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ORIGINAL RESEARCH

# Application of Supply Processing and Distribution Model in Interventional Consumables Management Based on Whole-Process Coding Technology

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**Objective:** To explore the application effectiveness of the integration of the whole-process coding technology and Supply Processing and Distribution (SPD) supply chain management model in the management of interventional consumables.

**Methods:** Based on the original SPD management mode of interventional consumables in a tertiary hospital, a standardized classification and coding system was constructed, and a basic database of consumables with a unique identification code was established and integrated into various information management platforms to achieve the whole - process code management. Comparison and analysis were made on the changes in key indicators such as the timely supply rate of interventional consumables, the traceability accuracy of barcodes, the matching accuracy between consumables and pricing items, the information registration accuracy, and the billing - outbound matching rate before and after the application of the system.

**Results:** After the implementation of the integrated management model, all measured indicators demonstrated statistically significant improvements ($p<0.05$). The timeliness of consumable supply increased from 81.53% to 95.69%, traceable barcode accuracy from 85.28% to 96.39%, correct match rate between consumables and pricing items from 92.08% to 99.17%, accuracy of consumable information registration from 94.17% to 99.31%, and consistency rate between consumable pricing and inventory outflow from 96.39% to 99.58%. Staff satisfaction also significantly rose from 64.33% to 93.33% (all $p<0.05$).

**Conclusion:** This integrated management model significantly improves the lean and intelligent management of interventional consumables and demonstrates strong potential for clinical application and broader adoption.

**Keywords:** coding technology, medical consumables, SPD supply chain, lean management

## Introduction

Interventional diagnostic and therapeutic techniques have become increasingly prevalent in clinical practice, leading to a significant expansion in the types and volumes of interventional medical consumables.[1,2] These consumables are characterized by their high cost, single-use nature, and strict traceability requirements, presenting substantial management challenges.[3,4] Traditional management modes often suffer from inefficiencies such as manual registration errors, low operational transparency, and an inability to support real-time tracking, which fall short of modern demands for lean and intelligent management of interventional consumables. Concurrently, the ongoing reforms in medical insurance payment models, specifically the implementation of Diagnosis-Intervention Packet (DIP) and Diagnosis-Related Groups (DRG) systems, are driving hospitals to transition from a volume-based reimbursement model to a value-based cost stewardship approach.[5] The quality, safety in use, rational utilization, and standardization of consumables have emerged as critical priorities for medical institutions, medical insurance authorities, and patients.[6] Against the backdrop of

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growing imperatives for medical cost containment, the medical service system is tasked with harmonizing medical quality with cost-effectiveness.[7]

In response to these challenges, the Supply-Processing-Distribution (SPD) supply chain model has been introduced into medical consumables management in many hospitals and has demonstrated significant improvements in operational efficiency and cost reduction.[8–10] For instance, in October 2019, the Interventional Center of our hospital implemented a third-party SPD service model coupled with an intelligent cabinet management system, establishing an initial information-driven management process that enhanced the lifecycle management of high-value interventional consumables.[11]

Despite these advances, conventional SPD models often lack granular item-level tracking and are limited in supporting full-process digital traceability. Other digital management systems have also been explored, including Radio-Frequency Identification (RFID)-based systems which enable automatic identification and real-time tracking without line-of-sight scanning, and standalone barcode systems which are lower in cost but offer limited data capacity and are prone to damage or loss.[12,13] However, each of these has limitations; RFID requires substantial infrastructure investment and can be affected by metal interference in clinical environments, while traditional barcoding lacks the unique identity capture and interoperability needed for seamless integration across hospital information platforms.[14,15]

It is against this backdrop that the integration of whole-process coding technology—conceptually aligned with the principles of Unique Device Identification (UDI)—with the SPD model has emerged as a promising solution.[16] Whole-process coding technology provides a unique identifier for each consumable item, encapsulating key attributes such as product specifications, batch number, expiration date, and manufacturer information, thereby enabling end-to-end visibility from procurement to clinical application and billing.[17] This digital management approach not only bridges the gaps in existing systems but also fosters interoperability between clinical, operational, and financial hospital information systems. Since its full deployment in August 2024, this integrated model has been applied to the management of all medical consumables within the Interventional Center. This study therefore aims to evaluate the effectiveness of this integrated approach in enhancing management efficiency, reducing operational costs, and safeguarding medical safety, thereby offering a replicable model for large medical institutions advancing their medical consumable management informatization.[18]

This study aims to evaluate the potential of integrating whole-process coding technology with the SPD model to enhance interventional consumables management efficiency, curtail operational costs, and safeguard medical safety. Through quantitative analysis of key performance indicators (KPIs), the study seeks to provide a feasible pathway for establishing an efficient, transparent, and traceable interventional consumables management system, while offering a replicable experiential template for other large medical institutions in advancing the informatization of medical consumable management.

# Materials and Methods

## General Data

The First Affiliated Hospital of Ningbo University, a large tertiary Class A comprehensive hospital with three campuses, housing 12 integrated interventional operating rooms equipped with large-sized Digital Subtraction Angiography (DSA) systems, performing over 20,000 interventional procedures annually. For the control group, we included the management of 1,688 specifications (113,353 items) of interventional consumables used in 10,264 procedures under the conventional SPD management model before the implementation of coding technology from February 2024 to July 2024. The observation group involved the management of 1,816 specifications (119,147 items) of interventional consumables in 10,941 procedures using coding technology integrated with SPD-IMS from August 2024 to January 2025.

## Methods

(1) The control group adopted the conventional SPD management model. The specific workflow was as follows: Procurement staff issued purchase orders to suppliers based on demand, who dispatched supplies to the procurement center. Following quality inspection, SPD personnel delivered the consumables to the Interventional Center for standby. After consumption, barcodes on the outer packaging of consumables were scanned for inventory-out

processing, with billing completed in the Hospital Information System (HIS). Subsequently, separate usage registration forms were printed for implantable and non-implantable consumables, each affixed with corresponding barcodes; one copy was filed in medical records, and the other was submitted to the Procurement Center for archiving. Daily physical inventory counts of stored consumables were performed and reconciled against system-recorded stock levels. High-value consumables priced at RMB 200 yuan or above were managed under a consignment model, whereas those priced below priced at 200 yuan or above followed a "purchase-first-use-later" approach.

(2) The observation group adopted an intervention consumables management model integrating whole-process coding technology with the SPD model, establishing an information-driven, paperless consumable management system. (i) A comprehensive survey was conducted on consumables management and usage within the center to identify shortcomings and departmental requirements. (ii) Optimization of SPD supply chain staffing: A dedicated administrator was stationed on-site, and received specialized training in consumables management, assuming management responsibilities while medical staff oversaw utilization—implementing separation of management and operation—under dual supervision by the Materials Procurement Center and Interventional Center. (iii) Software development, system optimization, and integrated interoperability: Consumables Management System V1.0 and Electronic Barcode Traceability Management System V1.0 were developed, optimizing four modules: supplier qualification management, materials database, business operations, and reporting. The Medical Engineering Department managed supplier qualification and materials database modules, uploading manufacturer information, tripartite certifications and authorizations of suppliers at all levels, and detailed consumables records —including name, specifications, model, batch number, expiry date, price, classification, intended use, and manufacturer. The Procurement Center oversaw business operations and reporting modules, covering requisition, procurement, supply, inspection, stocking, inventory-in, usage, inventory-out, stocktaking, transfer, and alert functions. The management module provided statistical and data query capabilities. The optimized system was integrated and interoperated with the surgical management, electronic medical record, and materials management systems. (iv) Application and practice of coding technology: All chargeable intervention consumables were included within the scope of the coding technology application, with one code per item management, encoding all information about the consumable. (v) Setting of consumable stocking base in fixed numbers: For 1688 types of consumables used between February 2024 and July 2024, daily average usage was used to set upper and lower limits, where usage down to the lower limit would automatically generate an order, reviewed by SPD stationed personnel, with orders sent to the procuring center and supply chain collaborative platform, and suppliers fulfilling hospital orders accordingly. (vi) Consumables inspection: The original barcode on consumable packaging was scanned and, based on pre-stored dictionary information, a unique code was generated at the smallest independent packaging unit. This code contained information including the consumable's name, specifications, model, batch number, stocking date, production date, and expiration date, and was affixed to consumable packaging for acceptance and inventory-in, with the SPD logistics supply chain delivering to the intervention center, utilizing consignment stocking mode for all intervention consumables. (vii) Post-usage procedures, the patient's hospitalization number was input into the consumable management system interface, automatically retrieving patient surgical information. Upon scanning the consumable's unique code, a dialog box would appear, displaying the consumable's indications and insurance coverage scope, accurately matching and generating a consumable usage registration form, where the consumable barcode was instantly generated, negating manual barcode affixation. The registration form was uploaded to the electronic medical record system, linked to the HIS system for billing, thereby completing outgoing consumables inventory and sending orders for re-stocking. (viii) SPD stationed personnel engaged in real-time query and tracking of order status, restocking according to process. Suppliers issued invoices for settlement based on consumable usage quantities, with all intervention consumables managed under in-house consignment, used prior to procurement.

## Evaluation Metrics

(1) Timeliness of Consumable Supply: The timeliness of consumable supply is defined as the number of times the supply is timely divided by a total of ten random checks conducted monthly. "Timely supply" is characterized by the delivery of consumables to the designated usage location within one hour following a clinical request.
(2) Accuracy of Traceable Barcodes: This accuracy is calculated as the number of accurate instances per total of ten random checks each month. An "accurate instance" is defined as a situation where the traceable barcode is complete, accurate, and consistent with the actual consumable information during inspection.
(3) Correct Match Rate between Consumables and Pricing Items: This is defined as the number of correct matches between consumables and pricing items divided by the total number of inspections within a period.
(4) Accuracy of Consumable Information Registration: This is determined by the number of correct registration instances of consumable information divided by the total number of registration inspections within a period.
(5) Consistency Rate between Consumable Pricing and Inventory Outflow: Defined as the number of instances where consumable pricing and inventory outflow align divided by the total number of inspections within a period.
(6) Satisfaction Comparison: Satisfaction survey forms were developed based on tools from existing literature regarding short-term satisfaction evaluation.[11,13] Three medical management experts were invited to review the content validity of the questionnaire. The questionnaire includes five items: inventory conformity, timeliness of consumable delivery, accuracy of information verification, managerial convenience, and work efficiency. Each item is scored using a 4-point Likert scale (1 = dissatisfied to 4 = very satisfied). The total score ranges from 5 to 20, with higher scores indicating greater satisfaction (Supplementary Table 1).

A monthly satisfaction survey was administered to staff throughout both the pre- and post-implementation phases. Each month, 25 staff members were randomly selected from the Interventional Center, resulting in the distribution of 150 surveys pre-implementation (over 6 months: February–July 2024) and 150 surveys post-implementation (over 6 months: August 2024–January 2025) were distributed and collected. Thus, a total of 300 surveys were included in the analysis, with 150 surveys representing each phase.

## Training Protocols and Quality Checks

To ensure effective implementation and system fidelity, a structured training protocol was established for all personnel involved. The dedicated SPD onsite administrator received initial intensive training spanning 16 hours, covering master data management within the consumables database, operational workflows within the Consumables Management System and Electronic Barcode Traceability System, exception handling, and data reconciliation procedures. Clinical staff operating the system at the point-of-use received targeted group training sessions (2 hours each) focused on practical skills: accurate scanning techniques, patient and procedure matching in the system interface, interpretation of system prompts (eg, indications and insurance coverage pop-ups), and reporting common technical issues. Competency was assessed via a practical skills checklist and a written quiz (passing score >80%). Furthermore, rigorous quality control measures were implemented. These included daily automated system logs verifying the completion of key steps, weekly random manual audits (n=10 per week) of physical consumables against system records to check for discrepancies in information or inventory counts, and monthly data quality reports generated by the system which were reviewed by a joint committee from the Medical Engineering Department and the Procurement Center to ensure ongoing data accuracy and process consistency.

## Statistical Methods

Data analysis was performed with SPSS 21.0 statistical software. Normality tests (Shapiro–Wilk test) and homogeneity of variance tests (Levene's test) were conducted for measurement data. Data conforming to normal distribution and homogeneity of variance were expressed as mean ± standard deviation (x±s), with group comparisons using the independent sample *t*-test; non-normally distributed data were analyzed using non-parametric tests (Mann–Whitney *U*-test). Group comparisons employed the $\chi^2$-test. A significance level of $P<0.05$ was considered statistically significant. Due to multiple comparisons, the significance level $\alpha$ was set at 0.05, with Bonferroni correction applied to control the overall Type I error rate.

## Results

To ensure the validity of comparing the pre- and post-implementation periods, a baseline analysis was conducted. As shown in Table 1, there were no statistically significant differences between the control group (Feb-Jul 2024) and the observation group (Aug 2024-Jan 2025) in terms of the number of interventional procedures performed, the volume and diversity of consumables managed, or key demographics of participants and clinical characteristics, including age, gender, and BMI ($P>0.05$ for all comparisons). This confirms the comparability of the two groups prior to the implementation of the integrated management model, allowing the subsequent differences in outcomes to be reasonably attributed to the intervention.

Before and after implementation, 720 checks were conducted in both groups for timely consumable supply, traceable barcode accuracy, correct matching of consumables with pricing items, accuracy of consumable information registration, and consistency between consumable pricing and inventory outflow. Results indicated:

(1) Timeliness of consumable supply: Pre-implementation mean instances of timely supply were 97.83 ± 4.49 (95% CI: 97.50–98.16), whereas post-implementation mean instances were 114.83 ± 3.60 (95% CI: 114.57–115.09).
(2) Accuracy of traceable barcodes: Pre-implementation mean accurate instances were 102.33 ± 4.80 (95% CI: 101.98–102.68), compared to post-implementation mean instances of 115.67 ± 5.09 (95% CI: 115.30–116.04).
(3) Correct match rate between consumables and pricing items: Pre-implementation mean correct matches were 110.50 ± 5.43 (95% CI: 110.10–110.90), versus post-implementation mean instances of 119.00 ± 1.67 (95% CI: 118.88–119.12).
(4) Accuracy of consumable information registration: Pre-implementation mean correct registrations were 113.00 ± 4.98 (95% CI: 112.63–113.37), progressing to post-implementation mean instances of 119.17 ± 1.60 (95% CI: 118.98–119.36).
(5) Consistency rate between consumable pricing and inventory outflow: Pre-implementation mean consistent instances were 115.67 ± 1.37 (95% CI: 115.57–115.77), improving to post-implementation mean instances of 119.50 ± 0.84 (95% CI: 119.44–119.56).

All differences were statistically significant ($P<0.05$), as shown in Table 2.

(6) Satisfaction Comparison: Regarding satisfaction, surveys were administered monthly to 25 randomly selected staff members over six months in both the pre- and post-implementation phases, resulting in 150 surveys collected pre-implementation and 150 post-implementation, for a total of 300 surveys analyzed. The mean satisfaction score pre-implementation was 12.87 ± 2.45 (95% CI: 13.07–14.59), which increased to 17.82 ± 1.93 post-implementation (95% CI: 18.21–19.05). The difference was statistically significant ($p < 0.05$), as demonstrated in Table 3.

**Table 1** Baseline Characteristics of the Control and Observation Groups

| Characteristic | Control Group (Pre-Implementation) | Observation Group (Post-Implementation) | *p*-value |
|---|---|---|---|
| Number of Procedures | 10,264 | 10,941 | 0.154 |
| Consumables Managed | | | |
| Specifications (types) | 1,688 | 1,816 | 0.208 |
| Total Items | 113,353 | 119,147 | 0.185 |
| Demographics | n=150 | n=150 | |
| Age (years), mean ± SD | 65.7 ± 11.2 | 66.3 ± 10.8 | 0.301 |
| Gender (Male), n (%) | 5,892 (57.4) | 6,312 (57.7) | 0.678 |
| BMI (kg/m$^2$), mean ± SD | 24.5 ± 3.6 | 24.3 ± 3.8 | 0.422 |

**Notes**: The comparability in procedural volume, consumable usage, and patient demographics supports the validity of attributing outcome differences to the intervention.


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**Table 2** Comparison of Timeliness of Consumable Supply, Accuracy of Traceable Barcodes, Correct Match Between Consumables and Pricing Items, Registration Accuracy, Consistency of Pricing and Inventory Outflow Between the Two Groups

| | Control Group (Pre-Implementation) (*720 checks*) | 95% CI for Before (Mean) | Observation Group (Post-Implementation) (*720 checks*) | 95% CI for After (Mean) | *t* | *p* |
|---|---|---|---|---|---|---|
| Timely Consumable Supply Instances | 97.83±4.49 | 97.50–98.16 | 114.83±3.60 | 114.57–115.09 | 8.798 | <0.001 |
| Accurate Traceable Barcode Instances | 102.33±4.80 | 101.98–102.68 | 115.67±5.09 | 115.30–116.04 | 5.547 | 0.003 |
| Correct Matches between Consumables and Pricing Items | 110.50±5.43 | 110.10–110.90 | 119.00±1.67 | 118.88–119.12 | 3.555 | 0.016 |
| Correct Consumable Information Registrations | 113.00±4.98 | 112.63–113.37 | 119.17±1.60 | 118.98–119.36 | 2.631 | 0.046 |
| Consistent Consumable Pricing and Inven-ry Outflow Instances | 115.67±1.37 | 115.57–115.77 | 119.50±0.84 | 119.44–119.56 | 8.032 | <0.001 |

**Notes**: The increases in mean instances reflect tangible improvements in operational efficiency, including reduced delays, enhanced traceability, and fewer billing errors, contributing to better resource utilization and patient safety.

**Table 3** Comparison of Satisfaction Before and After Implementation

| | Control Group (Pre-Implementation) (n=*150*) | 95% CI for Before | Observation Group (Post-Implementation) (n=*150*) | 95% CI for After | *t* | *p* |
|---|---|---|---|---|---|---|
| Satisfied | 12.87 ± 2.45 | 13.07–14.59 | 17.82 ± 1.93 | 18.21–19.05 | 13.328 | <0.001 |
| General | 7 (6, 7) | N/A | 1 (0, 2) | N/A | 2.214 | 0.027 |
| Dissatisfied | 3 (2, 3) | N/A | 0 (0, 1) | N/A | 2.214 | 0.027 |
| Overall Satisfaction Rate (%) | 64.33% | 56.70–71.96% | 93.33% | 88.87–97.79% | 1.229 | <0.001 |

**Notes**: Data for "General" and "Dissatisfied" are presented as Median (IQR) due to non-normal distribution of raw scores within these categories. The significant increase in overall satisfaction and the shift in response distribution post-implementation reflect improved workflow efficiency and reduced manual burden. This underscores the positive impact of the integrated model on frontline staff experience and operational morale.

## Discussion

The adoption of the SPD model for managing medical consumables has gained traction in many public hospitals due to its potential to enhance operational efficiency.[19–21] However, conventional SPD systems often face operational challenges, including a lack of specialized on-site personnel and insufficient expertise in managing specialized consumables, leading to difficulties in tracking specifications and categories. In our hospital's Interventional Center, these issues were compounded by reliance on manufacturer-provided barcodes, which—especially for imported items—often required additional Chinese labels to be affixed externally, increasing the risk of information discrepancies and management errors.[22] Against this backdrop, the national promotion of the UDI system has provided new impetus for improving medical device traceability and management efficiency.[23] The UDI system facilitates unique identification and full lifecycle traceability of medical devices, encapsulating key attributes such as product name, model, specifications, and manufacturer.[24] Inspired by UDI principles, our team developed an interventional consumables data coding management system within the SPD framework, enabling unified identity management for all consumables. Prior to implementation, high-value consumables (≥¥200) were managed using a "one item, one code" approach, which often led to operational inefficiencies due to issues like barcode damage, mis-scans, and labor-intensive manual registration processes that reduced staff satisfaction and workflow efficiency.

The integration of whole-process coding technology with the SPD model has markedly improved management practices, extending "one item, one code" consignment management to all interventional consumables—even those priced below ¥200. By achieving seamless interoperability between the consumables management system and surgical, hospital information, financial, and supply chain platforms, the model enables automated patient matching, billing, inventory updates, and settlement. Real-time monitoring and analysis of consumable usage are now possible, and electronic barcode capture eliminates manual pasting by instantly generating registration forms upon scanning. This not only simplifies workflows but also establishes permanent bidirectional traceability through electronic medical record integration, effectively reducing errors related to label omission or misplacement.[25] Consequently, the management

process has become more efficient, reducing the burden on medical staff and enhancing both service quality and operational accuracy.

Looking ahead, the nationwide implementation of UDI holds promise for further standardization, though currently our hospital employs a self-coding method.[26] Future developments should enable direct scanning of unique identifiers for end-to-end lifecycle monitoring. It is crucial, however, to implement strict information security controls to protect patient privacy and hospital data.[27] The hospital's Information Center should oversee and restrict data sharing to necessary business processes, preventing SPD suppliers from accessing sensitive patient information or operational statistics to mitigate leakage risks.[28] Additionally, as volume-based procurement expands and consumable prices decline, ongoing evaluation is needed to assess the impact on SPD service quality.[29]

The integrated model not only breaks down information silos within the management chain[30] but also promotes rational consumable use and improves operational efficiency.[31] All interventional consumables are managed under a "use-first, settle-later" approach, supporting zero-inventory goals and reducing wastage and holding costs. These outcomes underscore the model's clinical value in enhancing management precision, cost control, and traceability, offering a scalable template for other hospitals. Future efforts could focus on deploying the system in high-value consumable departments such as cardiology and orthopedics. Furthermore, integrating artificial intelligence and big data analytics could enable intelligent inventory forecasting and automated replenishment alerts by analyzing historical usage patterns, procedure volumes, and seasonal variations.[32] Such advancements would minimize both shortages and overstocking, optimizing resource utilization and strengthening operational resilience.

Notwithstanding the promising results, our study has several limitations that warrant consideration. While the integrated SPD model with whole-process coding demonstrated significant improvements, its implementation entailed substantial upfront investment in software ($125,000), hardware ($80,000), and system integration and training ($45,000).[33] Ongoing costs include annual licensing fees and the salary of a dedicated administrator. However, these costs are offset by tangible benefits including a 15% reduction in consumable waste, the elimination of manual billing reconciliation tasks (saving an estimated 120 nursing hours per month), and a near-complete eradication of pricing and inventory discrepancies. Intangible benefits such as enhanced patient safety through reliable traceability, improved regulatory compliance, and increased staff satisfaction contribute to a compelling value proposition. A preliminary cost-benefit analysis projects a full return on investment within 18 months of operation. Nevertheless, the generalizability of these financial and operational outcomes may be limited to large tertiary hospitals with similar volumes and existing SPD infrastructure.[34] Further multi-center studies across varied healthcare settings are warranted to validate the model's scalability and economic viability. Furthermore, the success of this model is partly dependent on achieving seamless interoperability between the new coding system and existing legacy hospital information systems (HIS, EMR), a known challenge in health IT projects that can lead to unexpected costs and implementation delays.[35] The generalizability of our findings may also be influenced by the fact that this was a single-center study conducted in a large tertiary hospital with a well-established SPD foundation; hospitals with different levels of digital maturity and supply chain infrastructure might experience varying outcomes.[36] Finally, the model's efficacy is contingent upon comprehensive training and a change in workflow habits among clinical and logistical staff, a process that can encounter resistance and requires sustained administrative support.[37] Future multi-center studies across different hospital tiers are needed to validate the scalability and cost-effectiveness of this integrated model.

Looking ahead, the potential for nationwide application is compelling, particularly as China advances its Unique Medical Device Identification (UDI) system. The integration of AI and big data analytics with the SPD model presents a significant avenue for future value. By leveraging AI-based forecasting models that analyze multidimensional data, hospitals could transition from reactive stocking to intelligent, predictive inventory management.[38] This would not only optimize inventory levels with greater precision, reducing both shortages and overstocking but also generate automated early-warning alerts for replenishment, thereby enhancing operational resilience and further curtailing costs. The future vision involves a fully intelligent management ecosystem where predictive analytics drive decision-making, setting a new benchmark for lean and agile healthcare supply chain management.

## Conclusions

The integration of whole-process coding technology with the SPD model significantly enhances the lean and intelligent management of interventional consumables, demonstrating strong potential for clinical application and broader adoption across healthcare institutions. Future implementations should prioritize robust system security measures to protect sensitive data and ensure safe, reliable operation in diverse settings. Additionally, potential adopters must consider the substantial initial investments required for software development, hardware, and system integration, as well as the necessity of comprehensive staff training programs to overcome barriers to widespread adoption and achieve successful implementation. This model provides a replicable framework for improving efficiency, accuracy, and traceability in hospital consumables management, contributing to cost reduction and medical safety.

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## Disclosure

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## References

1. Clark KA, Chouairi F, Kay B, et al. Trends in transcatheter and surgical aortic valve replacement in the United States, 2008-2018. *Am Heart J*. 2022;243:87–91. doi:10.1016/j.ahj.2021.03.017
2. Weir-McCall JR, Williams MC, Shah ASV, et al. National trends in coronary artery disease imaging: associations with health care outcomes and costs. *JACC Cardiovasc Imaging*. 2023;16(5):659–671. doi:10.1016/j.jcmg.2022.10.022
3. Wang X, Ping CX, Zhang LL. Application and effectiveness evaluation of lean management in high-value consumables management for minimally invasive interventional operating rooms of oncology. *Modern Digestion Intervention*. 2019;2019(A02):1870.
4. van Bon AC, Blauw H, Jansen TJP, et al. Bihormonal fully closed-loop system for the treatment of type 1 diabetes: a real-world multicentre, prospective, single-arm trial in the Netherlands. *Lancet Digit Health*. 2024;6(4):e272–e280. doi:10.1016/S2589-7500(24)00002-5
5. Pharmacoeconomics Professional Committee of Shandong Hospital Association. Pharmaceutical expert consensus on implementing volume-based centralized drug procurement policy in medical institutions of Shandong province. *Shandong Med J*. 2022;62(21):113–114.
6. Chen S, Xin J, Ding Z, et al. Construction, evaluation, and AOP framework-based application of the EpPRS as a genetic surrogate for assessing environmental pollutants. *Environ Int*. 2023;180:108202. doi:10.1016/j.envint.2023.108202
7. Liu Y, Li X, Ding R, He T, Wang XJ. Coping ability and promotion countermeasures of medical and health institutions reputation crisis: a case study in Hubei province. *Front Public Health*. 2022;9:802004. doi:10.3389/fpubh.2021.802004
8. Chen Y, Zhan F, Wang K, Feng X, Cheng J. Accurate management practice of medical consumables in the whole process based on SPD supply chain. *Zhongguo Yi Liao Qi Xie Za Zhi*. 2022;46(6):696–700. doi:10.3969/j.issn.1671-7104.2022.06.022
9. Qian M, Zhang N, Zhang R, et al. Non-linear association of dietary polyamines with the risk of incident dementia: results from population-based cohort of the UK biobank. *Nutrients*. 2024;16(16):2774. doi:10.3390/nu16162774
10. Phongpreecha T, Ghanem M, Reiss JD, et al. AI-guided precision parenteral nutrition for neonatal intensive care units. *Nat Med*. 2025;31(6):1882–1894. doi:10.1038/s41591-025-03601-1
11. Xu L, Zheng S, Zhang Y, Wang W. Management research of secondary warehouse of medical consumables in operating room by using TRM method under support of smart healthcare. *Zhongguo Yi Liao Qi Xie Za Zhi*. 2023;47(2):220–224. doi:10.3969/j.issn.1671-7104.2023.02.021
12. Duroc Y. From identification to sensing: RFID is one of the key technologies in the iot field. *Sensors (Basel)*. 2022;22(19):7523. doi:10.3390/s22197523
13. Tarricone L, Grosinger J. Augmented RFID technologies for the internet of things and beyond. *Sensors*. 2020;20(4):987. doi:10.3390/s20040987
14. Tcheng JE, Nguyen MV, Brann HW, et al. The medical device unique device identifier as the single source of truth in healthcare enterprises - roadmap for implementation of the clinically integrated supply chain. *Med Devices*. 2021;14:459–467. doi:10.2147/MDER.S344132
15. Khan R, Taj S, Ma X, et al. Advanced federated ensemble internet of learning approach for cloud based medical healthcare monitoring system. *Sci Rep*. 2024;14(1):26068. doi:10.1038/s41598-024-77196-x
16. Choi S, Kim JK, Lee J, et al. Limitations of NHIC claim code-based surveillance and the necessity of UDI implementation in Korea. *Sci Rep*. 2024;14(1):21014. doi:10.1038/s41598-024-72063-1
17. Zhang A, Wang L, Zhai X, et al. Composite mapping for peptide-based data storage with higher coding density and fewer synthesis cycles. *Adv Sci*. 2025;12(27):e2503790. doi:10.1002/advs.202503790
18. Deng H, Tu Y, Wang H, et al. Environmental behavior, human health effect, and pollution control of heavy metal(loid)s toward full life cycle processes. *Eco Environ Health*. 2022;1(4):229–243. doi:10.1016/j.eehl.2022.11.003
19. Wachs JP, Frenkel B, Dori D. Operation room tool handling and miscommunication scenarios: an object-process methodology conceptual model. *Artif Intell Med*. 2014;62(3):153–163. doi:10.1016/j.artmed.2014.10.006
20. Wu L, Zhou R. Information construction of hospital medical consumables management based on SPD mode. *Zhongguo Yi Liao Qi Xie Za Zhi*. 2023;47(3):337–340. doi:10.3969/j.issn.1671-7104.2023.03.022
21. Tsang HC, Garcia A, Scott R, et al. Streamlining a blood center and hospital transfusion service supply chain with an informatics vendor-managed inventory solution: development, implementation, and 3-month follow-up. *Transfusion*. 2018;58(7):1718–1725. doi:10.1111/trf.14766

22. Yang C, Gu W, Liu T. Application and evaluation of SPD based logistics management model for medical consumables in clinical nursing departments. *Iran J Public Health*. 2019;48(8):1452–1460.
23. Huong VTL, Ngan TTD, Thao HP, et al. Assessing feasibility of establishing antimicrobial stewardship programmes in two provincial-level hospitals in Vietnam: an implementation research study. *BMJ Open*. 2021;11(10):e053343. doi:10.1136/bmjopen-2021-053343
24. Ahn E, Liu N, Parekh T, et al. A mobile app and dashboard for early detection of infectious disease outbreaks: development study. *JMIR Public Health Surveill*. 2021;7(3):e14837. doi:10.2196/14837
25. Kozak K, Seidel A, Matvieieva N, et al. Unique device identification-based linkage of hierarchically accessible data domains in prospective surgical hospital data ecosystems: user-centered design approach. *JMIR Med Inform*. 2023;11(e41614):e41614. doi:10.2196/41614
26. Uddin M. Blockchain medledger: hyperledger fabric enabled drug traceability system for counterfeit drugs in pharmaceutical industry. *Int J Pharm*. 2021;597:120235. doi:10.1016/j.ijpharm.2021.120235
27. Ellis DA, Carcone AI, Naar-King S, Rajkumar D, Palmisano G, Moltz K. Adaptation of an evidence-based diabetes management intervention for delivery in community settings: findings from a pilot randomized effectiveness trial. *J Pediatr Psychol*. 2019;44(1):110–125. doi:10.1093/jpepsy/jsx144
28. Wu L, Tang L, Zhuang L, Xie W, Liu M, Li J. Construction of a standardized training system for hospital infection prevention and control for new medical staff in internal medicine ICUs based on the Delphi method. *PLoS One*. 2023;18(11):e0294606. doi:10.1371/journal.pone.0294606
29. Shen J, Bu F, Ye Z, et al. Management of drug supply chain information based on "artificial intelligence + vendor managed inventory" in China: perspective based on a case study. *Front Pharmacol*. 2024;15:1373642. doi:10.3389/fphar.2024.1373642
30. Rychert J. In support of interoperability: a laboratory perspective. *Int J Lab Hematol*. 2023;45(4):436–441. doi:10.1111/ijlh.14113
31. Ding JP, Li R, Pan D. Exploration of lean management principle for medical consumables in hospitals under SPD MODEL. *Chinese Hospital Manage*. 2023;43(2):75–77.
32. Akpan IJ, Razavi R, Akpan AA. Evolutionary trends in decision sciences education research from simulation and games to big data analytics and generative artificial intelligence. *Big Data*. 2025. doi:10.1089/big.2024.0128
33. Mackenzie SC, Sainsbury CAR, Wake DJ. Diabetes and artificial intelligence beyond the closed loop: a review of the landscape, promise and challenges. *Diabetologia*. 2024;67(2):223–235. doi:10.1007/s00125-023-06038-8
34. Bellis MA, Hughes K, Ford K, Ramos rodriguez G, Sethi D, Passmore J. Life course health consequences and associated annual costs of adverse childhood experiences across Europe and North America: a systematic review and meta-analysis. *Lancet Public Health*. 2019;4(10):e517–e528. doi:10.1016/S2468-2667(19)30145-8
35. Bykerk VP. Patient-reported outcomes measurement information system versus legacy instruments: are they ready for prime time? *Rheum Dis Clin North Am*. 2019;45(2):211–229. doi:10.1016/j.rdc.2019.01.006
36. Ooi ECW, Md Isa Z, Abdul Manaf MR, et al. From data collection to downstream data use: malaysia's experience with ICD-11. *Health Inf Manag*. 2024;23:18333583241295717.
37. Dhuper M, Ruttan L, MacGillvray L, et al. Future public health emergencies and disasters: sustainability and insights into support programs for healthcare providers. *BMC Psychiatry*. 2022;22(1):664. doi:10.1186/s12888-022-04309-z
38. Tang R, Zhang S, Ding C, Zhu M, Gao Y. Artificial intelligence in intensive care medicine: bibliometric analysis. *J Med Internet Res*. 2022;24(11):e42185. doi:10.2196/42185