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Research on the Application Effect of Intelligent Management System for Residual Analgesic Pump Fluid in the Whole-Process Supervision of Narcotic and Psychotropic Drugs

Ping Lai, Xiaojuan Huang, Jing Zhang, Xianjie Zhang

Deyang People's Hospital, Deyang 618000, Sichuan, China

Abstract: *Objective:* To study the application effect of an intelligent management system for residual analgesic pump fluid in the whole-process supervision of narcotic and psychotropic drugs. *Methods:* The period from October to December 2024, when routine management of controlled substances was implemented, is designated as the pre-implementation phase. The period from January to March 2025, when the intelligent management system for residual analgesic pump fluid was used for the full-process management of controlled substances, is designated as the post-implementation phase. Data related to residual analgesic pump fluid handling were collected from 500 cases in each of the two groups. The average error in residual fluid measurement, time spent on a single residual fluid handling, drug loss rate, and satisfaction rate of medical staff were compared. After implementation, the average error in residual liquid measurement decreased from (3.47 ± 0.25) ml to (0.58 ± 0.19) ml ($P < 0.05$); the time for a single residual liquid treatment decreased from (7.42 ± 0.33) min to (1.85 ± 0.12) min ($P < 0.05$); the drug loss rate decreased from 1.60% to 0.20 % ($P < 0.05$); and the satisfaction rate of medical staff increased from 81.82% to 96.36% ($P < 0.05$). *Conclusion:* The intelligent management system for residual analgesic pump fluid has shown significant effectiveness in the whole-process supervision of narcotic and psychotropic drugs, which helps to improve the accuracy, safety and efficiency of narcotic and psychotropic drug management.

Keywords: Intelligent management system for residual analgesic pump fluid; Narcotic and psychotropic drugs; Full-process supervision

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1. Foreword

The standardized management of narcotic and psychotropic drugs is one of the core difficulties in hospital pharmacy management [1]. The traditional method of measuring residual fluid from analgesic pumps relies on manual estimation, which has problems such as large errors, opaque records, and non-standard handling

of residual fluid, which can easily lead to drug loss or medication safety hazards [2]. Although existing drug management systems (such as smart medicine cabinets) have achieved drug storage and retrieval traceability, the accurate measurement and safe handling of residual fluid from analgesic pumps are still blind spots [3]. The intelligent management system for residual fluid from analgesic pumps is a model built through the Internet of Things and AI algorithms. The system can automatically generate electronic ledgers and issue early warnings of inventory anomalies, which has the advantage of reducing the burden of manual registration for medical staff. Therefore, this study analyzes the application effect of the intelligent management system for residual fluid from analgesic pumps in the whole process supervision of narcotic and psychotropic drugs. The aim is to control the average error of residual fluid measurement within the medical-grade standard through comparative analysis before and after implementation, and to provide empirical evidence for the closed-loop management of narcotic and psychotropic drugs. The specific report is as follows.

2. Materials and methods

2.1. General information

The period from October 2024 to December 2024, when routine management of narcotic and psychotropic drugs was implemented, is designated as the pre-implementation phase. The period from January 2025 to March 2025, when the intelligent management system for residual analgesic pump fluid was used for the full-process management of narcotic and psychotropic drugs, is designated as the post-implementation phase. Data related to the handling of residual analgesic pump fluid were collected from 500 cases in each of the two groups. In the pre-implementation phase, there were 240 males and 260 females, with a mean age of (55.26 ± 19.11) years (range 19–87 years). In the post-implementation phase, there were 245 males and 255 females, with a mean age of (55.31 ± 19.08) years (range 20–86 years).

Inclusion criteria: (1) All adult patients who used an electronic analgesia pump after surgery and required residual fluid disposal; (2) Cases using the same brand of analgesia pump.

Exclusion criteria: (1) mechanical failure of the analgesia pump; (2) incomplete records; (3) cases in which the patient was transferred to another department or died during the course of treatment.

2.2. Methods

In the initial phase, routine management of narcotic and psychotropic drugs was implemented. Nurses visually estimated the remaining liquid volume, which was then checked by two people and manually recorded in a paper log. The residual liquid was poured into the sewer under the supervision of two people, and there was no automatic video recording for evidence preservation.

In the post-implementation phase, management based on the intelligent management system for residual analgesic pump fluid will be carried out.

(1) Hardware equipment development. (a) Intelligent residual fluid treatment terminal: integrates a multimodal metering module (flow sensor + machine vision dual verification), a safety processing module (drug neutralization + mechanical destruction), and a data acquisition module (RFID/QR code recognition) to realize automatic metering, harmless treatment, real-time data upload, image storage, and random export of residual fluid. (b) Mobile processing unit: adaptable to different brands of analgesic pumps, supports deployment in multiple scenarios such as operating rooms and wards, and meets the

needs of grassroots hospitals for shared use.

(2) Software system construction. (a) Closed-loop management cloud platform: includes four subsystems [intelligent monitoring system (AI analysis of abnormal drug use data), blockchain traceability system (operation data hashing on the chain, in compliance with the video recording requirements of the "Regulations on the Administration of Narcotic Drugs"), decision support system (optimizing inventory and distribution process), mobile supervision APP (real-time approval and query)]. (b) Hospital information system docking: interconnected with HIS, ERP, and hand anesthesia system to realize the full-process electronicization of "application-use-recycling-destruction" of narcotic drugs.

(3) Standardization of management processes. Establish supporting SOPs (Standard Operating Procedures) covering residual liquid measurement, dual-person verification, and video evidence storage, promoting the transformation of management processes from manual reliance to automation, digitalization, and intelligence. Operating process: (a) RFID/QR code identification of analgesic pump information; (b) Automatic injection into the metering module (flow sensor + machine vision dual-modal calibration); (c) Real-time data upload to HIS and blockchain platform; (d) Automatic chemical neutralization and physical destruction processing, with full video recording and hashing on the blockchain; (e) Generation of electronic ledgers supporting mobile approval.

2.3. Observation indicators

(1) The average error in residual liquid measurement, the time spent on a single residual liquid treatment, and the drug loss rate were statistically analyzed. Data were obtained through HIS system logs, on-site timing, questionnaires, and equipment records.

(2) Staff satisfaction rate. A self-developed satisfaction survey scale was used for evaluation. A total of 58 questionnaires were distributed, and 55 valid questionnaires were returned, resulting in a valid return rate of 94.8%. The questionnaire ranged from 100 points, with higher scores indicating better satisfaction. Scores were categorized as: Very satisfied (> 80 points), Somewhat satisfied (60-80 points), and Dissatisfied (< 60 points).

2.4. Statistical analysis

Data were processed using SPSS 20.0. Quantitative data were expressed as mean ± standard deviation (SD) and analyzed using t-tests. Categorical data were expressed as percentages (%) and analyzed using chi-square tests. $P < 0.05$ was considered statistically significant.

3. Results

3.1. Compare the average error of residual liquid metering and the time consumed in a single residual liquid treatment

Compared with the pre-implementation stage, the average error of residual liquid measurement was significantly reduced and the time for a single residual liquid treatment was significantly shortened in the post-implementation stage ($P < 0.05$). See **Table 1**.

Table 1. Comparison of average error in residual liquid metering and time consumed per residual liquid treatment

Group	Number of examples	Average error in residual liquid measurement (mL)	Time taken for a single residual liquid treatment (min)
Pre-implementation stage	500	3.47 ± 0.25	7.42 ± 0.33
Post-implementation phase	500	0.58 ± 0.19	1.85 ± 0.12
t-value	-	205.799	354.698
p-value	-	0. 0000	0. 0000

3.2. Comparison of drug loss rates

Compared with before implementation, the drug loss rate was significantly reduced after implementation ($P < 0.05$). See **Table 2**.

Table 2. Comparison of the incidence of irrational drug use in clinical practice

Group	Number of examples	Drug loss rate(example/%)
Pre-implementation stage	500	8 (1.60)
Post-implementation phase	500	1 (0.20)
χ^2 value	-	5. 494
p-value	-	0. 019

3.3. Comparison of medical staff satisfaction rates

Compared with before implementation, the satisfaction rate of medical staff was significantly improved after implementation ($P < 0.05$). See **Table 3**.

Table 3. Compares the satisfaction rates of medical staff

Group	Number of examples	Very satisfied (example/%)	Quite satisfied (example/%)	Dissatisfied (example/%)	Medical staff satisfaction rate (example/%)
Pre-implementation stage	55	30/54. 55	15/27. 27	10/18. 18	45/81. 82
Post-implementation phase	55	37/67. 27	16/29. 09	2/3. 64	53/96. 36
χ^2 value	-	-	-	-	5. 9864
p-value	-	-	-	-	0. 0144

4. Discussion

In recent years, the National Health Commission has strengthened the requirement of “one product, one code” for the whole process traceability of narcotic and psychotropic drugs. Medical institutions urgently need technological innovation to upgrade from “being able to manage” to “managing well”. At the same time, drug regulatory departments in many places (such as Hebei and Hunan) have promoted the “Spring Rain Action” of medical-engineering integration and the technology transfer matchmaking meeting, and have clearly listed the intelligentization of medical devices and the closed-loop management of narcotic and psychotropic drugs as key support directions [4]. Therefore, this paper analyzes and studies the application effect of the intelligent management system for residual analgesic pump in the whole process supervision of narcotic and psychotropic drugs.

The results showed that, compared with before implementation, the average error of residual liquid measurement and drug loss rate were significantly reduced after the implementation of the intelligent management system for residual liquid of analgesic pump ($P < 0.05$); the time for single residual liquid treatment was significantly shortened ($P < 0.05$); and the satisfaction of medical staff was significantly increased ($P < 0.05$). This proves that the application effect of the intelligent management system for residual liquid of analgesic pump in the whole process supervision of narcotic and psychotropic drugs is significant, which is conducive to improving the accuracy, safety and efficiency of narcotic and psychotropic drug management. The possible mechanism is analyzed as follows: First, in terms of measurement accuracy, the system adopts the dual-modal calibration technology of flow sensor and machine vision, and fuses data through the Kalman filter algorithm. The measurement error is far better than manual visual inspection [5]. Second, in terms of management efficiency and safety, the automated processing shortens the single operation time and effectively releases nursing human resources [6]. More importantly, the system's forced automatic destruction + blockchain evidence storage eliminates the possibility of residual liquid being privately retained or resold from a technical perspective, reducing the drug loss rate [7]. Furthermore, this system reduces drug waste through accurate measurement, lowers the risk of medical disputes caused by medication errors, and improves the satisfaction of medical staff, indicating that the system's ease of use and reduced workload have been clinically recognized.

5. Conclusion

In conclusion, the intelligent management system for residual analgesic pump fluid has shown significant effectiveness in the whole-process supervision of narcotic and psychotropic drugs, which helps to improve the accuracy, safety and efficiency of narcotic and psychotropic drug management.

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Disclosure statement

The authors declare no conflict of interest.

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