SPD-based Logistics Management Model of Medical Consumables in Hospitals

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Abstract

Background: With the rapid development of health services, the progress of medical science and technology, and the improvement of materials research, the consumption of medical consumables (MCs) in medical activities has increased in recent years. However, owing to the lack of effective management methods and the complexity of MCs, there are several management problems including MC waste, low management efficiency, high management difficulty, and frequent medical accidents. Therefore, there is urgent need for an effective logistics management model to handle these problems and challenges in hospitals.

Methods: We reviewed books and scientific literature (by searching the articles published from 2010 to 2015 in Engineering Village database) to understand supply chain related theories and methods and performed field investigations in hospitals across many cities to determine the actual state of MC logistics management of hospitals in China.

Results: We describe the definition, physical model, construction, and logistics operation processes of the supply, processing, and distribution (SPD) of MC logistics because of the traditional SPD model. With the establishment of a supply-procurement platform and a logistics lean management system, we applied the model to the MC logistics management of Anhui Provincial Hospital with good effects.

Conclusion: The SPD model plays a critical role in optimizing the logistics procedures of MCs, improving the management efficiency of logistics, and reducing the costs of logistics of hospitals in China.

Keywords: SPD, Logistics management, Medical consumables, Hospital

Introduction

With the rapid development of health services, the progress of medical science and technology, and improvements in materials research, the consumption of medical consumables (MCs) for medical activities is increasing and new medical materials are constantly emerging. MCs gradually become an important part of medical activities in hospitals (1-3). However, owing to the lack of effective management methods and the complexity of MCs, there exist several management problems including MC waste, low management effi-

ciency, high management difficulty, and frequent medical accidents (4-7). Given these issues, there is urgent need for an effective logistics management model to handle these problems and challenges in hospitals.

In recent years, with the development of supply chain management and the need of hospital logistics, researchers began to apply several supply chain management concepts (e. g. , "zero inventory", "JIT (Just In Time) purchasing") to the medical field, and respectively proposed optimi-

zation methods for the procurement, inventory, and distribution of hospital logistics (8-13). However, the current logistics management models of MCs for hospitals are mainly focused on the optimization of a single procedure of hospital logistics, rather than from the perspective of the entire supply chain, which results in low management efficiency and high management costs.

In the early 1960s, faced with the existing problems of MC management, Gordon A. Friesen proposed the concept of process optimization of MCs, which is the prototype of the supply, processing, and distribution (SPD) model. In the 1990s, Japanese researchers enlightened by the JIT production model (first proposed by the Toyota Motor Corporation), introduced it to the medical field to propose the SPD management model for hospital logistics. Until now, the model has been successfully applied to several Japanese hospitals with good results (14, 15). Recently, several Chinese hospitals began to introduce the SPD model to optimize hospital logistics (16). In 2011, Nanjing Drum Tower Hospital first introduced the SPD management model, and has realized the unified management of drugs including the procedures of procurement, inventory, distribution, and consumption. TEDA International Cardiovascular Hospital introduced the SPD model in 2012, and by the integration of suppliers and the unified management of drug procurement and inventory, the hospital has realized tailored-packing and automatic counting management. In addition, several hospitals in Shanghai are also trying to apply the SPD model to the management of drugs.

Faced with the current management challenges of MCs, there is urgent need for a new logistics management model. Although scholars have achieved some effects in the exploration of the SPD model, most of them are focused on drug management, and the application of the SPD model on MCs has not yet been observed. According to the actual conditions of MC logistics management of hospitals in China, and combined with the supply chain related theories and methods, in the present manuscript, we designed a model of SPD management of MCs of hospitals in China based on the traditional SPD model.

Methods

We adopted two strategies to understand supply chain related theories and methods including literature review and field investigation. For literature review, on one hand we searched Google for recently published books, WebPages, conference papers, etc. On the other hand, we searched Engineering Village database for articles published from 2010 to 2015. The keywords for literature review included "supply chain", "logistics", "SPD", "medical consumable" and "medical material". For field investigation, during 2013 and 2015, we visited hospitals across many cities including Shanghai, Nanjing, Hefei, etc. to collect the data regarding logistics process, supplier evaluation, inventory control, etc. to determine the actual state of MC logistics management of hospitals in China. At last, we incorporated the ideas/concepts from these two data sources (data from the literature review and the field investigation) into a practical SPD logistics model for MCs management.

Results

Definition of the SPD model
SPD refers to a model for the department of hospital logistics management. With the help of logistics informatization, the model aims to realize unified management of MCs in hospitals by rationally using the resources in the medical logistics supply chain. The SPD model contains three components including S, P, and D. The S represents the procedure of supply management. With the construction of supply-procurement platforms, the classification of MCs, and the evaluation and integration of suppliers, the hospital realizes the online processing of procurement and the classified and centralized procurement of MCs. This greatly simplifies the work of procurement and improves the procurement efficiency. The P represents the procedure of

processing management. By establishing the central warehouse, adopting tailored-packing and barcode management, and establishing the inventory controlling model, the hospital realizes scientific, elaborate, and transparent inventory management of MCs, and finally decreases the inventory costs and risks of MCs to a large extent. The D represents the procedure of distribution management. With the consumption monitoring of MCs and the distribution of both amount-based packages (ABP) (applies to normal clinical departments) and procedure-based packages (PBP) (applies to operating rooms), the hospital realizes timely and accurate distribution of MCs, which guarantees the safety of medical activities. In this paper, ABP refers to dividing original large packages into smaller packages tailored to the needs of individual clinical departments, while PBP refers to packing the original MCs into packages tailored to the procedures of individual operating rooms.

In the traditional models, the management of hospitals mainly focuses on the single procedure of the medical logistics process. The SPD model takes the characteristics, operation rules, and internal connections of the medical logistics process into consideration, and introduces the concept of management of supply chains into the logistics process of MCs in hospitals. The SPD model utilizes advanced concepts and technologies of supply chain management (e. g. , "zero inventory", "JIT purchasing") to optimize the logistics process of MCs in hospitals; it is a new supply chain model that is applicable to the current state of hospital management. In this model, the management of MCs is mainly divided into three components, including: supply management over the MC suppliers, processing management over the MCs of various level warehouses, and distribution management for the consumption departments including outpatient and emergency, wards, and operating rooms.

Physical model of the SPD model

According to the aforementioned definition and characteristics of the SPD model, combined with the features of logistics procedures of MCs in typical Chinese hospitals, we conceived a physical model of the MC logistics process of the SPD model. As shown in Fig. 1, the operation of MCs in hospitals usually involves the collaboration of the departments of supply, logistics management center, and the department of consumption. In this model, MC suppliers distribute the MCs to the logistics management center according to the orders; after several procedures such as inspection, putaway, and processing, the MCs will be distributed to the outpatient and emergency departments and wards. Consumption of any package of MCs is determined only when the barcode is scanned by a nurse of a clinical department. Furthermore, it is the scanning that triggers settlement between the hospital and MC suppliers, and this arrangement shifts the costs of inventory to the suppliers.

Construction of the SPD model

According to the conceived physical model of MC logistics, combined with the concept of SPD and the concept of supply chain management, we designed a new SPD-based logistics management model of MCs. As shown in Fig. 2, in the SPD model, the management of MCs can be divided into three components including supply management (S), processing management (P) and distribution management (D).

Supply management

As shown in Fig. 3, the supply management we proposed has several important features. First, it uses online procurement. By establishing an on-line supply-procurement platform to handle the transactions, the hospital realizes real-time query of the status of MCs (including receiving, distribution, and inspection) and fund flow. Second, it utilizes classified procurement. By classifying MCs into categories with different implications (e. g. , strategic MCs, leverage MCs, bottleneck MCs, non-critical MCs), the department of procurement can make differential procurement and supply plans and focus on the relatively important categories.
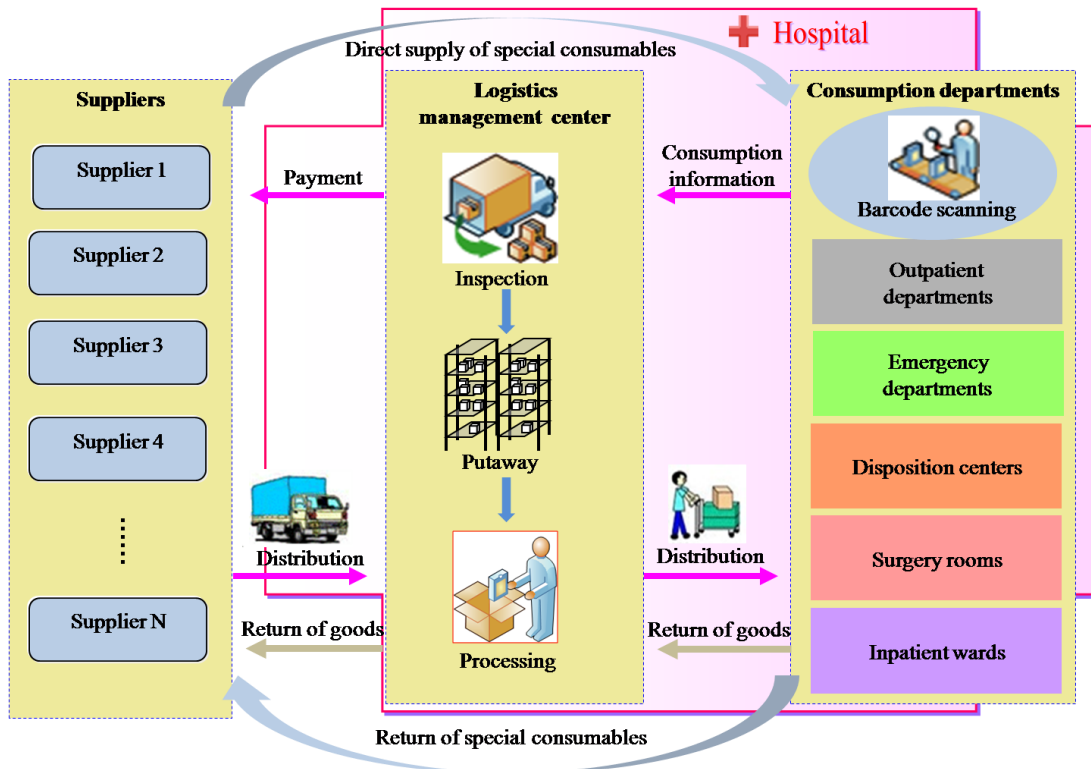
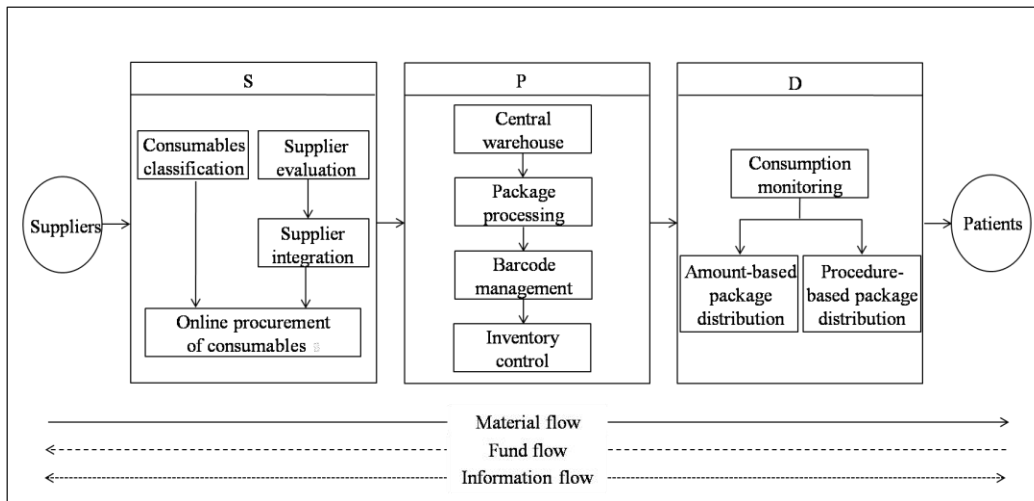**Fig. 1:** Physical model of the SPD model

Fig. 2: Structure of the SPD model

Third, it leverages integration of suppliers. By integrating the consumable suppliers and adopting relatively centralized procurement, the hospital not only reduces the workload of the supply management, such as procurement and settlement, but also prompts the suppliers to provide more MCs with a price advantage. Fourth, it employs evaluation of suppliers. By introducing supplier evaluation criteria based on the timeliness and quality of MCs provided previously, the hospital can identify and select suppliers with high scores to maintain long-term cooperation.
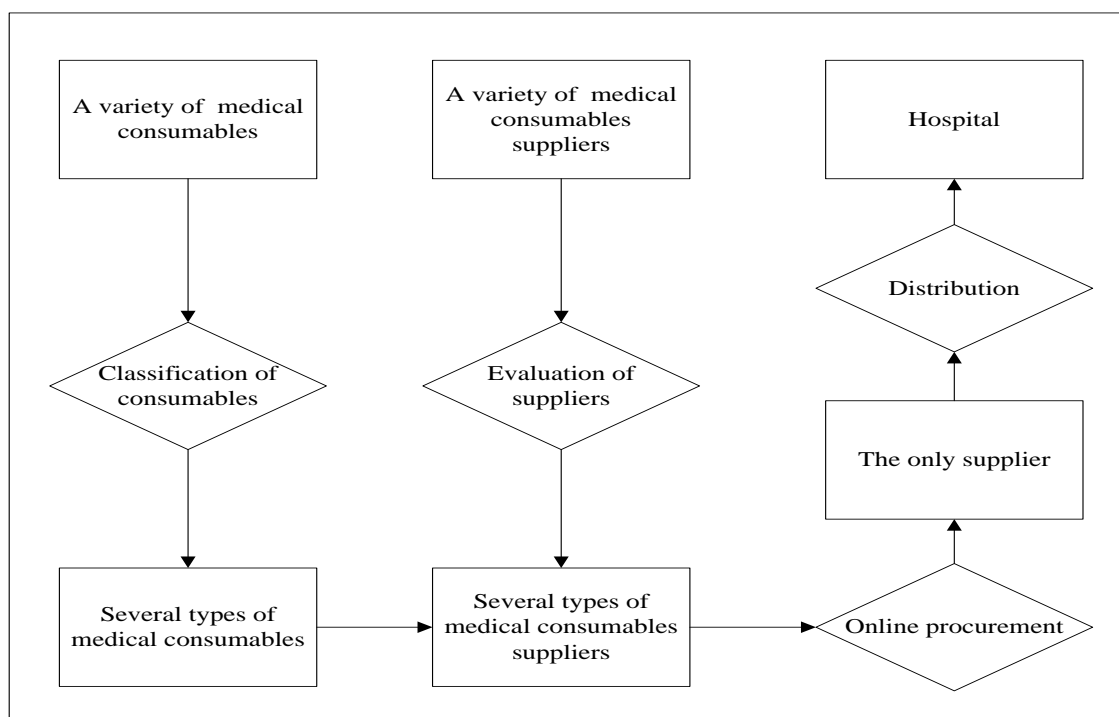
Fig. 3: Supply management of the SPD model

Processing management

Processing management includes processing and inventory management of MCs. For their implementation, four critical measures are adopted. First, the hospital establishes a central warehouse of MCs to manage affairs including putaway, short-term storage, and processing of MCs. In addition, for normal clinical departments, the original MCs will be packed into ABPs that are easy to access and count according to the consumption habits (e.g., consumption rates and consumption frequency) of clinical departments; at the same time, according to the actual habits of surgeons and characteristics of operations, the MCs will be packed into PBPs. Furthermore, MC packages must undergo barcode attachment during inspection and processing, respectively, and barcode scanning during putaway and consumption, respectively. Finally, by demand forecasting and analysis of inventory influencing factors, the hospital identifies the order points, order cycle, order amount, and safety inventory of MCs to build single-echelon inventory control models

and multi-echelon inventory joint optimization models, by which the hospital achieves effective control of MC inventories. The main structure of processing management is shown in Fig. 4.

Distribution management

In the SPD model, the effective management of distribution is supported by several technologies. First, through the establishment of a hospital logistics management platform, combined with barcode technology, the hospital monitors and manages the status of MCs during each of the procedures, to obtain data on storage and consumption at all levels of inventory in the hospital. In addition, via monitoring and analyzing the inventories of consumption departments, the hospital arranges for staff to perform ABP distribution for normal clinical departments according to the actual consumption and perform PBP distribution for operating rooms according to the operation schedules. The main structure of distribution management is shown in Fig. 5.
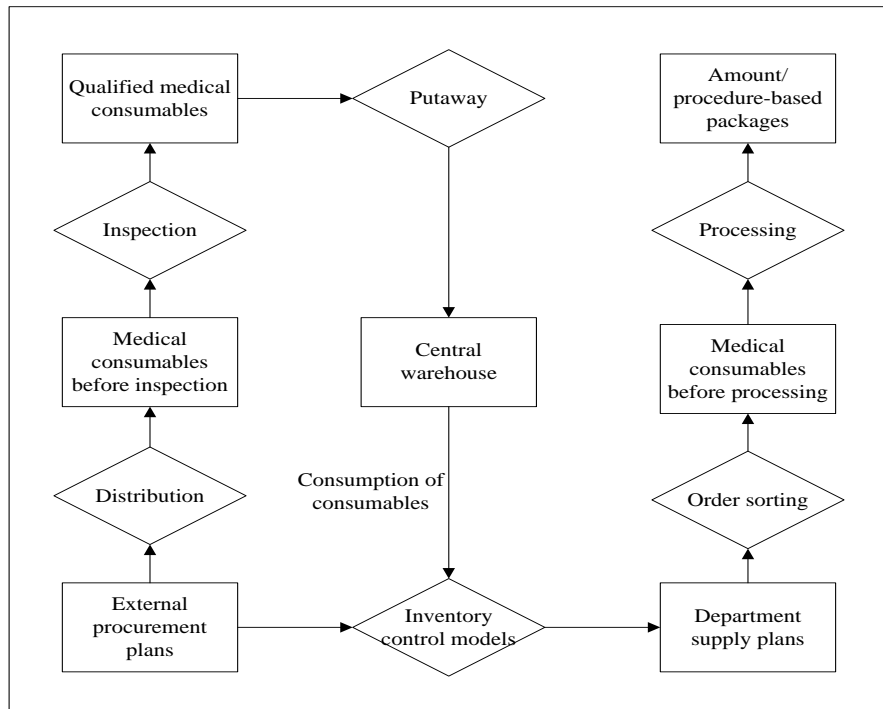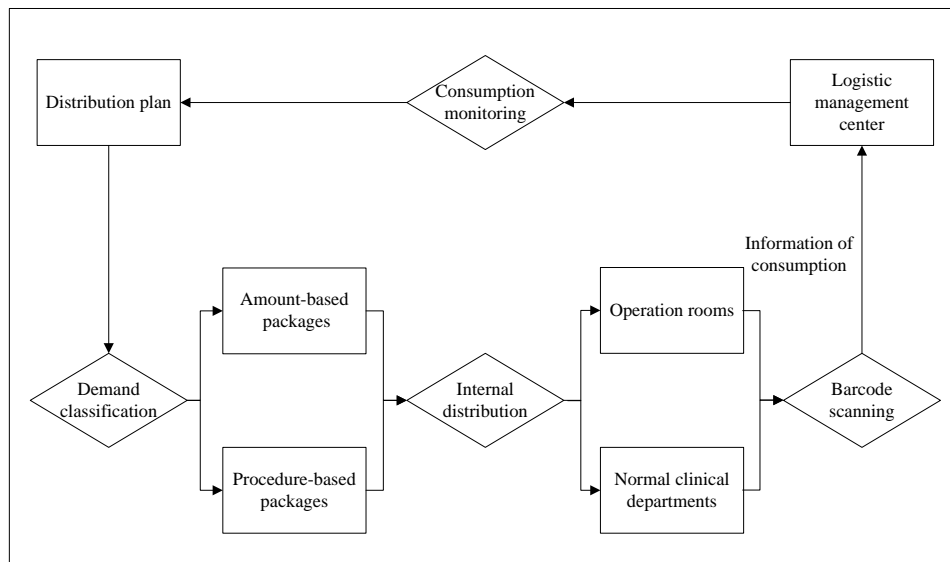
Fig. 4: Processing management of the SPD model

Fig. 5: Distribution management of the SPD model

Logistics operation processes of the SPD model

In the traditional model, the procurement of MCs mainly depends on the application of departments and requires a round of approvals in the hospital, which affects the normal implemen-

tation of clinical activities to some extent. Simultaneously, large amounts of MCs and office supplies are stored in the warehouse of the logistics management center, which occupies considerable space and inventory costs of the hospital. In contrast, by establishing a supply-procurement plat-

form, the SPD model realizes online processing of procurement affairs; by establishing a central warehouse, the model realizes short-term storage and package processing of MCs; by monitoring real-time consumption of clinical depart- ments/operating rooms, the model realizes time- ly and accurate consumable distribution. More detailed comparisons between the traditional model and the SPD model are shown in Table 1.

Table 1: Comparison between the traditional model and SPD model of medical consumables

Procedure	Traditional model	SPD model
Supply & procurement	The department of procurement in the hospital maintains the supply relationship with hundreds of suppliers, the procurement orders are arranged via telephone.	The procurement and external distribution of MCs are undertaken by only one supplier, the procurement is uniformly processed on the supply-procurement platform.
Inspection & putaway	In addition to checking the brand and original packaging of MCs, the staff also must inspect the certification of suppliers, product registration certificates, and the expiry dates of certificates.	With the support of the related information system, the model realizes automatic qualification certificate management, electronic inspection management, as well as automatic expiry date validation of certificates.
Inventory & picking	The inventories are independent of each other and there is no information sharing; when the clinical departments apply to the logistics management center for MCs, the center arranges for staff to perform consumable picking after a round of approvals.	Hospital monitors real-time consumable consumption and inventory reduction, traces the status of inventory at all levels and finally realizes visual management of MCs; the inventory control model automatically generates barcodes for order picking when the inventories of clinical departments reduces to safety inventory.
Processing & distribution	Original large MC packages are simply unpacked into scattered packages; when the clinical departments apply to the logistics management center for MCs, the center arranges for staff to perform consumable distribution after a round of approvals.	The staff of central warehouses process the raw MCs into tailored-packages with barcodes according to the habits of doctors/nurses and history of previous consumption; according to the consumption monitoring of clinical departments, the model arranges for staff to perform internal distribution of ABPs for normal clinical departments, and distribution of PBPs for operating rooms.
Consumption & settlement	The consumption mainly depends on the amount of goods received by clinical departments; the settlement of MCs is based on the amount of consumables inspected by the staff of hospitals.	The hospital performs settlement with suppliers after the MCs have been consumed; consumption of any package of MCs is determined only when the barcode is scanned by a nurse of a clinical department; the scanning triggers settlement between the hospital and MC suppliers.

Note: MC=medical consumable; ABP=amount-based package; PBP=procedure-based package

Supply & procurement

In the traditional model, the department of procurement in hospitals is required to maintain connections with a variety of suppliers, which is difficult to manage. Furthermore, telephone is the only technology that is adopted to perform the procurement, the procurement affairs are relatively complicated, and the efficiency of procurement is relatively low. In contrast, in the SPD model, the hospital evaluates all of the suppliers and selects suppliers with high scores to maintain long-term cooperation, which guaran-

tees the quality and supply timeliness of MCs. In addition, the model achieves relatively centralized procurement and management through the integration of suppliers, which largely reduces the workload of management affairs. Furthermore, the brand of single MCs is simplified to one or two types, which effectively reduces the complexity of the management work. Finally, by establishing the supply-procurement platform to handle the transactions online, the SPD model realizes real-time query of the status of orders (e.g., receiving, inspection, and distribution) and fund flow.

Inspection & putaway

In the past, the inspection of items included not only the brand and original packaging of MCs, but also information such as certification of suppliers, product registration certificates, and expiry dates of certificates. The work of inspection was complex and error-prone. However, the SPD model introduces the management system of certification and qualification to manage automatically the inspection of consumables, which largely reduces repeated inspections of contents. Similarly, by adopting the plan of distribution in order, the SPD model arranges for suppliers to distribute the MCs in a planned way, which effectively avoids the phenomenon of cluster distribution. Furthermore, with the application of barcode technology, the SPD model realizes barcode scanning putaway of inspected MCs.

Inventory & picking

The storage of MCs in hospitals involves the warehouse of the logistics management center, the warehouses of clinical departments, and the warehouses of operating rooms. In the normal model, the inventories are independent of each other and information is not shared between them. With the help of the logistics lean management system, the SPD model realizes visual management of MCs by monitoring real-time consumable consumption and inventory reduction, and tracing the status of inventory at all levels. In the typical model, when the clinical departments/operating rooms applied to the logistics management center for MCs, the center ar-

ranged for staff to perform consumable picking after a round of approvals in the hospital. The efficiency of this procedure is relatively low. However, by analyzing the history of consumption data of clinical departments and the schedules for surgery, the SPD model identifies the variables of safety inventory, distribution amount, and maximum inventory, by which the barcodes for order picking are generated automatically when the storage of consumption departments reduces to safety inventory.

Processing & distribution

In the old model, original large MC packages were simply unpacked into smaller packages before distribution, while in the new model, the staff of central warehouses pack the raw MCs into ABPs with barcodes according to the habits of doctors/nurses and history of previous consumption; simultaneously, the staff also process the raw MCs into PBPs with barcodes according to the actual habits of surgeons and the characteristics of operations. Depending on the consumption of normal clinical departments, hospitals arrange for staff to perform ABP distribution and putaway of secondary warehouses. According to the schedules of operations, hospitals arrange for staff to perform PBP distribution.

Consumption & settlement

In the previous model, hospitals paid for the MCs from the consumable suppliers after the products have been inspected by hospital staff. In contrast, the SPD model insists hospitals perform the settlement with suppliers after the MCs have been consumed. In this model, consumption of any package of MCs is determined only when the barcode is scanned by a nurse of a clinical department (even if the unpacked packages are not consumed). It is the scanning that triggers settlement between the hospital and MC suppliers, and this arrangement shifts the costs of inventory to the suppliers.

Model application and analysis

With the deepening of health reform in China, hospitals should not only provide safe and high

quality health services, but also take the sustainable development of hospitals into consideration. On the premise of high costs of medicine, MCs and medical equipment in hospitals, designing a new logistics management model of MCs to optimize the procedures of medical logistics to improve the efficiency of logistics management is an effective way of controlling costs. With the support of related information systems of logistics management, the SPD model broke the traditional barriers between each procedure in the logistics process of MCs and realizes visual management of the MCs from the warehouse of suppliers to the final consumption. It is a new logistics model that is well worth trying.

Anhui Provincial Hospital first researched and developed the SPD model of MCs in China based on the experience of foreign countries. Until now, the hospital has completed the development and implementation of several logistics information systems including the supply-procurement platform (Fig. 6) and the logistics lean management system (Fig. 7), by which the hospital has realized medical procurement transformation from telephone to the supply-procurement platform and closed-loop supply chain management of MCs in hospitals. Through the implementation of barcode management and tailored-packing, the hospital has realized timely and accurate consumable distribution. For detailed description of application of the SPD model in Anhui Provincial Hospital, please see the subsequent article.
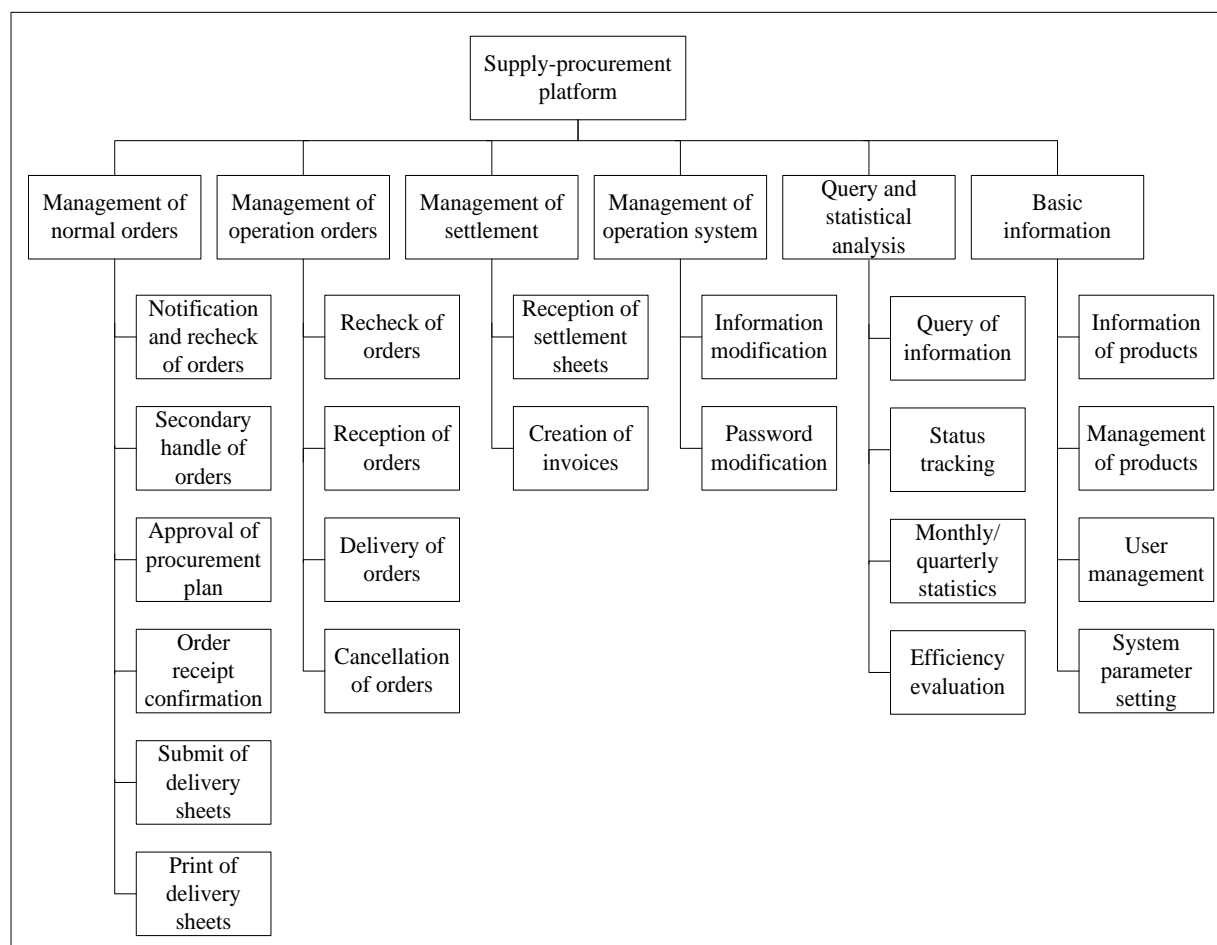
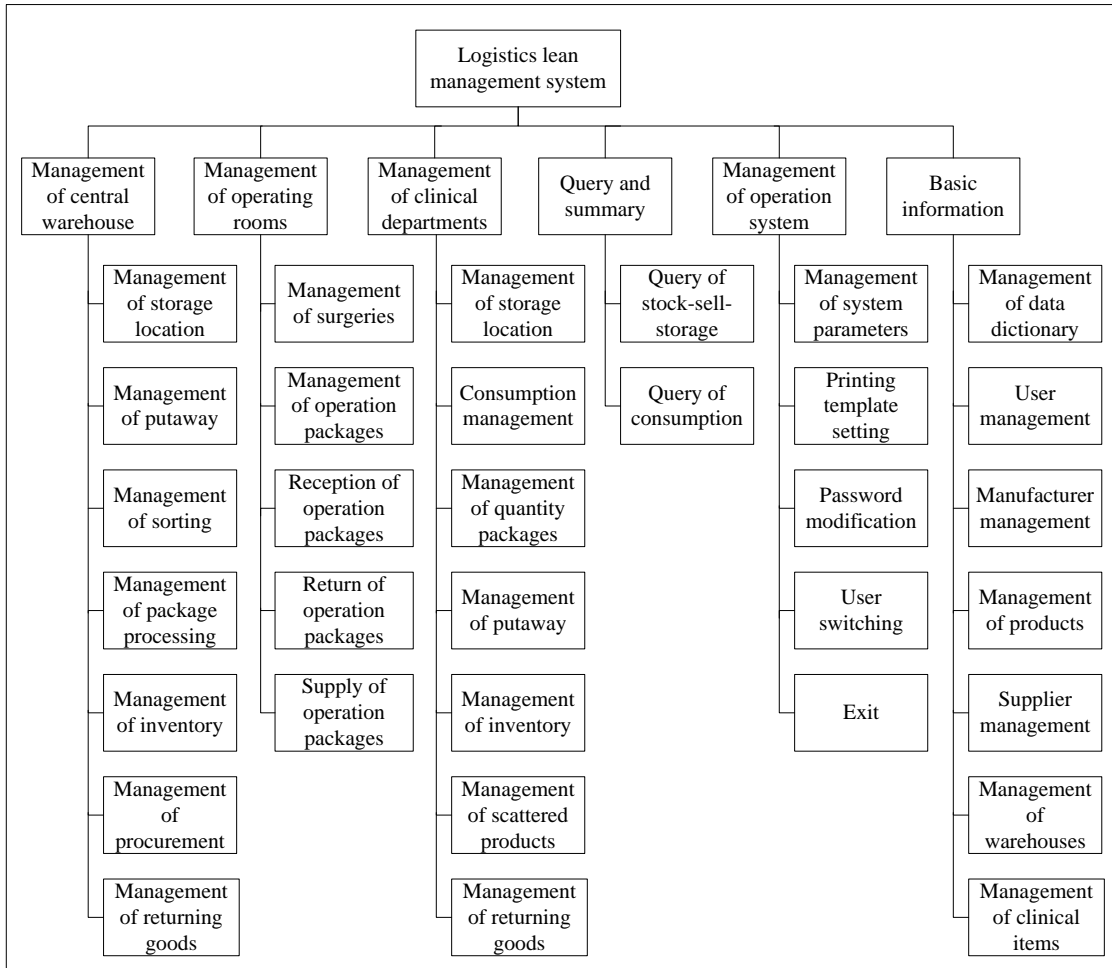**Fig. 6:** Supply-procurement platform of Anhui Provincial Hospital

Fig. 7: Logistics lean management system of Anhui Provincial Hospital

Discussion

Compared with the traditional model, the SPD model has the following advantages for the management of MCs. a) Supply management: by establishing a supply-procurement platform, adopting classified procurement and implementing evaluation and integration of suppliers, the model realizes online processing of procurement and classified and centralized procurement of MCs, which largely reduces the workload of the department of procurement and increases the efficiency of procurement; b) Processing management: with the construction of a central warehouse, implementation of tailored-packing and barcode management, and the establishment of

the inventory control model, the model realizes scientific, lean, and transparent management of MCs, which effectively reduces the inventory costs and risks of MCs in hospitals; c) Distribution management: by adopting consumption monitoring of MCs, employing ABP distribution for normal clinical departments, and PBP distribution for operating rooms, the hospital realizes timely and accurate distribution of MCs, which effectively ensures the safe implementation of medical activities.

However, because the SPD model is a new model introduced in China, there is a lack of practical experience. The SPD model may encounter many difficulties and problems the traditional SPD model cannot solve. This requires flexibility and innovation to improve the traditional SPD model

according to actual situations in hospitals, to make scientific and reasonable implementation plans and schedules. In addition, the successful implementation of the SPD model requires collaborative participation of administrative departments in hospitals (i. e., the department of information, logistics, nursing, medical, and financial) and timely response of external suppliers.

Conclusion

The SPD model we have proposed incorporates supply management (S), processing management (P) and distribution management (D) in a synergetic way. It may help greatly in optimizing the logistics procedures of MCs, improving the management efficiency of logistics, and reducing the costs of logistics of hospitals in China. However, implementation of the model merits scientific and reasonable plans and schedules, collaborative participation of administrative departments in hospitals and timely response of external suppliers as well.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Acknowledgements

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