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# Dual-Mode QR Code and NFC Management Improves Equipment Full Life-cycle Traceability Efficiency in Central Sterile Supply Department

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**ABSTRACT: Objective** This study aims to evaluate the application value of combining QR code and near field communication (NFC) in the whole-lifecycle management of equipment in the Central Sterile Supply Department (CSSD) and to provide a reference for optimizing equipment operation and maintenance processes. **Methods** A total of 35 conventional devices in use at the CSSD of our hospital from January to December 2025 were selected as the study subjects. The traditional manual ledger management model applied from January to June 2025 served as the control group, while the intelligent management model combining QR code and NFC applied from July to December 2025 served as the observation group. In the observation group, a unique electronic identity was established for each device, enabling one-click retrieval of device information, rapid online fault reporting, automatic inspection task reminders, real-time uploading of maintenance records, and full-process traceability. The control group continued to use traditional management methods, including paper registration, manual reminders, and handwritten ledgers. The two groups were compared in terms of equipment repair response time, record retrieval time, and the number of overdue regular maintenance events. **Results** The median equipment repair response time and record retrieval time in the observation group were significantly shorter than those in the control group (repair response time (median): 40 min vs. 65 min; record retrieval time (median): 4 min vs. 20 min), and the number of overdue regular maintenance events was significantly lower (99.30% vs. 79.60%). The differences between the two groups for all three indicators were statistically significant (all $P<0.05$). **Conclusion** The integration of QR code and NFC enables intelligent, visual, and traceable management of CSSD equipment, enhances the efficiency of equipment operation and maintenance along with management precision, ensures reliable equipment performance, and contributes to the quality and safety of sterile items.

**KEY WORDS:** Two-dimensional code (QR Code); Near field communication (NFC); Central Sterile Supply Department (CSSD); Whole-life cycle management of equipment; Operation and maintenance efficiency; Sterile safety

The Central Sterile Supply Department (CSSD) is an indispensable component of hospital operations, as it is responsible for cleaning, disinfecting, sterilizing, and supplying all reusable medical instruments, devices, and items, thereby ensuring medical quality and safety[1]. Medical equipment serves as the core foundation for the high-quality functioning of the CSSD, and its stable operation directly determines the quality of sterile item processing and the level of nosocomial infection prevention and control[2]. At present, most primary and general hospitals still rely on traditional management models for their CSSDs, including paper ledgers, manual registration, and handwritten reminders. These models are characterized by delayed updates of equipment files, fragmented data preservation, and incomplete information integrity[3]. In addition, problems such as inadequate implementation of regular maintenance, slow fault reporting processes, and weak oversight of operation and maintenance are common, which

hinders compliance with the requirements of modern quality control management[4].

With the rapid development of information-based traceability technology, digital tools such as QR codes, NFC, and the Internet of Things (IoT) have been widely adopted for refined management in hospital departments[5]. Establishing a whole-lifecycle equipment management system based on smart tags can effectively address the shortcomings of traditional management and has become an important strategy for improving quality and efficiency in CSSD[6]. The *Central sterile supply department (CSSD) — Part 1: Management standard* explicitly requires that a designated person be responsible for the maintenance and regular inspection of CSSD equipment and that equipment files be established[1]. This study investigated 35 pieces of equipment in use at the CSSD of our hospital, compared the application effects of traditional manual management and the intelligent dual-mode management combining QR code and NFC, and explored a digital equipment control solution suitable for CSSD, thereby providing practical references for equipment management upgrades in similar departments.

## 1 Materials and Methods

1.1 General information

A total of 35 conventional devices in use at the CSSD of our hospital from January to December 2025 were selected as the study subjects. All devices were purchased through regular channels, met relevant national standards, were in normal operating condition, and had no major hidden faults. The equipment types included six pulsating vacuum sterilizers, three hydrogen peroxide low-temperature plasma sterilizers, six fully automatic washer-disinfectors, one ultrasonic cleaner, three medical drying cabinets, and 16 other auxiliary devices. All devices were within their normal service life and exhibited balanced daily usage frequencies.

The devices managed using the traditional manual ledger model from January to June 2025 served as the control group, while those managed with the QR code combined with NFC intelligent model from July to December 2025 served as the observation group. No statistically significant differences were found between the two groups in general characteristics such as equipment type, quantity, purchase time, and usage frequency ($P$>0.05), indicating that the two groups were comparable.

A total of six equipment management personnel participated in this study, including three senior nurses, two junior nurses, and one nurse. All had more than five years of experience in equipment management within the CSSD, were familiar with equipment operation and traditional management processes, and, after systematic training, became proficient in operating the QR code and NFC intelligent management system, thereby ensuring the smooth conduct of the study.

1.2 Methods

1.2.1 Control group: Traditional manual ledger management

The traditional manual management method was adopted, which included the following components: (1) Equipment information management: paper ledgers were created; equipment information such as name, model, purchase date, and repair and maintenance records was manually recorded and updated, with regular filing; (2) Equipment repair reporting: when a fault occurred, a repair request form was manually completed and submitted to the person in charge, who then contacted the maintenance staff. After the repair, relevant information was manually documented; (3) Equipment inspection: inspections were carried out manually according to the schedule; operating parameters and anomalies were manually recorded and signed. Inspection reminders relied on memory; (4) Equipment maintenance: a paper maintenance plan was developed; reminders were given orally or on paper; and the ledger was manually updated after maintenance. All data were stored offline without any information-based traceability means.

1.2.2 Observation group: Intelligent management combining QR code and NFC

Based on the existing hospital information system, an intelligent management platform was established, utilizing a dedicated management appli-

cation, smartphones, a QR code printer, and other equipment. The integrated management of QR code and NFC dual tags was then implemented. The specific procedures were as follows:

(1) Establishment of electronic identity for equipment: A unique code was assigned to each device, and a dedicated QR code and NFC induction tag were bound. The QR code stored the full lifecycle detailed information, while the NFC tag facilitated rapid identification. The tags were attached to the equipment in positions that are resistant to disinfection and easy to recognize.

(2) Information-based data management: Staff scanned the QR code or used NFC to read equipment information, and edited and updated the electronic ledger in real time. The data were synchronized and shared via the hospital cloud, automatically categorized and summarized, and management reports were generated, thereby completely solving the problems of cumbersome paper file retrieval and susceptibility to damage or loss[7].

(3) Equipment repair reporting: When an equipment anomaly occurred, the operator could report the fault with one click on the mobile terminal, describe the fault, and upload live images. The system sent the information directly to the administrator and maintenance personnel. After repair completion, online closed-loop confirmation was performed, making the entire process traceable and progress trackable.

(4) Equipment inspection management: The system presets personalized inspection items and cycles for each device, with automatic pop-up reminders when due. On-site inspection reporting was completed by scanning the code. Anomalies were reported in real time with automatic system alerts, enabling early detection and early intervention for hidden risks[8].

(5) Equipment maintenance management: Based on device manuals and operational data, the system automatically generated periodic maintenance plans with smart reminders for overdue tasks. After maintenance, work records and supporting materials were uploaded online, and the maintenance plan was dynamically optimized, thereby improving the scientific basis of equipment care[9].

(6) Personnel training: Before implementing the model, systematic training was provided to management personnel, operators, and maintenance staff, covering technical principles, platform operation, tag usage, process specifications, and related aspects. A combination of theoretical instruction and practical exercise was adopted, and only those who passed the assessment were allowed to participate in the study.

1.3 Observation indicators

The following three core indicators were compared between the two groups, with dedicated personnel ensuring data accuracy: (1) equipment repair response time: the average time from submission of a repair request to the arrival of maintenance personnel (in minutes); (2) equipment record retrieval time: the average time required to retrieve records in 20 randomly selected instances (in minutes); and (3) number of overdue regular maintenance events: regular maintenance for each device was required to strictly follow the maintenance schedule specified in the device manual. A delay of one week or more in performing regular maintenance was counted as one overdue event.

1.4 Statistical analysis

Statistical analyses were performed using SPSS version 23.0. Continuous data were reported as median and interquartile range (IQR), and differences between groups were tested using the Mann-Whitney U rank sum test. Categorical data were reported as frequencies and percentages, and differences between groups were tested using the chi-square test. A significance level of $\alpha=0.05$ was adopted.

## 2 Results

The median equipment repair response time in the observation group was 40 minutes (30, 50), which was shorter than that in the control group [65 minutes (50, 80)]. The median record retrieval time in the observation group was 4 minutes (3, 5), compared with 20 minutes (15, 25) in the control group. These differences were statistically significant ($Z=4.52$ and $Z=5.16$, respectively; $P<0.001$). Detailed results are presented in Table 1.

**Table 1 Comparison of equipment repair response time and record retrieval time between two groups**

| Indicators | Control group (median (IQR)) | Observation group (median (IQR)) | *Z* | *P* value |
|---|---|---|---|---|
| Repair response time (min) | 65(50,80) | 40(30,50) | 4. 52 | <0. 001 |
| Record retrieval time (min) | 20(15,25) | 4(3,5) | 5. 16 | <0. 001 |

IQR: interquartile range.

During the intervention period, a total of 142 regular maintenance events were scheduled in both the observation group and the control group. The observation group recorded 1 overdue maintenance event, corresponding to an on-time rate of 99.30%, whereas the control group had 29 overdue events, with an on-time rate of 79.60%. The difference between the two groups was statistically significant ($\chi^2$=29.22, $P$<0.001). Detailed results are presented in Table 2.

## 3 Discussion

QR code and NFC technologies complement each other. The combined dual-mode application enables rapid identification, massive data storage, and short-range inductive interaction, thereby overcoming the disadvantages of manual handwriting errors and ledger disorganization. Electronic ledgers are updated in real-time and stored in the cloud, thereby breaking temporal and spatial constraints. Management personnel can quickly retrieve the full lifecycle data of equipment, substantially reducing file search time and improving management convenience. The results of this study demonstrate that data retrieval efficiency in the observation group was significantly enhanced, confirming the application value of digital tags in information management. Compared with using QR codes alone, the dual-mode scheme incorporating NFC tags does not require screen activation or precise alignment; it allows a “tap-to-read” operation, which is more convenient in the equipment-dense, high-activity environment of the CSSD. Compared with using NFC alone, QR codes offer the advantages of low cost, high universality, and no need for dedicated reading terminals, making them suitable for collaborative use across multiple scenarios. The two technologies serve as backups for each other: when one tag is damaged, identification can still be accomplished, thereby improving system fault tolerance and on-site adaptability. This study preliminarily verifies the feasibility and efficiency advantages of dual-mode integration in the CSSD setting.

Equipment operation and maintenance management is a key focus of daily quality control in the CSSD. Under the traditional model, the repair reporting process is lengthy, information transfer is delayed, and maintenance work depends on human memory, which can easily result in missed or delayed maintenance, accelerate equipment aging, and increase operational risks[10]. The dual smart tag management model establishes a new operation and maintenance system characterized by online repair reporting, intelligent reminders, and closed-loop verification, thereby shortening the waiting time for repairs and ensuring rapid handling of equipment faults. The systematic maintenance reminder mechanism effectively reduces the incidence of overdue maintenance and helps maintain equipment in good operating condition[11].

Full-process digital recording is a core requirement for medical quality traceability. Dual-tag management uploads and stores the complete process records of inspection, maintenance, repair, and disposal in real time, forming an electronic archive that cannot be arbitrarily altered and enabling full-chain traceability of equipment operation[12]. The system’s anomaly early warning function can identify potential equipment hazards in advance, reduce the inci-

**Table 2 Comparison of on-time rates of regular equipment maintenance between two groups**

| Groups | Total maintenance events | Overdue events | Non-overdue events | On-time rate (%) | $\chi^2$ | *P* value |
|---|---|---|---|---|---|---|
| Control group | 142 | 29 | 113 | 79. 60 | 29. 22 | <0. 001 |
| Observation group | 142 | 1 | 141 | 99. 30 | | |

dence of sudden failures, ensure the stable operation of key processes such as cleaning and sterilization at the source, and establish a robust defense line for sterile item quality and safety.

Furthermore, digital management effectively reduces repetitive manual work, alleviates the workload of nursing and quality control personnel, and enables management staff to concentrate on core tasks such as quality monitoring and process optimization, thereby comprehensively enhancing the level of departmental refinement in management[13]. In the context of smart healthcare, the integration of digital technologies, including the IoT and smart tags, into departmental management has become an inevitable trend for medical institution logistics and equipment control[14].

This study has several limitations. It is a single-center before-after controlled study, which may be subject to time-related confounding factors. The sample size is limited, and the follow-up period is relatively short, with no long-term monitoring of indicators such as equipment failure rate or service life. Future studies should include multi-center controlled designs, extend the observation period, further evaluate the long-term benefits and cost-effectiveness of this model, and expand its application to equipment management in other key departments, such as operating rooms and ICUs.

## 4 Conclusion

The dual-mode, whole-lifecycle management combining QR code and NFC effectively optimizes equipment inspection, maintenance, and repair reporting processes in the CSSD. It reduces the repair response time and equipment record retrieval time, and decreases the frequency of overdue regular maintenance events. This model is easy to operate and highly practical, enabling intelligent, standardized, and traceable equipment management. It supports the orderly conduct of CSSD clinical work and meets the requirements for nosocomial infection quality control and smart hospital construction. Therefore, it is suitable for widespread adoption in CSSDs across hospitals at various levels.

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