality of its operations directly impacts the safety of clinical drug administration[1]. Although intravenous medications act rapidly, they entail significant risks. Errors related to the drug, dosage, solvent, labeling, or delivery can adversely affect patient treatment outcomes and may lead to serious medication safety concerns[2]. Therefore, enhancing error prevention and control in pharmacy intravenous admixture services is of paramount importance. The workflow in these services is complex, encompassing multiple stages including medical order review, drug placement, dispensing, rechecking, packaging, and delivery. Given the extensive variety of medications, high workload, and the presence of numerous similar drugs, staff members are susceptible to errors influenced by various factors during the operational process. Traditional management approaches typically focus on recording and correcting errors post-occurrence, which is inadequate for the early detection and proactive prevention of potential risks.

The PDCA cycle is a widely utilized quality improvement method that facilitates continuous enhancement of work quality through four sequential stages: planning, execution, inspection, and corrective action[3]. Predictive nursing focuses on the early identification of risks and the implementation of preventive measures prior to the occurrence of issues[4]. The integration of the PDCA cycle with predictive nursing in the prevention and control of errors in pharmacy intravenous admixture services enables the proactive identification of risks, optimization of workflow processes, and reduction of dispensing errors. This study investigates the effectiveness of combining the PDCA cycle with predictive nursing in error prevention and control in pharmacy intravenous admixture services, with the objective of providing a reference framework for enhancing the safety management of medication in this context.

2 Materials and methods

2.1 General information The intravenous medication dispensing data from the Department of Pharmacy Intravenous Admixture Services at Taihe Hospital, spanning January 2024 to December 2025, were utilized as the study subjects. The period from January to December 2024, during which routine management was implemented, served as the control group. The subsequent period from January to December 2025, characterized by the implementation of the PDCA cycle combined with predictive nursing management, constituted the observation group. A total of 124 680 intravenous medication orders were prepared in the control group, compared to 128 420 orders in the observation group. No statistically significant differences were observed between the two groups regarding working environment, personnel allocation, service departments, drug types, and work processes, indicating comparability.

2.1.1 Inclusion criteria. The inclusion criteria were as follows: intravenous medication orders that were centrally prepared by the pharmacy intravenous admixture service; completion of the dispensing process, encompassing medical order review, drug arrangement, placement, dispensing, rechecking, packaging, and delivery; and availability of complete relevant records suitable for sta-

Received: March 10, 2026 Accepted: May 5, 2026

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tistical analysis.

2.1.2 Exclusion criteria. Exclusion criteria included intravenous medications prepared independently by clinical departments; medical orders that were not fully executed due to patient discharge, transfer to another department, or cancellation; and cases with incomplete data records.

2.2 Control group The control group was managed using conventional methods. Staff members performed tasks including medical order review, drug arrangement, placement, dispensing, rechecking, packaging, and delivery in accordance with the established protocols of the pharmacy intravenous admixture service. Upon identification of any errors, these were documented, and the responsible individual was required to notify the relevant personnel and implement corrective measures.

2.3 Observation group The observation group applied the PDCA cycle in conjunction with predictive nursing management, building upon standard management practices. The specific methods employed were detailed as follows.

2.3.1 Planning stage. A quality improvement team was formed, comprising the individual responsible for the pharmacy intravenous admixture service, pharmacists, nursing staff, dispensers, reviewers, and delivery personnel. The team conducted an analysis of errors that had occurred in prior intravenous admixture processes and identified high-risk links, including drug placement, label verification, dispensing operations, final product rechecking, and delivery handover. Based on practical experience, the primary causes of errors were identified as follows: the wide variety of medications, with similar drugs leading to confusion; high workload during peak hours resulting in staff negligence; insufficiently conspicuous drug labels and special markings; an inadequately detailed check process; and the lack of proficiency among newly recruited or rotated employees. In response to these issues, the following improvement objectives were established: reducing the incidence of errors in intravenous medication dispensing, increasing the recheck pass rate of finished infusion products, improving the timely delivery rate, and enhancing staff awareness of risk prevention.

2.3.2 Execution stage. (i) Strengthening risk predictive nursing. Based on the common types of errors observed in the pharmacy intravenous admixture service, the links most susceptible to errors were identified and prioritized as key management areas. High-alert medications, drugs with similar names, medications with similar packaging, and those requiring special storage conditions were clearly labeled and stored separately to minimize the risk of drug confusion at the source. (ii) Improving the check process. The procedures for medical order review, drug placement, dispensing, and final product recheck were optimized. During the recheck process, particular attention was given to verifying the patient's name, department, bed number, drug name, specification, dosage, quantity, solvent, administration time, and route of administration. Any identified issues were addressed promptly. (iii) Implementing the double-person check system. High-alert medications, antineoplastic agents, parenteral nutrition solutions, and drugs requiring special dosing underwent verification by two qualified personnel. The procedures of drug placement, dispensing, rechecking, and delivery handover were each assigned to specific individuals to ensure accountability and minimize errors resulting from personal negligence. (iv) Strengthening personnel training. Staff regularly participated in organized training sessions to study the operational system of the pharmacy intravenous admixture service, common causes of errors, medication safety knowledge, aseptic technique requirements, and occupational protection protocols. New employees and those on rotational assignments were required to complete pre-employment training and successfully pass an assessment prior to engaging in independent work. (v) Optimizing the management of delivery handover. The finished infusion products were categorized and organized according to the department, batch number, and administration time. Prior to delivery, the quantity, department, and batch were jointly verified by both the reviewer and the delivery personnel. Upon delivery to the clinical department, a formal handover and receipt acknowledgment, including signatures, was completed. (vi) Establishing a problem feedback mechanism. Errors or potential risk events that occurred were documented, including the time of occurrence, the link, the type, the cause, and the corrective actions taken. A monthly quality analysis meeting was conducted to discuss existing issues and propose improvement measures.

2.3.3 Inspection stage. The quality improvement team conducted monthly inspections to assess the implementation of management measures. These inspections evaluated the clarity of drug labels, the standardization of the checking process, the execution of double-person verification, the completeness of delivery handover records, and the timeliness of error registration. Additionally, statistical analyses were performed on the incidence of errors, the qualification rates of rechecks, and the timeliness of deliveries to evaluate the effectiveness of management practices.

2.3.4 Corrective action stage. The issues identified during the inspection were promptly addressed. Measures demonstrating greater effectiveness were integrated into the routine management system of the pharmacy intravenous admixture service. For the remaining issues, ongoing cause analysis would be conducted, new improvement strategies formulated, and these would be incorporated into the subsequent PDCA cycle to facilitate continuous improvement.

2.4 Observation indicators

2.4.1 Dispensing error rate. Dispensing errors encompassed inaccuracies related to drug names, specifications, quantities, solvents, labels, batch numbers, drug placement, as well as omis-

sions during rechecking and delivery processes. Dispensing error rate = Number of error cases/Total number of dispensing medication orders × 100%

2.4.2 Recheck pass rate of finished infusion products. Recheck pass rate of finished infusion products = Number of qualified items/Number of spot-checked items × 100%

2.4.3 Timely delivery rate. Timely delivery rate = Number of delivery batches completed within the stipulated time/ Total number of delivery batches × 100%

2.4.4 Risk prevention awareness scores among staff. The evaluation was conducted using a self-designed scoring sheet encompassing risk identification, recheck awareness, system implementation, error reporting, and proactive improvement awareness. The total possible score was 100 points, with higher scores indicating a stronger awareness of risk prevention.

2.5 Statistical methods Data analysis was performed using SPSS 28.0. Categorical data were presented as number of cases and percentages, and comparisons between groups were conducted using the chi-square (χ^2) test. Measurement data were expressed as mean ± standard deviation ($\bar{x} \pm s$), and group comparisons were carried out using the *t*-test. A *P*-value less than 0.05 was considered indicative of statistical significance.

3 Results and analysis

3.1 Dispensing error rate In the control group, a total of 124 680 intravenous medication orders were processed, with 152 errors identified, resulting in an error rate of 0.122%. In the observation group, 128 420 intravenous medication orders were prepared, with 68 errors recorded, corresponding to an error rate of 0.053%. The dispensing error rate in the observation group was significantly lower than that in the control group, and this difference was statistically significant ($P < 0.05$, Table 1).

Table 1 Comparison of dispensing error rates between the two groups

Group	Number of medication orders // group	Number of errors // case	Error rate // %
Control	124 680	152	0.122
Observation	128 420	68	0.053
χ^2	…	…	38.421
P	…	…	< 0.001

3.2 Recheck pass rate of finished infusion products In the control group, 10 000 finished infusion products were randomly inspected, of which 9 938 were deemed qualified upon re-examination, resulting in a recheck pass rate of 99.38%. Similarly, the observation group randomly inspected 10 000 finished infusion products, with 9 982 products qualifying after re-examination, corresponding to a recheck pass rate of 99.82%. The recheck pass rate in the observation group was higher than that in the control group, and this difference was statistically significant ($P < 0.05$, Table 2).

Table 2 Comparison of recheck pass rates of finished infusion products between the two groups

Group	Number of spot-checked items // pieces	Number of qualified items // pieces	Recheck pass rate // %
Control	10 000	9 938	99.380
Observation	10 000	9 982	99.820
χ^2	…	…	24.916
P	…	…	< 0.001

3.3 Timely delivery rate The control group comprised 2 360 delivery batches, of which 2 268 were delivered punctually, resulting in a timely delivery rate of 96.10%. In contrast, the observation group included 2 420 delivery batches, with 2 389 delivered on time, yielding a timely delivery rate of 98.72%. The observation group demonstrated a significantly higher timely delivery rate compared to the control group, and this difference was statistically significant ($P < 0.05$, Table 3).

Table 3 Comparison of timely delivery rates between the two groups

Group	Number of delivery batches	Number of timely delivery batches	Timely delivery rate // %
Control	2 360	2 268	96.100
Observation	2 420	2 389	98.720
χ^2	…	…	34.672
P	…	…	< 0.001

3.4 Risk prevention awareness scores among staff Following the implementation of the PDCA cycle combined with predictive nursing, the staff's risk prevention awareness score increased from (82.45 ± 5.36) points in the control group to (93.26 ± 4.18) points in the observation group. The score in the observation group was significantly higher than that in the control group, with the difference reaching statistical significance ($P < 0.05$, Table 4).

Table 4 Comparison of staff's risk prevention awareness scores between the two groups (points, $\bar{x} \pm s$)

Group	Number of people	Score
Control	28	82.45 ± 5.36
Observation	28	93.26 ± 4.18
t	…	8.417
P	…	< 0.001

4 Discussion and conclusions

The pharmacy intravenous admixture service plays a critical role in the safety management of intravenous medications within hospital settings. This service encompasses a wide range of tasks, and inadequate management can lead to errors involving drugs, dosages, labeling, solvents, or delivery methods[5]. Given that intravenous medications are administered directly into the patient's body, any errors may compromise therapeutic efficacy and potentially result in adverse outcomes. Consequently, enhancing error prevention and control measures in pharmacy intravenous admixture services holds substantial clinical importance.

The results of this study indicate that following the implementation of the PDCA cycle combined with predictive nursing, the dispensing error rate in the observation group was lower than that in the control group. This finding suggests that this management approach can effectively reduce errors in intravenous medication dispensing. The PDCA management cycle facilitates staff in promptly identifying problems, analyzing their causes, formulating corrective measures, and continuously improving processes, thereby standardizing the management of pharmacy intravenous admixture services. Predictive nursing prioritizes the early identification of risks prior to the occurrence of errors, thereby shifting the focus of management from reactive "post-event responses" to proactive "pre-event prevention"[6-7]. The integrated application of these two approaches has facilitated proactive and sustainable error prevention and control. During implementation, the quality improvement team conducted a thorough analysis of previous errors to accurately identify high-risk processes, including drug placement, label verification, final product recheck, and delivery handover. Subsequently, targeted improvements were introduced, such as enhancing the management of look-alike drugs, refining the recheck procedures, instituting double-person verification, strengthening staff training, and optimizing delivery handover protocols. These measures effectively reduced errors attributable to negligence or ambiguous procedures.

This study demonstrated that the recheck pass rate of finished infusion products in the observation group was higher than that in the control group, suggesting that enhancing the review content, strengthening the verification of critical drugs, and standardizing operational procedures can improve the quality of finished infusion product recheck. The rechecking process serves as a crucial line of defense for error prevention and control in pharmacy intravenous admixture services. Strict verification of patient information, drug names, and other relevant details is essential to identify and rectify issues promptly, thereby preventing errors from progressing to the clinical application stage. Additionally, the observation group exhibited a higher timely delivery rate compared to the control group, indicating that the integration of the PDCA cycle with predictive nursing not only reduces errors but also enhances work efficiency. By classifying and organizing finished product infusions according to department, batch, and medication time, and by reinforcing pre-delivery verification and handover signatures, issues such as incorrect delivery, missed delivery, and delayed delivery can be mitigated, thereby ensuring timely medication administration in clinical departments. Furthermore, the risk prevention awareness scores among staff in the observation group were higher than those in the control group, suggesting that regular training sessions, quality analysis meetings, and error feedback mechanisms effectively enhance staff risk awareness. Consequently, staff members demonstrate increased attention to operational details, proactively identify problems, and report them promptly, which contributes to fostering a positive safety management environment.

In conclusion, the implementation of the PDCA cycle in conjunction with predictive nursing within pharmacy intravenous admixture services effectively reduces dispensing error rates, improves the recheck pass rate of completed infusion products, and enhances the timely delivery rate. Additionally, this approach fosters increased risk prevention awareness among staff. Given its operational simplicity and practicality, this method aligns well with the routine management requirements of pharmacy intravenous admixture services and holds significant potential for broader application and dissemination.

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