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ORIGINAL RESEARCH

Optimizing Pathological Examination Cost Control Through Process Management Information Systems: A Mixed-Methods Study

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Background: This study aimed to investigate the effects of process management information systems used for consumable management in the Department of Pathology.

Methods: Data, such as workload capacity of each work group from 2022 to 2023, consumable consumption, warehouse receiving and dispatching, and price of consumables, were extracted from the hospital information system (HIS) and the Goldisc Picture Archiving and Communication System (PACS) of West China Second University Hospital, Sichuan University. Chi-square test and 95% confidence interval (CI) analysis were performed to assess the effects of the systems in optimizing pathological examination cost control. The focus group interviews were conducted to investigate the advantages, limitations and optimization strategy of the systems.

Results: The workload capacities of the cellular pathology group, molecular pathology group, frozen section group, immunohistochemistry group, and routine pathological examination group increased by 20.17%, 22.72%, 24.10%, 24.28%, and 20.11%, respectively ($P < 0.0001$) (95% CI: 19.74%, 24.81%). The difference in the quantity of medical consumables received at the warehouse between 2022 and 2023 was 148,975 ($P < 0.0001$). The difference in the quantity of dispatched medical consumables between 2022 and 2023 was 150,282 ($P < 0.0001$). The overstock inventory of medical consumables decreased from 996,527.33 (Chinese Yuan) for 2022 to 832,401.60 (Chinese Yuan) for 2023. The quantity of waste in glass slides decreased from 17,244 for 2022 to 1,538 for 2023 ($P < 0.0001$). The timeliness rate of histopathological diagnosis in 2023 increased from 65.07% (data for 2022) to 95.46%. The timeliness rate of intraoperative pathological rapid diagnosis in 2023 increased from 67.34% (data for 2022) to 89.45%.

Conclusion: Intelligent information management modules should be configured for medical consumables to optimize the allocation of medical resources and reduce the cost of pathological examinations. The process management information systems could significantly optimize pathological examination cost control.

Keywords: cost control, information management, materials management, pathology department, hospital

Introduction

The unreasonable increase in medical expenses has become a prominent issue in hospitals in China, particularly in public hospitals.[1,2] Due to the lack of effective cost-control measures, the national health insurance program has incurred losses in many regions in China.[3] The Chinese government has introduced several policies, including the zero-markup policy for drugs and payment based on the diagnosis-related groups, to curb the unreasonable growth of medical expenses. However, its effects are not significant. The results of Dai et al[4] have shown that medical expenses in the public hospitals in Jiangsu and Zhejiang (two provinces located in eastern China with faster economic development compared to other regions in China) continued to rise year-on-year from 2008 to 2021. This occurred despite the hospitals benefiting from optimization of the structure of hospital revenues and improvement in internal cost control and cost accounting.

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Pathological examination is characterized by "4 highs and 3 complexes". The "4 highs" refers to (1) pathological examinations being highly sensitive to consequences. A pathological examination is recognized as the "gold standard" in the medical field.[5,6] Diagnostic errors can directly affect the follow-up clinical treatment of patients; (2) pathological examination having a highly standardized process and involving multiple disciplines.[7,8] It concerns various steps, including medical consumable management, sampling, and result reporting. The process management information systems of pathological examinations are of great significance for ensuring the accuracy of pathological diagnosis and improving the efficiency of healthcare services.[9] As tumors are highly complex and heterogeneous, specific knowledge of biology, immunology and genetics are applied to pathological diagnosis; (3) the management of medical consumables for pathological examinations being highly resource-specific. Management of medical consumables in the Department of Pathology used to rely on manual records and manual operations, with low management transparency and insufficient informatization. However, this option can lead to recording errors or missing records in consumable receiving and dispatching, overstock, and shortage of consumables, thereby leading to an increase in hospitals' operating costs and waste in consumables.[10–12] The non-standardized management of consumables may have a negative impact on the efficiency and quality of pathological diagnosis; (4) China National Accreditation Service for Conformity Assessment setting high regulatory requirements for pathology laboratories.[13] Management information systems can improve data accuracy and real-time monitoring capabilities under efficient operation and can also effectively overcome the shortcomings of traditional management; this is despite the high initial investment, high technical requirements and the reduced interpersonal communication.[14,15] The "3 complexes" refers to (1) the complex life cycle of pathological specimens. Pathological examination requires the full traceability from specimen collection to data archiving;[16] (2) complex quality control system concerning tissue processing, sectioning, staining, and pathological diagnosis;[17] (3) complex time coupling. Multiple conflicts in time sensitivity, resource allocation and work procedures exist between rapid intraoperative pathological diagnosis and conventional pathological diagnosis.[18]

In China, the procurement of medical consumables is regarded as a high-risk field of corruption and bribery.[19,20] Therefore, ensuring the fairness and transparency of the procurement process has always been an important task for government in the management of medical consumables. This is directly related to public health security.[21] After the COVID-19 epidemic, Chinese government has further strengthened the supervision of medical consumables to ensure their safety and effectiveness.

Under the constraints of multiple conditions, such as a highly standardized process, highly resource-specific management in medical consumables, and complex time coupling, quantitative evaluation of process management information systems is an urgent issue for optimizing department operation, such as work efficiency, inspection cost, and quality. Both the United States and the United Kingdom attach importance to the application of information technology in the cost-control of medical consumables but have different modes and emphasis in application. Through the bidding plan supported by information technology and the procurement by group procurement organizations, the United States uses a unified coding system to integrate the procurement needs of hospitals, and bids with suppliers to reduce procurement costs, improve procurement transparency and efficiency, and reduce intermediate costs.[22] The United Kingdom implements centralized procurement utilizing information technology, uses electronic procurement strategy and a medical product coding system to standardize procurement process, improve efficiency, enhance bargaining power with large procurement volume, and effectively reduce procurement costs.[23] These two countries have made full use of information technology in the cost control of medical consumables. Through the establishment of a unified coding system, the adoption of electronic procurement strategy and the application of information technology in procurement management, these two countries have effectively reduced procurement cost, and improved the efficiency and transparency of medical consumables. Their experiences are of great significance to the management of medical consumables in other countries. However, most of the previous studies focus on a single step of consumable management, such as inventory management or procurement process, lacking systematic research on the process management information systems of medical consumables in pathology laboratories.

This studies was conducted in the Department of Pathology of our hospital. Our hospital is classified as a tertiary Grade A hospital, with 72 employees in the Department of Pathology who manage 519 types of medical consumables. Based on the data collected from 2022 to 2023, this study evaluated the methods for reducing waste in consumables and improving cost-efficiency through systematic management. This study innovatively applied process management information systems to

consumable management in the Department of Pathology and verified the effect of the process management information systems using mixed-methods research. The effects include reducing hospital's operating costs, optimizing consumable management and improving quality of healthcare services by quantitative analysis and focus group interviews. In the future, the structured data from the process management information systems, such as the use of consumables, can be combined with digital pathology (such as whole slide imaging) to develop a multi-modal diagnostic model.[24,25]

Methods

Ethics Approval

This study was conducted in accordance with the Declaration of Helsinki. All research methods were carried out in accordance with the relevant guidelines and regulations. Ethics approval of this study was obtained from the Medical Ethics Committee of West China Second University Hospital, Sichuan University [2024 Medical Scientific Research for Ethical Approval No. (272)]. All experimental protocols were approved by the Medical Ethics Committee of West China Second University Hospital, Sichuan University. Due to the retrospective nature of the study, the Medical Ethics Committee of West China Second University Hospital, Sichuan University waived the need of obtaining informed consent. During the research, we strictly focused on the principle of data confidentiality to ensure the security and privacy of patient data. All data was anonymized to ensure that patients were not identified. Research team members only accessed relevant data when necessary, and all data was stored on a secure server with strict access permission and encryption measures. All collected data were only used for this study and was properly processed and stored after the completion of the study in accordance with relevant regulations.

Data Source

The process management information systems have been used in pathological cost control within the Department of Pathology of our hospital since 2023. Data for the period from January 2022 to December 2023 were collected from the hospital information system (HIS) and the Goldisc Picture Archiving and Communication System (PACS). The data collected concerned the following aspects: workload capacity of each work group (namely cellular pathology group, molecular pathology group, frozen section group, immunohistochemistry group, and routine pathological examination group); number of pathological sections of each work group; number of pathology reports issued; quantity of consumed consumables; proportion of consumables consumed by each work group; types of consumables; frequency of consumable consumption; inventory; and quality control indicators (namely timeliness rate of histopathological diagnosis, timeliness rate of intraoperative rapid pathological diagnosis, and rate of hematoxylin-eosin staining sections with excellent or good quality).

HIS System

The HIS system is one of the core technologies in modern healthcare institution operation. It can integrate and manage a large quantity of patient data, has significant advantages, and can be applied in a wide range of fields.[26,27] It can be used to manage the electronic medical records to help healthcare staff effectively track medical history and treatment processes of patients. Its clinical decision support system can assist healthcare staff in making data-based diagnostic decisions. Moreover, the application of the HIS system in financial management can ensure the accurate and real-time financial data. Hospitals can more effectively carry out cost control, hospital revenue management and financial analysis through the HIS system, to improve overall financial management. In addition, this system plays a key role in optimizing the allocation of hospital resources and information integration for the Department of Pathology and the Department of Medical Imaging. The HIS system is characterized by high integration, operational automation, real-time data updates and remote access. It can be used to improve the quality of healthcare services and the hospital operational efficiency. The scalability, data security, and standardized design of the HIS system can ensure hospitals' adaptation to the changing technology and regulatory environment while protecting patient privacy and data integrity.[28] In the development of hospital management information systems, the HIS system has become an indispensable infrastructure to improve the quality of healthcare services and optimize hospital management.

PACS System

The PACS system can be used for image storage. It can store various medical images such as computed tomography scan, magnetic resonance imaging, ultrasound and pathological section images in digital format.[29] Images stored in the PACS system can be transmitted and shared, using the network technology to realize the rapid transmission of image data within and between healthcare institutions. It can provide rich image resources for medical education, professional training and clinical skills improvement. It can be integrated with the electronic medical records in the HIS system to provide doctors with comprehensive medical information about patients. It can also be used for image classification, labeling and management, to provide data support for clinical research.

The PACS system is fully digitized and can convert images of the stained glass sections into a digital format for easy storage and processing. It can improve image access speed and reduce the waiting/turnaround time for pathology report issuance. Characterized by modularity and integration, the PACS system can be integrated with the HIS system to realize data sharing. Moreover, the PACS system is scalable. It can be scaled and upgraded according to the needs of users. The PACS system adopts the multi-level information system security and patient privacy assurance technologies, including data encryption, access control and audit trail, to ensure information security.

Four modules (technology, consumable management, statistics, and quality control indicators) are integrated into the PACS system. The technology module involves cytopathology, molecular pathology, special examination, paraffin processing and frozen sections. This module was used to confirm work handover using scanning and to record relevant information in the system.

The consumable management module was used to produce the code for immunohistochemistry reagents and low-value consumables according to national guidelines and hospital requirements, to improve the medical resource coding system. The hospital's warehouse was considered a level 1 warehouse. A general warehouse of the Department of Pathology was considered a level 2 warehouse. The warehouse for each work group of the Department of Pathology was considered a level 3 warehouse. The warehouses at different levels and those at the same levels were not mutually accessible. Each warehouse had its own access and manipulation permissions. The consumable management module had an alert system that fully considered the influence of suppliers and logistic response time, to ensure there were sufficient, unexpired medical consumables in stock. Information concerning the name, quantity, specification, expiration date, manufacturer, and storage location of all in-use consumables in the Department of Pathology was coded in the PACS system using the radio frequency identification technology for identification and data exchange. Dispatching from the warehouses was completed by scanning using a handheld scanner. The consumables that expired first should be used first. Information concerning inventory (such as name of the reagent, batch number, clone number and specification) should be updated in time.

Data concerning monthly workload of staff, quantity of consumed reagents each month, quantity of consumables collected by each work group each month, and quality control indicators, were processed using the statistics module of the PACS system.

The quality control indicators in pathology are the premise of pathological diagnosis, and its standardized development and quality control management are an important performance indicator of the Department of Pathology. The quality control indicators were subject to the Notice of Medical Quality Control Indicators for Pathology (Edition 2015) issued by the National Health and Family Planning Commission of China, involving 13 quality control indicators, such as the standardized fixation rate of specimens, rate of hematoxylin-eosin staining sections with excellent or good quality, and the timeliness rate of intraoperative rapid pathological diagnosis.[30]

Data Extraction

In this study, we used multiple software tools and set clear selection criteria when extracting data from the HIS and PACS systems. For the detailed data of pathological examination costs stored in the HIS system, SQL Server Management Studio was used to write accurate Structured Query Language (SQL) queries; table data concerning patient information, pathological examination items and costs were extracted from the database of finance module of the HIS system.[31,32] The SQL tool was used to directly connect the HIS system for inquiry, and Excel 2019 was used to classify and summarize the data. The

following selection criteria were strictly adhered to during the data extraction process to ensure the consistency and accuracy of the data: (1) the time range was set from January 2022 to December 2023 to ensure the timeliness and relevance of the data; (2) the patients included were those who received pathological examinations in the Department of Pathology of our hospital to ensure the pertinence of the study; (3) the types of pathological diagnosis were divided into cytology, routine pathology, molecular pathology, and others in accordance with the National Technical Specifications for Healthcare Service Items (Edition 2023).[33] For the extraction of data from the consumable management module in the PACS system, the application programming interface and scripts were written in Python programming language and used to obtain patient image data and records related to the use of medical consumables.[34] The extracted data included type and date of pathological examination, type of medical consumable, quantity of medical consumable consumption, and unit price. Excel 2019 was used to quantitatively analyze the data concerning consumption frequency, quantity and price to provide data support for subsequent cost control.

Focus Group Interview

Characteristics of Focus Group Interview

As a mature qualitative research method, the focus group interview has many unique advantages. First, it can capture a wider range and depth of data. In focus groups, the interactions between participants can stimulate discussions, thereby enriching the data. The famous sociologist Robert K. Merton, who introduced the "focus group interview" in the 1940s, suggested that focus groups could allow for the expression of a variety of different points of view, which can gain the experience of many different individuals, enrich the data as team members inspire each other through the interactions between individuals, and can also reform opinions by exchanging ideas amongst individuals.[35] Second, focus groups are highly interactive, making them ideal for when interactions between participants help to inspire thinking. The interactions can lead to new perspectives and solutions. For example, in the early stages of a new system's development, focus groups can provide insight into the needs and preferences of potential users. Furthermore, focus groups are flexible and adaptable to a variety of scenarios, which can be used to either follow-up on employee satisfaction survey results or gain insight into the patient experience. It can collect a large amount of information in a short period of time with high cost-effectiveness.[36,37] Finally, focus groups can provide more data than employee surveys; employee surveys usually collect only quantitative data, while focus groups can collect a combination of qualitative and quantitative data. Moreover, the level of interaction between participants in a focus group is its most significant advantage. Participants can inspire each other and generate new perspectives during discussions, while in employee surveys, individual responses are often isolated and lack such interactions. In summary, focus groups have significant advantages in gaining in-depth insights, facilitating interactions, and adapting to multiple research scenarios. Focus groups are ideal when research requires exploring complex issues, understanding different perspectives, or accessing rich data in a relatively short period of time.

Role of Focus Group Interview in Management of Medical Consumables

The core topic of our focus group interview was on the management process of medical consumables and their loss control. Specifically, it contained the following: (1) discussing the procurement process of medical consumables and analyzing the experience of each job post in actual operation and the problems encountered; (2) in-depth research on the loss of consumables in the process of management, to understand the view points and countermeasures of employees at different job positions to cope with consumables loss and to know whether there were omissions in management; (3) solving the problems and ignorance in the management of medical consumables from the perspective of each job position; (4) putting forward suggestions to optimize the consumable management process, and collect participants' opinions on improving the process, reducing losses, and improving efficiency.

Participants in the Focus Group

There were 8 participants in the focus group. They came from the following job titles: (1) *Secretary of the Department of Pathology*. The department secretary was the moderator in the focus group and led other participants through discussion; (2) *Head of the Department of Pathology and diagnosis doctor of routine pathological examination group*. They were responsible for the review of pathological diagnosis. (3) *Leader of immunohistochemistry group*. The leader of the

immunohistochemistry group was responsible for material management supervision. (4) *Leader of routine pathological examination group*. The leader of the routine pathological examination group was responsible for technical manipulations. (5) *Material administrator*. The material administrator was responsible for procurement and warehouse receiving and discharging of consumables used for tissue sectioning and staining. (6) *Pathology technician*. The technician was responsible for specimen processing and technical operation. (7) *Supporting member*. The supporting member was in charge of daily support work. The above personnel were divided into two groups. Group 1 consisted of the head of the Department of Pathology, the secretary of the Department of Pathology, the leader of the immunohistochemistry group, the leader of the routine pathological examination group, and the material administrator. Group 2 consisted of the secretary of the Department of Pathology, the diagnosis doctor from the routine pathological examination group, pathology technician, and a supporting member.

Focus Group Schedules

Focus group interviews had two sessions. One was conducted in early January 2023, and the other one was conducted in late October 2023. Each session lasted around 60 minutes to ensure that the topic was thoroughly discussed and all participants had enough opportunities to express their opinions.

Main problems existing in the management of medical consumables in the Department of Pathology were discussed among the group 1 members in the first session. In the demonstration-teaching classroom of the Department of Pathology, the moderator asked open-ended questions and encouraged participants to share their practical experience and challenges they encountered in consumable management.

Possible solutions to improve consumable management were discussed among the group 2 members in the second session. In the demonstration-teaching classroom, the moderator guided the participants to evaluate the feasibility of different management strategies, techniques and resources. Then, the moderator summarized the key conclusions.

Qualitative Data Collection

The secretary of the Department of Pathology was responsible for qualitative data collection. The following qualitative data collection methods were used to ensure the depth and breadth of focus group interviews: (1) *open-ended questions*. Open-end questions were provided, wherein participants were encouraged to freely express their actual experiences and challenges encountered in the management of medical consumables; (2) *data recording and sorting*. The interview process, including written and audio recordings, was recorded to ensure that all ideas and suggestions were accurately captured; (3) *analysis*. Subject analysis was carried out on the collected data to identify key problems and solutions and provide the basis for subsequent management optimization.

Through the focus group interviews, data concerning the actual work experience of each job position and the insights on consumable management were collected. This provided an important basis for the subsequent improvement of workflow and the improvement of cost control in the Department of Pathology. The content and results of discussion of focus group interviews are as follows:

(1) *Procurement process optimization*. Participants pointed out that the current procurement process was cumbersome and had redundant steps for procurement approval. Simplifying the procurement approval process and introducing management information systems was suggested to improve efficiency.
(2) *Loss control*. The main reasons for consumable loss were omissions in management and improper use. It was recommended to improve training and optimize inventory management, thereby reducing the losses.
(3) *Problems and blind spots in the information systems*. The inventory management process was not transparent, with lagging early alerts. It was recommended to adopt real-time data acquisition and multi-level early alert mechanisms.
(4) *Optimization*. For the Department of Pathology with an annual workload of >15,000 cases, configuring intelligent information consumable management module and establishing an integrated healthcare management system can significantly improve management efficiency, reduce consumable waste, and optimize resource allocation.

Statistical Methods

The quantitative data, such as workload capacity of each work group from 2022 to 2023, consumable consumption, warehouse receiving and dispatching, price of consumables, income of healthcare service items, and quality control indicators, were extracted from the HIS and PACS systems. Excel 2019 was used to summarize the classified data. SPSS 23.0 and GraphPad Prism 8.0.0 (224) were used for chi-square test and 95% confidence interval (CI) analysis. Combined with the qualitative data from focus group interviews, the advantages and limitations of the process management information systems in consumable management and cost control were investigated, the practical application effects of the systems were comprehensively evaluated, and targeted optimization measures were proposed.

Results

This study conducted a quantitative analysis of workload, consumable usage data and quality indicators in our hospital's Department of Pathology from January 2022 to December 2023; it then combined with focus group interviews to evaluate the effect of process management information systems in medical consumable management. This study was compared with the hospitals that did not adopt the process management information systems. Before adopting the intelligent information management system in 2015, Zhejiang Provincial People's Hospital encountered many difficulties in the management of medical consumables, such as achieving accurate match of consumable purchase-sales-inventory data, delayed information update and low management efficiency.[38] In contrast, our hospital successfully realized the whole process tracing and delicacy management of medical consumables through the implementation of the process management information systems, such as building a multi-disciplinary group, implementing the "two-code integration" of material coding and medical advice coding, and strictly implementing the principle of "one item, one code" to ensure the complete information supervision and traceability of all medical consumables.

This study highlights the significant advantages of the process management information systems in the management of medical consumables. The systems not only optimize the management process and improve work efficiency but also ensure the accuracy and traceability of the use of consumables, reduce the inventory overstock and slide waste, and directly saves 201,820.13 (Chinese Yuan), thereby providing strong support for the economic benefits and service quality of the hospital. The findings of this study can provide important reference experience for other healthcare institutions in the management of medical consumables.

Increase of Workload Capacity

Based on the data collected from the PACS and HIS systems, it was found that the workload capacity of each work group in the Department of Pathology significantly increased in 2023 (the time period after the application of process management information systems) compared with 2022 (the time period before the application of process management information systems). The chi-square test identified a P value of <0.0001, indicating a statistically significant difference in workload capacity. This has shown the effectiveness of process management information systems in improving work efficiency. In particular, the workload capacities of the immunohistochemistry group, frozen section group, and cellular pathology group increased by 24.28%, 24.10%, and 20.17%, respectively (95% CI: 19.74%–24.81%) (Table 1). Details of the number of the pathological reports issued in 2022 and 2023 are shown in Figure 1.

Table 1 Workload Capacity of Each Work Group

Work Groups	Workload Capacity		Percentage Increase	95% Confidence Interval
	Year of 2022	Year of 2023		
Cellular pathology group	108586	130,493	20.17%	19.74% to 24.81%
Molecular pathology group	64927	79,673	22.72%	
Frozen section group	15475	19,205	24.10%	
Immunohistochemistry group	85585	106,362	24.28%	
Routine pathological examination group	51838	62,262	20.11%	
	t=26.90, degree of freedom=4	*P*<0.0001		

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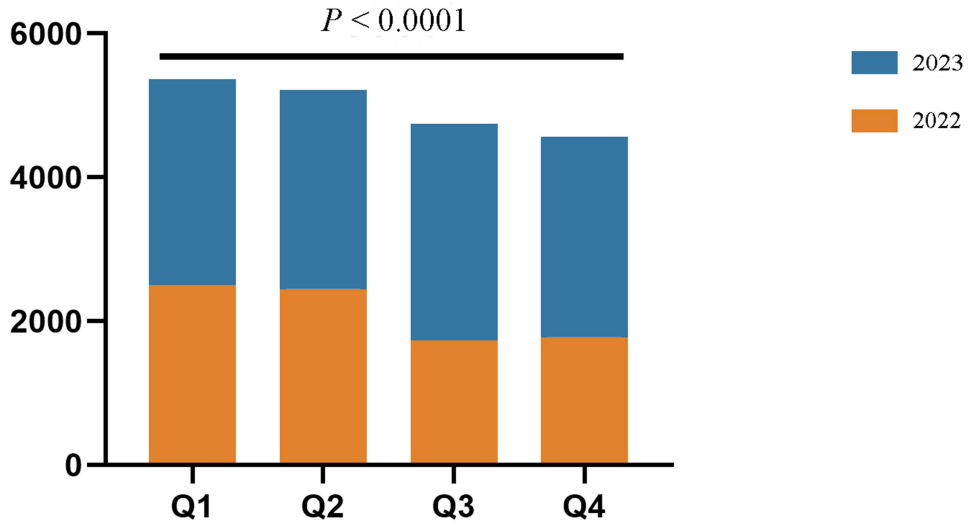

Figure 1 The number of the pathological reports issued in 2022 and 2023.

Improvement of Operational Efficiency and Effective Control of Costs

Using the statistical module of the PACS system and Excel 2019, it was found that the efficiency of inventory management was improved. The difference in the quantity of medical consumables received at the warehouse between 2022 and 2023 was 148,975, with a statistically significant difference ($P < 0.0001$). The difference in the quantity of dispatched medical consumables between 2022 and 2023 was 150,282, with a statistically significant difference ($P < 0.0001$). The overstock inventory of medical consumables decreased from 996,527.33 (Chinese Yuan) for 2022 to 832,401.60 (Chinese Yuan) for 2023, showing a decrease of 164,125.73 (Chinese Yuan) (16.47%). A P value of <0.0001 was identified in the chi-square test, indicating a statistically significant difference in the number of consumables received and dispatched from the warehouses (Figures 2 and 3). This demonstrated that the process management information systems could effectively improve the efficiency of inventory management. The amount of waste in glass slides in 2023 significantly decreased compared with 2022, with a decrease of 376,944.00 (Chinese Yuan), and a P value of <0.0001 was also identified in the chi-square test, indicating a statistically significant difference (Figure 4). This demonstrated that the process management information systems could help reduce healthcare costs and promote the sustainable development of the healthcare sector.

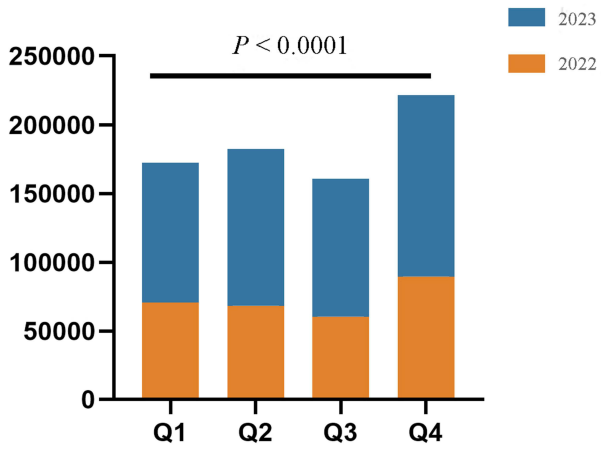

Figure 2 The number of medical consumables received at warehouse.

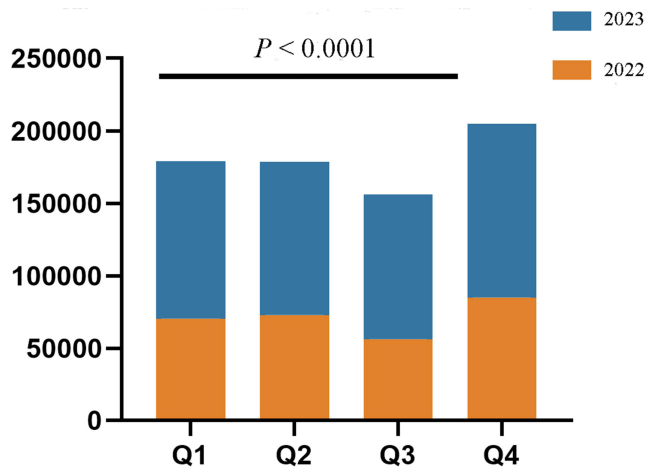

Figure 3 The number of medical consumables dispatched from warehouse.

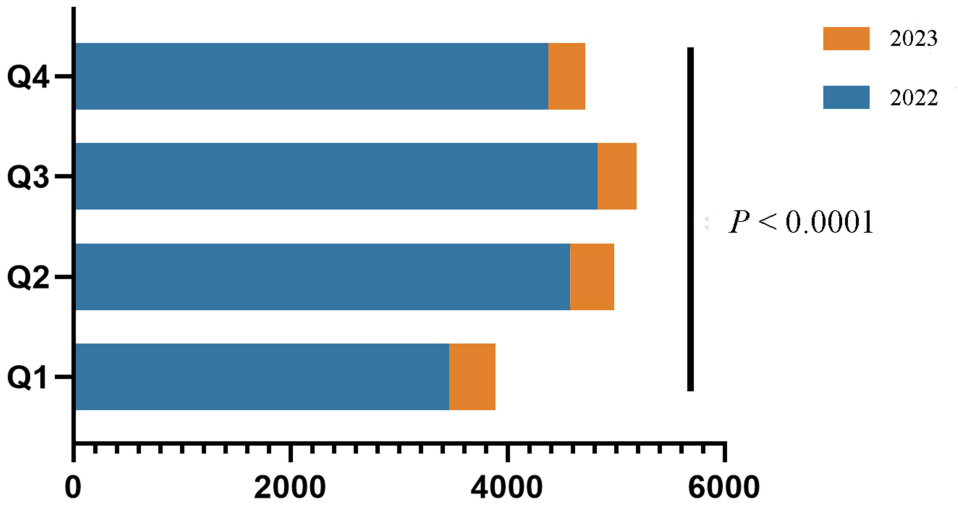

Figure 4 The number of waste in glass slides.

Improvement of Quality Control Indicators

Using the statistical module of the PACS system, the quality control indicators were improved in 2023. Table 2 depicts the values of major quality control indicators in 2022 and 2023. The timeliness rate of histopathological diagnosis increased to 95.46%, with an increase of 30.39%. The timeliness rate of intraoperative rapid pathological diagnosis increased to 89.45%, with an increase of 22.11%. The doctors in the focus group interviews generally believed that consumable turnover and pathological specimen processing speed were significantly improved in 2023, thereby reducing the delay caused by the shortage of consumables or poor management during the diagnosis. However, the rate of

Table 2 Quality Control Indicators in 2022 and 2023

	Quality Control Indicators		Percentage Increase
	Year of 2022	Year of 2023	
Timeliness rate of histopathological diagnosis	65.07%	95.46%	30.39%
Timeliness rate of Intraoperative pathological rapid diagnosis	67.34%	89.45%	22.11%
Rate of hematoxylin-eosin staining sections with excellent or good quality	98.70%	97.40%	−1.30%

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hematoxylin-eosin staining sections with excellent or good quality decreased to 97.04%. The pathology technician suggested that some work procedures still needed to be optimized to ensure quality of the sectioning, even though the process management information systems improved work efficiency overall.

Results of Focus Group Interviews

Focus group interviews further corroborated the findings of the data analysis. The head of the Department of Pathology, pathology technician and material administrator who participated in the focus group interviews shared their opinions on process management information systems. The head of the Department of Pathology said

> The department of pathology work efficiency has been significantly improved since the implementation of process management information systems. Manual recording of consumable use was prone to errors and required repetitive work, but the information systems record and update data automatically, saving time and manpower while significantly reducing error rates. For high-consumption consumables groups, such as the immunohistochemistry group, we expect further optimize management. The systems' early alert sometimes lag behind. If the inventory information can be updated in real time according to the logistics speed of suppliers and the consumption of near-expired consumables, the management will be more accurate and efficient.

This directly reflected the participants' positive evaluation results of the process management information systems in improving the consumable management process, reducing errors and improving efficiency. It also highlighted the shortcomings of the systems. Other interviewees agreed that the process management information systems effectively improved the consumable management process, reduced manual recording errors and repetitive labor, and significantly improved work efficiency.

Discussion

This study investigated the application of the process management information systems in the management of medical consumables in the Department of Pathology, and its impact on reducing hospital operating costs, optimizing resource management and improving the quality of healthcare services. It can provide a reference for more hospitals in cost control and management optimization. Through quantitative analysis of the workload of different work groups in the Department of Pathology before control (in 2022) and after control (in 2023) and the quantity of medical consumables received and dispatched from the warehouse, combined with qualitative analysis, we confirmed that the process management information systems have had a positive impact on the cost control and management efficiency of the Department of Pathology. This study revealed that the process management information systems could significantly improve work efficiency and reduce waste in consumables. In particular, the number of consumables received by warehouses in 2023 significantly increased compared with 2022, indicating that the process management information systems might improve the efficiency of inventory management and reduce overstocking or stranded inventory. The number of dispatched consumables in 2023 also increased significantly, suggesting that the process management information systems might make consumable turnover more efficient and timelier.[39] By comparing the data before and after the application of process management information systems, this study has provided empirical data on the effectiveness of cost control and a quantitative evaluation for management of pathological consumables.

Other Possible Contributing Factors

Changes in Policies and Regulations

Chinese government issued a series of policies, such as "Management Measures for Medical Consumables in Healthcare Institutions (Trial)" and "Opinions on Promoting High-quality Development of Public Hospitals",[40] which may have a positive impact on the consumable management in hospitals. For example, the new policy necessitates hospital management to be refined, promotes the rationalization of the use of consumables, and reduces unreasonable use. This may strengthen the supervision of the use of consumables and promote the hospital to improve the management process.

Human Factors

Measures such as staff training and process optimization within the hospital may also collaborate with the process management information systems to jointly promote the improvement of management efficiency. The experience accumulation and skill improvement of pathology department staff cannot be ignored. As employees become familiar with and adaptable with the use of new systems, their productivity and manipulation accuracy may gradually improve.

Potential Solutions to the Lagging of Early Alert Mechanism of the Process

It is necessary to perform real-time monitoring on inventory data. The supply, processing and distribution logistics system,[41] and radio frequency identification technology[42] could be used to ensure real-time update of inventory data and maintain the timeliness and accuracy of system data.

It is recommended to improve the accuracy of inventory early alerts. Data mining and artificial intelligence technology could be applied to analyze inventory data deeply, build accurate early alert models, and set personalized early alert indicators for each work group.

Automatic alert notification and evaluation functions were also recommended. The system can automatically trigger the alert notification and quickly notify the relevant personnel through email, short messages and other means. Different alert levels are set according to the severity of the problem and data trends to help act before the problem worsens. The early alert effect should be monitored regularly, and solution results are then collected to implement continuous improvement and optimize the early alert models and process.

Comparison with Other Scholars' Results

In terms of improving management efficiency, our study shows that the information systems can automatically process a large amount of data, reduce manual recording errors and repetitive labor, and improve management efficiency. This is similar with the results of Yan et al[43] who investigated the limitations of the traditional consumable management mode and combined the supply chain management theory and the just-in-time concept to build a new management mode to achieve the goal of reducing the cost of consumables and improving the efficiency of hospital management. For reducing the waste of consumables, Yıldız et al[44] managed the inventory of the public hospitals through a network-based information system, showing that information management can reduce unnecessary waste, improve the effective utilization rate of inventory and reduce the procurement cost of consumables. For quality control indicators, except for a slight decline in the rate of hematoxylin-eosin staining sections with excellent or good quality, the other two indicators showed significant improvement after the application of the process management information systems. The timeliness rate of histopathological diagnosis was improved significantly, which might have a positive impact on improving the efficiency of clinical diagnosis and patient satisfaction. The improvement in the timeliness rate of intraoperative rapid pathological diagnosis indicated the optimization of the relevant procedures, which is consistent with the trend of digital transformation of healthcare systems. Specifically, the results of our study echoed those of Doyle et al[45] who reported similar improvements in work efficiency after the implementation of an integrated digital management system. Our study extended these findings by providing detailed insights into the impact of digitization on specific aspects of consumable management.

It is noted that our study contributed to the literature by highlighting the unique challenges and opportunities in the management of medical consumables. This differs from general studies on hospital supply management. Our study focused on pathology and provided a more nuanced perspective on the roles of process management information systems in improving cost control and quality of service. Our study showed that consumable consumption within the Department of Pathology was significantly improved after the implementation of the process management information systems, which differed from the findings of Qi et al[46] who reported that inventory management was only slightly improved after the establishment of the cost control system. This difference is possibly because the study environment and the specific functions of the process management information systems in their studies were different from those used in ours. The approach our study took was more holistic and by integrating the HIS and PACS systems with other pathology device data streams, a supplier platform was established within the department.

Contributions to Existing Literature

The innovation of this study is that it is the first to comprehensively evaluate the impact of the process management information systems on medical consumable management in the Department of Pathology through mixed-methods research. Statistical methods such as the chi-square test were used to verify the significance of differences in workload capacity and consumable consumption. The existing literature mainly focuses on the utilization rate of consumables. However, our study not only analyzed the changes in the consumption of medical consumables but also revealed the effectiveness of the process management information systems in improving work efficiency through comparison of workload capacity of each work group. In addition, combined with the qualitative data from focus group interviews, this study discussed the problems and challenges encountered during the implementation of the information systems, providing a valuable reference for future system optimization.

This study suggested a multi-dimensional evaluation method for consumable management based on the differences in consumable consumption, workload capacity, quality control indicators, and percentage of consumables. Compared with the traditional analysis, which was only performed on consumable consumption rate, this study shows the full impact of process management information systems on workflow by means of statistical analysis.

This study was conducted in a large obstetrics and gynecology hospital in western China to investigate the effect of implementation of process management information systems with relatively limited resources. The setting of our study was different from that of the studies conducted in economically developed areas in China or large general hospitals. This study provided more targeted suggestions for healthcare institution management in economically underdeveloped areas in China, thereby having practical significance.

Limitations

This study has some limitations. First, the sample size was limited. The data was only collected from our hospital's Department of Pathology, lacking data support from other types of hospitals or different regions. Second, the time span for data collection was relatively short, ranging from January 2022 to December 2023. This timeframe might not fully demonstrate the full impact of process management information systems on long-term management efficiency and cost control. A longer time span for data collection is needed to explore the long-term effects of the systems. Short-term study might not capture potential changes and trends in the management of medical consumables, such as the change of consumable usage, and the long-term impact of supplier relationships. In addition, policy changes and market fluctuations might interfere with the research results in the short term, affecting the evaluation of the actual effect of the process management information systems. Long-term follow-up visits were recommended to comprehensively evaluate the effect of the systems, observe their performance and changes in different time periods, to provide a more reliable basis for management optimization. Third, this study might have been affected by external factors which could bring inaccurate results. The chi-square test was performed to verify the significance of differences in workload capacity and consumable consumption. The chi-square test is a basic statistical analysis means and cannot reveal more complex associations and causality. Future studies may consider using regression analysis or other advanced statistical analysis techniques to delve into specific associations between different variables.

Future Research Directions

Further studies can be conducted based on the improvement of the following aspects: (1) sample size should be expanded. Data from various types of hospitals and different regions should be collected for multi-center studies to verify the effect of implementation of process management information systems in different healthcare environments and explore its universality; (2) future studies can be conducted to investigate the long-term impact of process management information systems on hospital management and cost control through data collection over a longer period of time; (3) further optimization of the process management information systems should be performed based on the problems identified during the focus group interviews. For example, adding depreciation charges for equipment use to the immunohistochemistry group and molecular pathology group which had a high frequency of consumable consumption, to implement a delicacy management strategy for inventory management.

Conclusions

For the Department of Pathology that processes more than 15,000 specimens every year, it is essential to configure intelligent information management modules for medical consumables. Due to the heavy workload and complex consumable management in the Department of Pathology, intelligent consumable management modules can effectively improve work efficiency, reduce waste, and accurately manage inventory. The management modules should include functions for real-time monitoring, automatic alerts, use recording and supplier management, use supply, processing and distribution logistics system and radio frequency identification technology to provide real-time information concerning inventory, and optimize early alert system through data mining and machine learning, thereby improving management accuracy. More professional training should be provided for employees, and a feedback mechanism should be established to continuously improve the systems.

Integrated healthcare management mechanisms should be created, and allocation of medical resources should be optimized to reduce the cost of pathological examinations. Duplicate purchases and idling should be reduced by sharing equipment, personnel and consumables. Unified cost accounting and centralized procurement and management should be implemented to reduce procurement and management costs. Information platforms can be used to share data, promote the exchange of experience, and improve the rationality of resource allocation. The management process of the pathology department and the use of consumables should be evaluated first to identify the department's needs. The management module should be integrated with the existing hospital information systems to ensure data flow. Pilot implementation of the information systems can be used to collect feedback and optimize the systems. Then, the information systems can be popularized to the entire department to continuously evaluate the implementation effect, and establish a quantitative indicator system for rational use, according to the actual use of consumables.

For the scalability of the information systems, we found that the systems were not only suitable for the Department of Pathology but can also be applied in other hospital departments. For example, departments such as the pharmacy department, prenatal diagnosis center, and equipment department that also need refined management can achieve efficient management of resources on drugs, reagents and equipment through similar process management information systems. However, there are differences in the specific needs and work processes in different departments, so it is necessary to make appropriate adjustments and optimization according to the actual situation during the popularization.

This study demonstrates short-term positive results of process management information systems in the management of medical consumables in the Department of Pathology. However, long-term studies are essential to fully evaluate their effects and cost-effectiveness. Studies by foreign scholars confirm the significance of long-term studies. For example, the long-term cost-effectiveness of the process management information systems in American hospitals was evaluated after long-term follow-up studies, and it was found that management information systems can significantly reduce operating costs in long-term operation.[47] Long-term studies enable a more comprehensive assessment of the systems' performance at different stages, observing the adaptability and ongoing impact in a dynamic healthcare environment. Through long-term monitoring, the long-term cost-effectiveness of the systems can be accurately analyzed, and the balance between initial investment and long-term savings can also be revealed. Long-term studies can also provide a basis for continuous improvement of the systems and discover and solve new problems that arise at different stages, thereby ensuring continuous optimization of the systems. Additionally, long-term studies provide insight into the impact of the systems on quality of care and patient experience, observing its ongoing role in reducing patient wait time, increasing diagnostic accuracy, and improving treatment outcomes. Ultimately, long-term study results can provide stronger support for policy making and hospital management decision-making to ensure the sustainability and efficiency of healthcare services.

Data Sharing Statement

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

This study was conducted in accordance with the Declaration of Helsinki. All research methods were carried out in accordance with the relevant guidelines and regulations. Ethics approval of this study was obtained from the Medical Ethics Committee of

West China Second University Hospital, Sichuan University [2024 Medical Scientific Research for Ethical Approval No. (272)]. All experimental protocols were approved by the Medical Ethics Committee of West China Second University Hospital, Sichuan University. Due to the retrospective nature of the study, the Medical Ethics Committee of West China Second University Hospital, Sichuan University waived the need of obtaining informed consent.

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Disclosure

The authors report no conflicts of interest in this work.

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