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Impact of PDCA Cycle Combined with Instrument Mapping on Sterilization and Supply of Surgical Instruments

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Abstract: *Objective:* To explore the effect of applying the Plan-Do-Check-Act (PDCA) cycle combined with instrument mapping to manage surgical instruments in a hospital sterilization supply center. *Methods:* A total of 600 surgical instruments in a hospital's surgical instrument sterilization and supply management center were sampled and grouped based on the introduction of the PDCA cycle combined with instrument mapping. The control group included 300 surgical instruments subject to routine sterilization management from November 2023 to January 2024. The observation group included 300 surgical instruments managed with the PDCA cycle combined with instrument mapping from February 2024 to April 2024. The quality of surgical instrument management, incidence of adverse events, and other indicators were compared between the two groups. *Results:* The observation group demonstrated significantly higher scores in management quality indices compared to the control group, with scores for disassembly and assembly (93.28 ± 1.57 vs. 87.41 ± 1.48), cleaning (95.04 ± 2.08 vs. 90.23 ± 2.12), disinfection and sterilization (95.33 ± 1.27 vs. 91.95 ± 1.39), waste disposal (93.26 ± 1.24 vs. 89.65 ± 1.18), packaging and traceability (94.35 ± 1.74 vs. 92.23 ± 1.65), and issuance and recycling (95.79 ± 1.72 vs. 90.22 ± 1.81) (all $P < 0.05$). The observation group reported two adverse events (one incomplete instrument specification and one case of instrument package overweight) with an incidence rate of 0.67%. Conversely, the control group reported six adverse events (including shortages, incomplete specifications, unqualified sterilization, defective instruments, untimely or incorrect delivery, and overweight instrument packages) with an incidence rate of 3%, demonstrating statistically significant differences between groups ($P < 0.05$). *Conclusion:* Applying the PDCA cycle combined with instrument mapping for surgical instrument management in hospital sterilization supply centers significantly improves management quality and reduces adverse events. Its application is recommended for wider adoption in hospital sterilization supply centers.

Keywords: Sterile supply center; PDCA cycle management; Instrument mapping; Management quality; Adverse events

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1. Introduction

In the modern medical environment, the management of surgical instrument sterilization and supply is a critical component of ensuring medical quality and safety in hospitals. High-quality sterilization and supply processes are essential for facilitating smooth surgical procedures, reducing surgical infection risks, and promoting patient recovery [1]. With advancements in medical technology and the increasing complexity and diversity of surgical procedures, the types of surgical instruments have proliferated, placing higher demands on sterilization and supply management [2].

Traditional sterilization and supply management often rely on experience-based and routine processes. However, with the rising use of precision instruments in modern healthcare, the complexity of disassembly and assembly processes has increased significantly. Insufficient knowledge of complex surgical instrument structures and cleaning requirements among staff can lead to damaged instruments, substandard packaging, unqualified sterilization, and heightened risks of surgical site infections. These issues not only compromise the performance and longevity of surgical instruments but also pose serious safety risks to patients, including prolonged pain and potential complications [3].

The Plan-Do-Check-Act (PDCA) cycle, an emerging quality management method, has demonstrated exceptional value across various fields. Its integration into the sterilization and supply management of surgical instruments enables continuous improvement of processes [4]. Moreover, combining the PDCA cycle with instrument mapping offers an intuitive understanding of surgical instrument details, providing precise guidance for practical operations. This approach enhances the quality and effectiveness of sterilization and supply management, thereby improving medical safety [5].

This study aims to evaluate the practical application of the PDCA cycle combined with instrument mapping in managing surgical instrument sterilization and supply. The findings are intended to serve as a reference for optimizing sterilization and supply management in hospitals.

2. Materials and methods

2.1. General information

A total of 600 surgical instruments from the surgical instrument sterilization and supply management center of a hospital were selected as the study sample. Based on the introduction time of the PDCA cycle combined with the instrument mapping method, 300 surgical instruments subjected to routine disinfection management during the period from November 2023 to January 2024 were included in the control group. This group comprised 102 forceps, 84 dental instruments, and 114 luminal instruments. Similarly, 300 surgical instruments managed using the PDCA cycle combined with instrument mapping from February 2024 to April 2024 were included in the observation group. This group consisted of 92 forceps, 112 dental instruments, and 96 luminal instruments. Baseline data comparisons between the two groups revealed no statistically significant differences ($P > 0.05$).

2.2. Methodology

2.2.1. Control group

Routine sterilization and supply management procedures were implemented. Specific measures included:

(1) Developing a standardized surgical instrument management process with strict quality control across all stages, including instrument recovery, cleaning, disinfection, inspection and maintenance, packaging,

sterilization, storage, and issuance. Dedicated staff members were assigned to each stage.

(2) Selecting appropriate cleaning methods and detergents based on the type of instrument, and strictly controlling cleaning time and temperature.

(3) Applying disinfection methods scientifically, such as wet heat or chemical disinfection, depending on the instruments' material and usage.

(4) Inspecting instruments post-cleaning and disinfection to ensure integrity and cleanliness, addressing problematic instruments promptly, and using compliant packaging materials to store instruments in a suitable environment with moisture-proof and antibacterial measures.

(5) Establishing a record-keeping system for surgical instrument inflow and outflow to ensure detailed traceability and facilitate management.

2.2.2. Observation group

The PDCA cycle combined with instrument mapping management was implemented, consisting of the following stages:

(1) Planning (Plan) stage: A quality control team comprising sterilization supply center staff and operating theatre nurses was established. The team analyzed existing issues, including incomplete cleaning, substandard packaging, inaccurate sterilization parameters, and process inefficiencies. A management plan was developed, including a personalized sterilization supply process based on instrument mapping. Instrument maps detailed structures, disassembly methods, and key cleaning areas, ensuring accurate operation by staff.

(2) Execution (Action) stage: Comprehensive training based on instrument mapping was provided, covering theoretical explanations and on-site demonstrations. Staff adhered to the mapped sterilization supply process, ensuring proper disassembly and thorough cleaning of complex instruments. Instrument integrity and placement were verified during packaging, and sterilization parameters were set according to instrument material and mapping prompts. An information management system tracked the sterilization and supply status of instruments in real time.

(3) Checking (Check) stage: The management team evaluated the entire process using quality standards and assessment indicators, such as cleaning efficacy, functional integrity, package sealing, labeling accuracy, and sterilization parameter records. Compliance with instrument mapping was also assessed, and any detected issues were documented for analysis and resolution.

(4) Processing (Act) stage: Identified issues were addressed promptly by the management team. For personnel errors, training and supervision were enhanced, while process or standard-related issues were resolved by adjusting and optimizing the management plan. The sterilization and supply process was continuously refined based on accumulated experience to maintain high-quality outcomes.

2.3. Observation indicators

2.3.1. Quality assessment of sterilization and supply management

The hospital's sterilization and supply management center applied a self-developed quality assessment scale to evaluate instrument management. The assessment covered six dimensions: disassembly and assembly, cleaning, disinfection and sterilization, waste treatment, packaging and traceability, and issuance and recycling. Each dimension was scored on a 100-point scale.

2.3.2. Adverse events in instrument handling and supply

The occurrence of adverse events, including instrument shortages, incomplete specifications, disinfection and sterilization failures, defective instruments, errors in receipt and delivery, and overweight instrument packages, was recorded. The incidence rate was calculated as: Incidence rate = (Number of detected cases/Total number of instruments) × 100%.

2.4. Statistical analysis

SPSS 23.0 statistical software was used for data analysis. Categorical data were expressed as [*n* (%)], and the chi-squared test (χ^2) was employed. Continuous data were presented as mean ± standard deviation (SD), and independent samples *t*-tests were conducted. Statistical significance was indicated by $P < 0.05$.

3. Results

3.1. Comparison of management quality scores between the two groups

The management quality scores for disassembly and assembly, cleaning, disinfection and sterilization, waste treatment, packaging and traceability, and distribution and recycling in the observation group were significantly higher than those in the control group. The differences were statistically significant ($P < 0.05$), as shown in **Table 1**.

Table 1. Comparison of quality of management scores between the two groups (mean ± SD, points)

Group	Disassembly and assembly	Cleaning	Sterilization	Waste disposal	Packaging and traceability	Issuance and recycling
Control group (n = 300)	87.41 ± 1.48	90.23 ± 2.12	91.95 ± 1.39	89.65 ± 1.18	92.23 ± 1.65	90.22 ± 1.81
Observation group (n = 300)	93.28 ± 1.57	95.04 ± 2.08	95.33 ± 1.27	93.26 ± 1.24	94.35 ± 1.74	95.79 ± 1.72
t	47.1221	28.0521	31.2157	36.5287	15.3129	38.6380
P	0.0000	0.0000	0.000	0.0000	0.0000	0.0000

3.2. Comparison of adverse events between the two groups

The incidence of adverse events, including shortage of instruments, incomplete specifications, unqualified disinfection and sterilization, mutilated instruments, untimely receipt and delivery or errors and omissions, and overweight instrument packages, was significantly lower in the observation group compared to the control group. The difference was statistically significant ($P < 0.05$), as shown in **Table 2**.

Table 2. Comparison of adverse event rates between the two groups [*n* (%)]

Group	Shortage of instruments	Incomplete specifications	Failure to sterilize	Instrument mutilation	Untimely or erroneous receipt or omission	Overweight equipment bags	Rate of occurrence
Control group (n = 300)	1	1	1	1	3	2	9 (3.00)
Observation group (n = 300)	0	1	0	0	0	1	2 (0.67)
t							4.5377
P							0.0332

4. Discussion

The hospital disinfection supply management center plays a pivotal role in medical operations. Its responsibilities primarily encompass the recovery, cleaning, disinfection, sterilization, packaging, and distribution of various types of surgical instruments [6]. Staff must not only handle common surgical tools and complex precision instruments but also ensure their careful maintenance and management to guarantee the safety and usability of medical equipment [6]. Therefore, it is imperative for staff to adhere strictly to established norms and procedures, ensuring that every step complies with stringent hygiene standards.

High-quality sterilization and supply management of surgical instruments can prolong the service life of instruments, reduce hospital procurement costs, significantly lower the risk of patient infections during surgeries, and ensure patient safety and optimal postoperative recovery [7]. However, conventional management methods for surgical instrument disinfection and supply are prone to certain limitations. For instance, during instrument recovery, there is a risk of missing or incorrectly collecting instruments, which can result in shortages and disrupt surgical procedures [8]. Inadequate standardization and supervision during cleaning often lead to incomplete cleaning, with residual dirt and bacteria increasing the risk of infection. Additionally, improper control of parameters such as temperature and time during disinfection and sterilization frequently results in suboptimal sterilization outcomes [9]. Irregularities in packaging labeling during the sealing and storage processes often cause confusion and distribution errors, thereby affecting the timeliness and accuracy of surgeries.

The PDCA cycle is a modern scientific management method that establishes a quality management cycle by optimizing processes through the phases of planning (Plan), execution (Do), checking (Check), and processing (Act). Instrument mapping, on the other hand, provides detailed illustrations and descriptions of surgical instruments, including their names, models, structures, and uses, offering an intuitive and accurate foundation for instrument identification, handling, and management [10].

This study aimed to evaluate the application of the PDCA cycle combined with instrument mapping in hospital surgical instrument sterilization and supply management. A sample of 600 surgical instruments was analyzed before and after implementing this management model. The results indicated that the observation group achieved significantly higher scores in management quality across parameters such as disassembly and assembly, cleaning, disinfection and sterilization, waste disposal, packaging and traceability, and issuance and recycling compared to the control group. Furthermore, the observation group demonstrated a significantly lower incidence of adverse events, including shortages, incomplete specifications, unqualified disinfection and sterilization, defective instruments, untimely receipt and delivery, errors and omissions, and overweight instrument packages, with statistical significance.

These findings can be attributed to the multiple advantages of the PDCA cycle combined with instrument mapping:

(1) The PDCA cycle systematically identifies and addresses issues in surgical instrument sterilization and supply management. By continuously optimizing management processes and standards, it effectively enhances management quality [11].

(2) Instrument mapping provides staff with a clearer and more precise understanding of surgical instruments, thereby minimizing operational errors.

The integration of these two approaches complements and reinforces their respective strengths. This organic combination significantly improves work efficiency, reduces the risks of instrument damage and loss, enhances the quality of medical services, establishes a positive institutional reputation, and fosters greater patient trust in the hospital [12].

5. Conclusion

In conclusion, the implementation of the PDCA cycle combined with instrument mapping in surgical instrument sterilization and supply management significantly improves management quality and reduces the occurrence of adverse events. Its application is highly recommended for broader adoption in hospital settings.

Disclosure statement

The authors declare no conflict of interest.

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