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A pilot study investigating the efficiency of an Internet of things (IOT)-aided warehouse management system in the management of consumables for the operating room in a Chinese setting

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SUMMARY: The aim of this study was to investigate the value of an Internet of things (IOT)-aided warehouse management system (IAWMS) to improve the efficiency of consumables management for the operating room (OR). Indices in three domains (error alerts, time taken for work, and level of satisfaction) were selected. Records were compared for two groups, namely the IAWMS group (records after implementation of IAWMS from March 2024 to September 2024) and the control group (manual work before implementation of IAWMS from July 2023 to December 2023). Results revealed that the IAWMS significantly reduced error alerts and the time taken for routine work. The level of satisfaction of the medical staff improved significantly. Noticeably, the time taken to conduct a physical inventory decreased markedly (12.57 ± 1.27 min *vs*. 840.00 ± 120.00 min, $p < 0.0001$). This pilot study confirmed the value of an IAWMS in improving the operational efficiency of consumables management for the OR in a Chinese setting. The IAWMS relieves medical staff from heavy manual work. Thus, the IAWMS is recommended for routine management of consumables for the OR.

Keywords: Internet of things (IOT), consumables management, operating room, operational efficiency, level of satisfaction

An operating room (OR) is one of the most important locations in a general hospital. Research has indicated that over 60% of patients are treated in the OR, accounting for 33% of inpatient costs (*1*). The OR markedly affects revenue and costs in a given hospital. Moreover, the OR plays a crucial role in the efficiency and safety of hospitals. Warehouse management plays a vital role in OR management. Warehouse management, and particularly consumables management, significantly influences the surgical process (*2*). Highly efficient and convenient consumable availability help to reduce medical costs and improve the quality of care (*3*). Conversely, disruption of or inefficiency in the OR, such as a disruption of flow, may cause the cessation of surgery or increase the operating time, ultimately influencing surgical efficiency. Accordingly, improving warehouse management, and particularly consumables management, is an urgent task for OR managers. However, conventional management of consumables for the OR in warehouses relies on manual work. There are often scores of consumables for the OR; the demand is high, but the medical staffing is insufficient. Poor management can cause medical errors, loss of consumables, or unnecessary waste. Moreover, a large amount of time may be spent and manpower allocated to perform routine work, such as registering consumables upon receipt/return, conducting a physical inventory, and calculation of costs. Therefore, a more effective OR-related warehouse management system is required. Thanks to the development of computer technology, many computer-based management systems have been developed and used in OR management in Chinese settings.

An Internet of things (IOT)-aided warehouse management system (IAWMS, Figure 1A) was introduced to manage consumables for the OR in March 2024. Thus, this pilot study was designed to investigate the efficiency of the IAWMS. We investigated whether the IAWMS can reduce error alerts and the time taken for work. The level of satisfaction among the medical staff involved was also investigated. This study should help to gain a better understanding of the value of an IAWMS during management of consumables for the OR.

Figure 1A shows the system configuration for the IAWMS. The supply, processing, and distribution (SPD) smart management system serves as the host machine, which is connected to sensors, a face recognition system, user interface, storage system, and alarm system *via* a local area network (Figure 1A). All consumables are categorized and encoded with a label with a quick response (QR) code, with colors representing the attributes of these consumables (Figure 1B). Figure 1C depicts the standard operating procedure (SOP) for different implementation scenarios. First, all qualified medical staff members are registered in the system for face recognition. When receiving consumables, they enter the warehouse and select the required consumables, scan the QR code on the consumable *via* a portable data assistant (PDA) terminal connected to the WIFI network, and obtain the consumable. All information regarding consumables is recorded in the system, including the number of consumables and their costs. When returning consumables, all QR codes on the returned consumables are scanned and recorded in the system. During a physical inventory, consumables are conveniently managed by scanning the QR codes. All procedures are connected to and supervised by hospital management

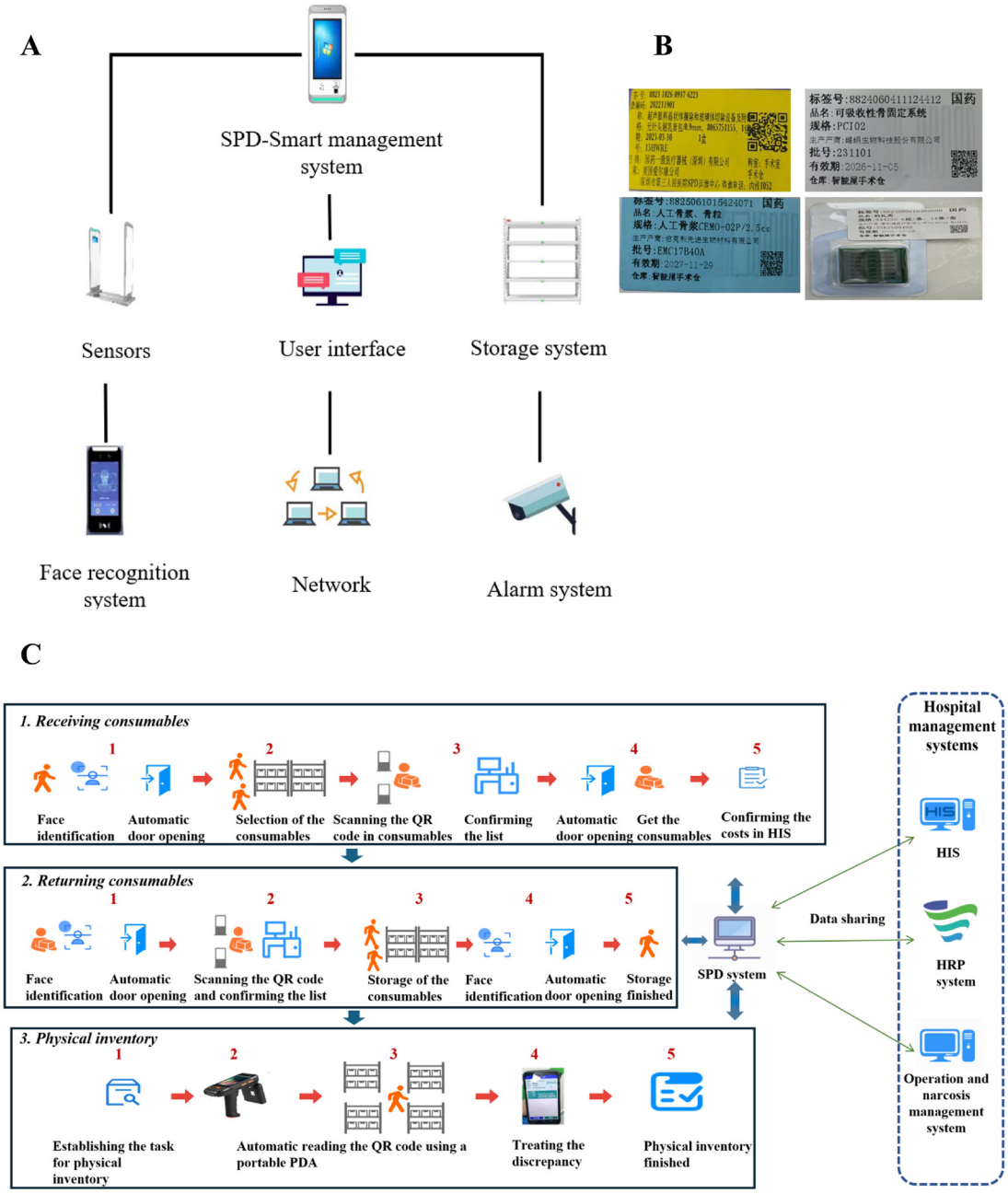

Figure 1. Diagram of the use of an IOT-aided warehouse management system (IAWMS) in a clinical setting. (A) Diagram of the IAWMS. **(B)** Labels for consumables with different colors, which represent different categories of consumables. (C) Standard operating procedures for receiving consumables, returning consumables, and physical inventory using the IAWMS. IAWMS, IOT-aided warehouse management system; IOT, Internet of things; HIS, hospital information system; HRP, hospital resource planning; PDA, portable data assistant; QR code, quick response code; SPD, supply, processing, and distribution.

Table 1. Indices of warehouse management

Item	IAWMS group	Control group	*p*
Total number of warehouses exits	205.7 ± 36.35	204.8 ± 35.89	0.85
Error alerts	*n* = 90	*n* = 92	
No QR code scanned during warehouse exit	0.37 ± 0.68	21.96 ± 11.96	< 0.001
No QR code scanned during invoicing	0.48 ± 0.71	16.83 ± 7.14	< 0.001
Errors in system login	0.13 ± 0.34	16.4 ± 6.88	< 0.001
Errors involving items not returned to their original position	0.28 ± 0.45	0.63 ± 5.46	< 0.001
Time (minutes) taken for work	*n* = 4,075	*n* = 4,116	
Time taken to conduct a physical inventory	12.57 ± 1.27	840.00 ± 120.00	< 0.0001
Time taken to receive consumables	0.16 ± 0.05	15.48 ± 2.72	< 0.001
Time taken to audit expenses	4.25 ± 0.10	29.94 ± 4.56	< 0.001
Level of satisfaction (%) (*n* = 76)			
Convenient process	81.82	25.00	< 0.0001
Trace management	77.27	14.47	< 0.0001
Sorting and reorganizing	81.82	6.58	< 0.0001

systems, and data are shared (Figure 1).

Records of two groups were compared, namely the IAWMS group (records after implementation of the IAWMS from March 2024 to September 2024) and the control group (manual work before implementation of the IAWMS from July 2023 to December 2023). This study included indices in three domains. The first domain was the "error alerts" generated by the IAWMS and previous manual records, including the indices of "No QR code scanned during warehouse exit", "QR code scanned during invoicing", "errors in system login", and "errors involving items not returned to their original position." We analyzed the errors recorded in the system. The second domain was the "time taken for work", which recorded times including "the time taken to conduct a physical inventory", "the time taken to receive consumables", and "the time taken to audit expenses." The time taken for each index was recorded in a clinical setting. The third domain was the "level of satisfaction", which covered a "convenient process", "trace management", and "sorting and reorganizing." A three-question questionnaire was developed in light of the problems that were identified in a poll before implementation of the IAWMS, that is the top three concerns regarding the manual management of consumables for the OR. It was used to investigate the level of satisfaction with the three aspects above.

The software SPSS (V26.00, IBM, IL, USA) was used for statistical analysis. The Kolmogorov-Smirnov test was used to confirm the normal distribution of the data. Data are expressed as the mean ± standard deviation (SD). The Student's t-test was used to compare the differences in continuous variables between the two groups. The chi-square test was used to compare the differences in rates between the two groups. $p < 0.05$ was considered to indicate a statistically significant difference.

Table 1 shows the improvements resulting from use of the IAWMS. The first domain is the "error alerts" generated by the system. A total of 182 records (90 from the IAWMS group and 92 from the control group) were analyzed. Indices of "No QR code scanned during warehouse exit" (0.37 ± 0.68 *vs*. 21.96 ± 11.96, $p < 0.001$), "No QR code scanned during invoicing" (0.48 ± 0.71 *vs*. 16.83 ± 7.14, $p < 0.001$), "errors in system login" (0.13 ± 0.34 *vs*. 16.4 ± 6.88, $p < 0.001$), and "errors involving items not returned to their original position" (0.28 ± 0.45 *vs*. 0.63 ± 5.46, $p < 0.001$) decreased significantly due to use of the IAWMS (IAWMS group *vs*. control group). In the domain of "time taken for work", a total of 8,191 records (4,075 in the IAWMS group and 4,116 in the control group) were investigated. Using the IAWMS significantly reduced "the time taken to conduct a physical inventory" (12.57 ± 1.27 min *vs*. 840.00 ± 120.00 min, $p < 0.0001$), "the time taken to receive consumables" (0.16 ± 0.05 min *vs*. 15.48 ± 2.72 min, $p < 0.001$), and "the time taken to audit expenses" (4.25 ± 0.10 min *vs*. 29.94 ± 4.56 min, $p < 0.001$) compared to times for the control group. Notably, the time taken to conduct a physical inventory decreased markedly (average 12.57 min for the IAWMS group *vs*. 840.00 min for the control group). A total of 76 valid questionnaires were received with respect to the domain of satisfaction. The IAWMS group had a significantly improved level of satisfaction with the "convenient process" (81.82% *vs*. 25.00%, $p < 0.001$), "trace management" (77.27% *vs*. 14.47%, $p < 0.001$), and "sorting and reorganizing" (81.82% *vs*. 6.58%, $p < 0.001$) compared to the control group (Table 1). Hence, the implementation of an IAWMS significantly improved the operational efficiency of consumables management for the OR.

The present study conducted a pilot study to compare the efficiency of consumables management for the OR of a general hospital in China before and after use of an IAWMS. Results revealed that the implementation of the IAWMS significantly reduced error alerts and the time taken for routine work. The level of satisfaction of the medical staff improved significantly. Findings indicated the value of an IAWMS in improving consumables management for the OR.

The quality of OR management significantly affects

the quality of medical care in a clinical setting. Studies worldwide have confirmed that improved management can indeed enhance operational efficiency in the OR (*2,4-6*). The evidence obtained in this study is that the IAWMS helps to reduce errors. This means that the accuracy improved significantly, which agrees with the results of a previous study conducted in China. Liu *et al*. found that using an intelligent mode reduced the total error rate from 4% to 1% (*6*). The second piece of evidence is that the IAWMS reduced the time taken for routine work, and particularly conducting a physical inventory (average 12.57 min *vs*. 840.00 min). Compared to a previous study in which the inventory time was 12 ± 5 min less, the inventory accuracy increased from 94.6% to 98.6% in Liu's study (*6*), and the improvements noted in the current study are greater. Indeed, the IAWMS was highly capable of reducing the time taken for work. Thus, the operational efficiency improved and manpower was saved. Moreover, the IAWMS helped to improve the level of satisfaction of the medical staff. Before the implementation of the IAWMS, the routine work of consumables management, such as conducting a physical inventory, was a heavy and stressful job because it mainly relied on manual work. Using a simple "scan", the IAWMS relieves the medical staff from heavy manual work. Improvement of the level of satisfaction helps to alleviate workplace stress and improve operational efficiency, which may help to improve the quality of medical care.

Although this study verified the value of an IAWMS in improving the operational efficiency of consumables management, a point that should be borne in mind is that the IAWMS, as a computer-based system, should be optimized in response to the development of surgical technology and novel consumables. Moreover, this "improvement" was based on the machine record and investigation of medical staff. However, once the efficiency of consumables management is improved, it can reduce the time for surgical preparations and the duration of anesthesia, thereby decreasing surgical complications. We believe that improvements provided by an IAWMS may directly improve surgical procedures. Future studies should focus on direct improvement in the quality of surgery and clinical outcomes for patients.

This study had several limitations: *i*) This study used a before-and-after experimental design rather than a randomized or contemporaneous control setting, so the present findings might be influenced by time-related confounders, such as seasonal effects, changes in hospital policy, and staff turnover, thereby potentially inflating the intervention's effect size. *ii*) We did not measure the reliability of these investigations in this pilot study, such as test-retest and internal consistency, which should be addressed in a future study.

In conclusion, this pilot study investigated the value of an IAWMS in improving the operational efficiency of consumables management for the OR in a Chinese setting. The IAWMS relieves medical staff from heavy manual work. Accordingly, it reduced error alerts and the time taken during routine work, and it improved the level of satisfaction among the medical staff. Thus, an IAWMS is recommended for routine consumables management for the OR.

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Conflict of Interest: The authors have no conflicts of interest to disclose.

References

1. Hosseinzadeh F, Sepehri MM, Khasha R, Taherkhani N. A framework to find flow disruptions in the operating rooms' consumable supplies. Periop Care OR Mgmt. 2020; 21:100136.
2. Mohan S, Mangal TD, Colbourn T, *et al*. Factors associated with medical consumable availability in level 1 facilities in Malawi: A secondary analysis of a facility census. Lancet Glob Health. 2024; 12:e1027-e1037.
3. Zhao F, Yu M, Zhao Z, Zhou X. Cost control and management of low-value consumables in operating room. 2019.
4. Berry M, Berry-Stolzle T, Schleppers A. Operating room management and operating room productivity: The case of Germany. Health Care Manag Sci. 2008; 11:228-239.
5. Pugliesi PS, Frick H, Guillot S, Ferrare K, Renzullo C, Benoist A, Ribes S, Beltramo G, Maldiney T, Ter Schiphorst R, Abdul Malak C, Bevand A, Marrauld L, Lejeune C. Cost of carbon in the total cost of a healthcare procedure: Example of micro-costing study in a French setting. Appl Health Econ Health Policy. 2025; 23:265-275.
6. Liu J, Xing LM, Shi X. Application of intelligent management mode for drugs and consumables in anesthesiology department. Eur Rev Med Pharmacol Sci. 2022; 26:5053-5062.

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