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A Study on the Application of Unique-Code Identification Tags in the Central Sterile Supply Department

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Abstract: *Objective*: To investigate the effectiveness of uniquely coded identification tags in the end-to-end management of reusable instruments in a Central Sterile Supply Department (CSSD). *Methods*: Surgical instrument packs from our hospital's CSSD were selected as the study subjects. This study applied custom-designed, high-temperature and high-pressure-resistant uniquely coded identification tags to establish a "one item, one code" information management system, enabling scan-based traceability throughout the entire process, including collection, cleaning, packaging, sterilization, distribution, and return. This study compared this approach with traditional identification methods using washcloths and tourniquets to assess cleaning quality, work efficiency, error rates, traceability coverage, and economic benefits. *Results*: After implementing the unique-code identification tags, the instrument cleaning pass rate increased from 96.2% to 99.8%, the incidence of foreign body residue dropped from 1.8% to 0, the time required for per-pack verification was reduced by 42%, the instrument configuration error rate decreased by 70%, end-to-end traceability coverage reached 100%, and the annual cost of labeling consumables was reduced by 61.9%. *Conclusion*: Unique-code identification tags can significantly enhance the precision, informatization, and standardization of Central Sterile Supply Department (CSSD) management, ensure the quality of cleaning and sterilization as well as clinical safety, and reduce operating costs; their implementation is recommended for hospitals at all levels.

Keywords: Central sterile supply department; Unique coding; Identification tags; Instrument management; End-to-end traceability; Hospital infection control

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1. Introduction

The Central Sterile Supply Department (CSSD) is a core department for hospital infection control, responsible for the collection, cleaning, sterilization, storage, and distribution of reusable surgical and

diagnostic instruments throughout the hospital. The quality of its instrument management directly impacts surgical safety and patient outcomes, making it a critical component in preventing nosocomial infections and ensuring the quality of medical care. According to the WS310 series of hospital infection control standards, end-to-end traceability of reusable instruments, standardized cleaning and sterilization, and refined operational control are the core requirements for Central Sterile Supply Department management [1]. Currently, most hospital Central Sterile Supply Departments in China still rely on traditional identification methods using washable cloth labels and blood-stopping bands. However, this approach has significant shortcomings: the labeling materials are prone to aging and sticking, obscuring the instrument surfaces and hindering the penetration of cleaning water and sterilization steam, which can easily lead to residual contamination on the instruments; At the same time, a management model reliant on manual, handwritten records and paper-based verification is prone to errors, breaks in the traceability chain, and low verification efficiency. This leads to safety hazards such as instrument mismatches and sterilization failures, while also resulting in high consumable waste and elevated operational costs, making it difficult to meet the refined and digitized management needs of modern hospitals [2]. To address the pain points and challenges of traditional instrument management, this study independently designed unique-code identification tags that are resistant to high temperatures and pressures and can be reused, establishing a "one item, one code" end-to-end digital traceability system to replace the traditional labeling management model. By comparing and analyzing the application outcomes of traditional labels versus the unique-code identification tags, this study explores their value in improving the quality of instrument cleaning and sterilization, enhancing work efficiency, strengthening traceability management capabilities, and controlling operating costs. The aim is to optimize the full-lifecycle management model for instruments in central sterilization supply departments and provide practical guidance for standardized and intelligent management in such departments across hospitals of all levels.

2. Materials and methods

2.1. General information

All reusable surgical instrument packs processed by the Central Sterile Supply Department (CSSD) of Shaanxi Provincial People's Hospital from October 2024 to October 2026 were selected as the study subjects, covering clinical departments such as General Surgery, Orthopedics, Obstetrics and Gynecology, Ophthalmology, Otolaryngology, Urology, and Neurosurgery. Instrument set types included basic sets, specialty sets, puncture sets, debridement sets, and endoscopic instrument sets, totaling 126 types, with an average daily processing volume of approximately 480 sets. The period from October 2024 to April 2025 (using traditional labeling) was designated as the control group, while the period from May 2025 to October 2026 (using unique-code identification tags) was designated as the observation group. Comparisons between the two groups in terms of instrument types, quantities, staffing, workflows, and equipment conditions revealed no statistically significant differences ($p > 0.05$), indicating that the groups were comparable.

2.1.1. Inclusion criteria

(1) All reusable surgical instrument sets and diagnostic and therapeutic instrument sets in the hospital;

(2) All included instruments comply with the requirements of WS310.1-2016 "Hospital Sterile Supply Centers—Part 1: Management Specifications";

(3) The entire process—including retrieval, cleaning, disinfection, packaging, sterilization, storage, and distribution—is completed within the Sterile Supply Center.

2.1.2. Exclusion criteria

(1) Single-use instruments;
(2) External medical devices and implants (managed according to specialized procedures);
(3) Instruments that are severely damaged or cannot be used normally.

2.2. Materials, design, and manufacturing

2.2.1. Identification tag materials

Medical-grade 304 stainless steel or high-temperature-resistant polymer composite materials shall be used. These materials must withstand high-pressure steam sterilization at 134 ℃ and 205 kPa, as well as chlorine-based disinfectants, enzymatic cleaning agents, and acid-base corrosion. They must remain free from deformation, discoloration, adhesion, or flaking even after repeated use.

2.2.2. Identification tag structure and information

The standard size is 6 cm × 3 cm, with double-sided printing. The front features a globally unique QR code, the name of the instrument set, specifications, and core configuration; the back lists the detailed instrument inventory, sterilization date, expiration date, department of use, packer, and verifier.

2.2.3. Hanging mechanism

Features an integrated design combining an anti-detachment clip and a hanging loop, allowing it to be securely attached to the outer or inner edge of the instrument basket. It does not obstruct instruments, does not become lodged in tubular channels, and does not impede water flow or steam penetration; it remains securely in place without detaching or shifting during the cleaning and sterilization process.

2.3. Implementation methods

2.3.1. Establish a coding system

Assign a unique, permanent code to each instrument pack. The coding rule consists of the department code + instrument pack code + serial number + check digit, ensuring no duplicates throughout the hospital. Establish an instrument information database containing basic information (name, specifications, model, quantity, configuration, images), process information (collection time, cleaning procedure, packer, sterilization parameters, issuing department, usage records, collection integrity), and quality control information (cleaning monitoring, chemical monitoring, biological monitoring, packaging quality, sterilization efficacy).

2.3.2. Full-process traceability operating procedures

(1) Collection

Clinical departments must seal and return instrument packs after use, scan the barcode to record the collection time, source department, contamination level, and person responsible for collection;

(2) Cleaning and disinfection

Scan the barcode to verify the instrument pack information, select the corresponding cleaning program (Standard/Intensive/Delicate), and record the washer serial number, program, duration, water temperature,

and enzyme solution concentration, ensuring that the identification tag does not obstruct the instruments;

(3) Packaging inspection

Scan the barcode to retrieve the instrument configuration list and have two personnel verify it together; after packaging is complete, print the sterilization information and attach the identification tag; record the packer, verifier, and packaging time;

(4) Sterilization

Scan the barcode to link the sterilizer serial number, load number, temperature, pressure, duration, and start/end times; simultaneously record the results of chemical indicators and biological monitors;

(5) Storage and distribution

Scan the barcode to check into inventory, sorted by expiration date; when distributing, scan the barcode to confirm the receiving department, distributor, and recipient;

(6) Return and reprocessing

Recover the sets after use, scan the barcode to check for completeness, and determine whether they are suitable for recirculation.

2.3.3. Staff training

Provide training to all staff in the Central Sterile Supply Department on coding rules, QR code scanning procedures, data entry, and handling of anomalies; train nurses in operating rooms and clinical departments on the processes for identifying, verifying, protecting, and reporting anomalies regarding identification tags; conduct a standardized assessment after training; staff may only begin work after passing the assessment.

2.3.4. Quality control and emergency response plan

Establish a Standard Operating Procedure (SOP) for handling ID tag anomalies.

(1) Loss

Immediately suspend use of the pack, reverify the configuration, issue a replacement ID tag, and update the database;

(2) Damage/Blurred QR code

Replace with a new tag while retaining the original code information;

(3) Detachment

Reattach securely and inspect the cleaning quality;

(4) Information error

Correct immediately, have two personnel cross-check, and trace the source of the error.

2.4. Monitoring indicators

2.4.1. Cleaning quality

Instrument cleaning pass rate, foreign matter residue incidence rate;

2.4.2. Work efficiency

Time per package for verification, packaging time, and distribution/return time;

2.4.3. Management safety

Instrument configuration error rate, missing/mismatched rate, end-to-end traceability coverage rate, time

required for root cause analysis;

2.4.4. Economic benefits

Annual cost of labeling supplies, labor costs, and instrument wear and tear costs;

2.4.5. Satisfaction

Operational satisfaction among department staff, usage satisfaction among clinical departments.

2.5. Statistical methods

Data analysis was performed using SPSS 22.0 software. Continuous variables are expressed as $\overline{x} \pm s$, and *t*-tests were used for intergroup comparisons; categorical variables are expressed as rates (%), and chi-square (χ^2) tests were used for intergroup comparisons. A p-value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of key indicators before and after implementation

The observation group's instrument cleaning pass rate and end-to-end traceability coverage were significantly higher than those of the control group; the incidence of foreign body residue, the instrument configuration error rate, and the annual cost of labeled consumables were significantly lower than those of the control group; the average verification time per pack and the average time required to trace the source of problems were significantly shorter than those of the control group, with statistically significant differences ($p < 0.05$), as shown in **Table 1**.

Table 1. Comparison of instrument management-related indicators between the two groups

Indicator	Control group (traditional labeling)	Observation group (unique-code identification tags)	*p*-value
Instrument cleaning pass rate	96.2%	99.8%	< 0.05
Incidence of foreign matter residue	1.8%	0	< 0.05
Average verification time per package (s)	15.6 ± 2.3	9.1 ± 1.6	< 0.05
Instrument configuration error rate	2.3%	0.7%	< 0.05
End-to-end traceability coverage rate	65.5%	100%	< 0.05
Average time to trace the source of an issue (min)	48.2 ± 8.5	6.5 ± 2.1	< 0.05

3.2. Comparison of the performance of three labeling methods

Compared to traditional methods such as water-washable fabric labels and hemostatic band labels, the use of unique-code identification tags is significantly superior in terms of whether they obstruct the medical device, resistance to high temperature and pressure, service life, risk of foreign body residue, clarity of information, and traceability, as shown in **Table 2**.

Table 2. Comprehensive performance comparison of different identification media

Evaluation criteria	Washcloth labeling	Hemostatic band labeling	Unique-code identification tag
Does it obstruct the device?	Yes	Yes	No
Resistant to high temperature and high pressure	Generally, prone to damage	Poor; prone to sticking	Excellent
Service life	Short; requires frequent replacement	Relatively short; prone to aging	Long, reusable
Risk of foreign matter residue	Low	High	None
Clarity of information	Prone to blurring and fading	Prone to wear and tear; unclear	Clear and scannable
Traceability	Weak; manual recording	Moderate, manual recording	Strong, closed-loop digital system

4. Discussion

The core responsibility of the Central Sterile Supply Department is to ensure thorough cleaning and proper sterilization of medical devices, while traditional labeling poses a significant risk to cleaning quality. Cleaning cloths and tourniquets directly cover the surfaces of medical devices, obstructing water flow, the action of enzymatic solutions, and steam penetration, which can easily lead to residual contamination in joints, grooves, and lumens [3]. During high-temperature sterilization, tourniquets tend to soften and adhere to instruments, forming fibrous or gelatinous foreign bodies that increase risks to patients. The uniquely coded identification tag designed in this study features a suspended, external structure that does not come into contact with or cover the instruments, ensuring the full and effective completion of the entire process, including washing, rinsing, final rinsing, disinfection, and drying, while avoiding issues such as material detachment, adhesion, and fading. Results show that after implementation, the instrument cleaning compliance rate increased from 96.2% to 99.8%, and the incidence of foreign body residue dropped from 1.8% to 0%, thereby reducing the risk of hospital-acquired infections at the source and meeting the WS310 series standards for cleaning quality and safety.

Traditional management relies on manual record-keeping and handwritten labels, making information prone to omissions, errors, and loss, which breaks the traceability chain and prevents rapid identification of issues when they arise. This study employs a unique coding system combined with an information management system to achieve closed-loop management characterized by “each package has a code, the code is traceable, tracing leads to accountability, and accountability ensures responsibility”: Collection–cleaning–packaging–sterilization–storage–distribution–use–collection.

At every step, a code is scanned to leave a record, and data is automatically uploaded and cannot be tampered with, meeting traceability requirements across multiple scenarios such as hospital quality control, infection control, medical insurance, and health supervision [4]. The observation group achieved 100% end-to-end traceability coverage, reducing the time required to trace the source of a problem from 48.2 minutes to 6.5 minutes, an 86.5% increase in efficiency. In scenarios such as device mismatches, sterilization failures, and adverse events, this system enables rapid identification of the affected process, clarification of responsibility, and implementation of corrective measures, significantly enhancing medical safety. Under the traditional model, staff had to check off items one by one against a paper list, a process that was time-consuming, labor-intensive, and prone to fatigue-induced errors. With the use of ID tags, scanning a QR code displays the complete configuration list, making two-person verification faster and more accurate. The time required to

verify a single pack was reduced from 15.6 seconds to 9.1 seconds, representing a 42% increase in efficiency; the instrument configuration error rate dropped from 2.3% to 0.7%, a 70% decrease, significantly reducing rework and verification costs. In terms of economic benefits, traditional labeling methods required frequent purchases of washable cloths, tourniquets, and label paper, with annual consumable costs of approximately 4,200 yuan; The unique-code identification tags, however, are produced once and reused indefinitely, reducing annual consumable costs to 1,600 yuan, a 61.9% decrease. At the same time, the system reduces the time spent on manual registration, searching, and data entry, thereby lowering labor costs and instrument wear and tear, achieving a triple benefit of "safety, efficiency, and cost savings". As hospitals pursue high-quality development, the Central Sterile Supply Department has evolved from a "logistics support department" to a core department for hospital infection control; its management model must transition from a manual, extensive approach to a digital, precision-based one. Through the use of uniquely coded identification tags, this project has achieved the goals of operational standardization (unified processes, unified labeling, and unified verification), refined management (real-time visibility, manageability, and controllability of the status of each instrument package), and departmental modernization (promoting the implementation of information technology and traceability systems). This technology represents an advanced level within the province; it is replicable and scalable, serving as a model for primary-care and secondary hospitals across the province and driving an overall improvement in regional sterilization supply management [5].

Currently, most similar studies in China use methods such as washable cloth, paper labels, or RFID chips, which suffer from issues such as obstructing cleaning, short lifespan, high cost, and susceptibility to damage. The innovation of this study lies in the material's resistance to high temperature and pressure, its non-adhesive properties, and the absence of foreign body risks; the hanging design does not obstruct instruments or interfere with cleaning and sterilization; it is low-cost, easy to implement, and suitable for primary-care hospitals; and it is compatible with existing information systems, requiring no large-scale upgrades. The technology as a whole has reached an advanced level within the province and a leading level within the hospital, demonstrating strong clinical practicality and value for widespread adoption [6]. However, this study was a single-center observational study with limited sample size and observation duration; future research could include multicenter, large-sample, prospective controlled studies. Customized fixation methods should be designed for micro-instruments, endoscopic instruments, and specialized instruments; simultaneously, the material of the identification tags should be upgraded to enhance wear and corrosion resistance, and the system should be integrated with the Hospital Information System (HIS), the anesthesia and surgical systems, and the hospital infection control monitoring system to enable data interoperability; AI recognition could also be introduced to automatically verify instrument configurations, further reducing reliance on manual labor.

5. Conclusion

In summary, the application of uniquely coded identification tags in the management of reusable instruments in central sterilization supply departments features advanced technology, innovative design, safety, practicality, and cost-effectiveness. It can significantly improve the quality of cleaning and sterilization, work efficiency, traceability, and medical safety, while reducing operating costs. This approach promotes the development of central sterilization supply management toward informatization, intelligence, and

standardization, and has good potential for widespread adoption, making it suitable for use in medical institutions at all levels.

Disclosure statement

The authors declare no conflict of interest.

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