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Current Status, Dilemmas, and Innovative Pathways of Informatization Management of Pharmaceuticals and Consumables in the Department of Anesthesiology

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Abstract: *Anesthesiology departments manage a wide variety of drugs and consumables with complex specifications, and their informatized management has become an important direction for improving hospital operational safety and efficiency. This article systematically reviews the current status of informatized management of drugs and consumables in anesthesiology departments, focusing on the applications and limitations of intelligent drug cabinets, SPD (Supply, Processing, and Distribution) systems, and information system integration in the management of narcotic and psychotropic drugs and high-value consumables. At present, although informatization tools can improve work efficiency, reduce errors, and enhance full-process traceability, their overall deployment rate remains low, with marked differences across regions and institutions. Links such as batch number tracking, empty ampoule collection, residual drug solution disposal, and consumable billing and traceability still rely heavily on manual operations. The constraints are diverse and overlapping, mainly including imbalances in funding and talent allocation, information silos and insufficient system usability, information security risks, lagging organizational awareness and training, and the structural contradiction between policy updates and software development cycles. In response to these dilemmas, this article proposes a gradual strategy of "from the inside out and from light to heavy," advocating low-cost self-development and modular platform integration, introducing agile development concepts, and building an institutional ecosystem that balances safety and efficiency while coordinating internal and external resources. This is intended to promote the transformation of drug and consumable management in anesthesiology departments from "passive recording" to "active governance," and to provide a reference for related management practices.*

Keywords: *Department of Anesthesiology; Pharmaceutical Management; Consumable Management; Informatization Management; Limited Resources*

1. Introduction

As a critical platform department in hospitals, the Department of Anesthesiology has long been a focal point of hospital management due to the wide variety and complex specifications of its pharmaceuticals and consumables. In recent years, with the continuous innovation and development of information technology, the use of information management systems to assist anesthesiology departments in managing pharmaceuticals and consumables has become a consensus in the field. In top-tier hospitals, the application of AIMS combined with integrated software and hardware systems such as ADCs and SPD has significantly improved work efficiency and reduced adverse events [1–3], while achieving high satisfaction among medical and nursing staff [4–5]. However, the proportion of hospitals actually adopting these informatization management tools remains relatively low, and the degree of informatization varies considerably among different regions and institutions. The underlying reasons involve not only structural barriers such as funding and talent allocation and information silos, but also practical dilemmas related to system usability and the contradiction between policy updates and development cycles. This article aims to systematically review the current status of informatization management of pharmaceuticals and consumables in anesthesiology departments, deeply analyze the core factors restricting its broader adoption, and propose innovative recommendations including low-

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cost self-development, modular integration, and the construction of a collaborative regulatory ecosystem, with the goal of providing references for promoting the transformation of pharmaceutical and consumable management in anesthesiology from "passive recording" to "active governance."

2. Current Status of Informatization Management of Pharmaceuticals and Consumables

The expert consensus published in 2024 has explicitly recommended the use of anesthesia information management systems as auxiliary tools for pharmaceutical and consumable management, particularly for the dispensing and auditing of narcotic and psychotropic drugs and high-value consumables [6]. Currently, most medical institutions have preliminarily achieved informatization management of drug warehousing, requisition, dispensing, and usage with the support of Hospital Information Systems (HIS). With the development of the Internet of Medical Things (IoMT), some qualified medical institutions are gradually strengthening the construction of software and hardware facilities. Relying on modern in-hospital logistics systems and information platforms, and utilizing the intelligent sensing, automatic control, and information linkage functions of intelligent anesthesia drug management cabinets, they are building intelligent information management platforms for narcotic and psychotropic drugs [7]. At present, ADCs can already support basic functions such as electronic prescription management for narcotic and psychotropic drugs, real-time inventory inquiry, and electronic special ledger inquiry. Related studies also generally bind drug informatization management closely with ADCs [8]. However, even in hospitals where ADCs have been deployed, a considerable proportion of processes—including batch tracking of narcotic and psychotropic drugs, empty ampoule recycling, synchronous linkage of dispensing–use–medical orders, and residual liquid management—still follow traditional management models [9].

From an international comparison perspective, there is a significant difference in the penetration rate of ADCs between China and foreign countries. The United States took the lead in introducing ADCs in the 1980s and has widely used them for the dispensing and replenishment of narcotic and psychotropic drugs [7]; by 2008, 83% of hospitals had completed deployment [10]. In contrast, although research and application of ADCs in China has a history of more than two decades, multiple surveys as of 2024 show that the deployment rate remains low. For example, the utilization rate of ADCs for narcotic and psychotropic drugs in secondary and above hospitals in Beijing is only 35.3% [11–12]; the proportion of secondary and above medical institutions in Jiangsu Province that have fully or partially equipped anesthesiology departments or operating rooms with ADCs is 45.5% [13]; and 47.7% of secondary and above hospitals in Guangxi had not yet deployed anesthesia information systems in 2023 [14].

In terms of consumable management, anesthesiology consumables are characterized by numerous product types, fine model specifications, coexistence of high-value and low-value items, and a strong correlation between intraoperative consumption and billing. Under traditional management models, high-value consumables are often managed using a "requisition-as-consumption" approach, resulting in extensive secondary warehouse management. Low-value consumables are prone to discrepancies between accounts and actual inventory, expiration, and waste. The traceability and billing accuracy of high-value consumables also rely heavily on manual verification [16]. The SPD model introduces supply chain management concepts to implement integrated and refined management of in-hospital material supply, inventory, processing, and distribution. In the anesthesiology setting, SPD can achieve closed-loop management of consumables—from admission, requisition, warehousing, storage, retrieval, billing, to traceability—through barcode/RFID identification, intelligent cabinets, fixed-quantity packages, and secondary operating room storerooms, and can interface with hospital information systems, surgical anesthesia systems, and billing systems, thereby effectively reducing leakage, waste, and duplicate data entry. However, current SPD construction is still concentrated in large hospitals, requiring substantial software and hardware investment and large-scale process reengineering, making it difficult for grassroots institutions or those with a weak informatization foundation to fully implement. In most medical institutions, equipment still remains at basic requisition, warehousing, and storage functions, making it difficult to support true intelligent management.

Restricted by both regional economic levels and the informatization degree of medical institutions themselves, many medical institutions still follow traditional management models in various segments of narcotic and psychotropic drug circulation [7]. Comparative analyses before and after the application of informatization tools in some hospitals show that, prior to the introduction of such tools, pharmaceutical and consumable management generally relied on manual dispensing operations and handwritten ledgers [1,15]. Specifically, consumable management typically involved manual registration for warehousing, storage on open shelves, requisition based on verbal or paper requests, and periodic

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inventory counts, but lacked dedicated expiration warning mechanisms. Narcotic drugs were managed according to the conventional "five-special" requirements, with dual-person dual-lock storage in dedicated cabinets, paper ledgers for recording incoming and outgoing information, single verification at the time of dispensing, no unified standards for residual liquid disposal, and manual intermittent monitoring of temperature and humidity [16]. Overall, the equipment in most medical institutions can only meet basic requisition, warehousing, and storage needs, far from meeting the requirements of informatization and intelligent management [13]..

3. Reasons for the Uneven Degree of Informatization

The uneven degree of informatization in pharmaceutical and consumable management in anesthesiology departments is not caused by a single factor, but rather results from the interweaving and superposition of multiple barriers, including resource allocation, system ecology, and organizational cognition.

First, imbalances at the resource allocation level constitute a fundamental constraint. Informatization construction depends on sufficient capital investment and a professional talent team. However, most hospitals place their development focus on clinical services and the expansion of medical programs, and funds for informatization units are often squeezed or unevenly distributed, severely restricting the effectiveness of informatization construction [17]. This problem is particularly prominent in grassroots hospitals: as a platform department, the construction of anesthesiology is often marginalized, with slow hardware upgrades, coexisting brain drain and staff overload, further exacerbating the difficulties in advancing informatization [15,18].

Second, fragmentation and functional deficiencies at the system ecology level hinder the in-depth implementation of informatization. On the one hand, hospital internal information systems are highly complex, making it difficult to develop a single complete clinical information system covering all applications. At present, domestic hospitals still need to meet the needs of various departments through system integration [19]. As a platform department, the Department of Anesthesiology needs to call upon multiple systems such as AIMS, HIS, LIS, and PACS in daily work. The development or upgrade of any information system must face the challenges of multi-system compatibility and data interconnection, thereby creating an "impossible triangle" of cost, timeliness, and usability. On the other hand, even in hospitals with relatively advanced informatization construction, information systems often fail to be truly embedded in core clinical diagnosis and treatment processes. They tend to function more as "recording tools" rather than "decision-support tools," leading to limited perceived practical value among medical staff. When a system is viewed as an "additional burden" rather than a "capable assistant," willingness to use it naturally decreases. In some hospitals, information systems have single functions and outdated technology, with electronic medical records coexisting with handwritten records, aging supporting hardware, and maintenance staff overwhelmed, which actually reduces work efficiency. When staff fail to derive tangible benefits from informatization, they may develop resistance to subsequent technological integration, ultimately trapping informatization construction in a vicious cycle [17,19,23]. In addition, information security and data compliance risks constitute hidden barriers. Informatization management of pharmaceuticals and consumables in anesthesiology relies heavily on sensitive data such as the flow of narcotic and psychotropic drugs, users, batch numbers, residual liquid disposal, and billing traceability of high-value consumables. Once data leakage, tampering, or loss occurs, it may trigger medical disputes and legal risks. Out of concern for network security, some hospitals tend to be cautious when promoting the integration of ADCs, SPD, and external systems, and still retain manual verification and paper records as "fallback" measures, creating a situation where systems and manual operations coexist. Without a unified mechanism for data classification and grading, access control, and audit tracing, information security concerns may instead weaken the benefits of informatization and increase operational burden. Therefore, information security should not be a reason to reject informatization, but should be addressed through improved institutional and technical safeguards [19].

Third, deficiencies at the organizational cognition level and dynamic changes in the external environment further increase the difficulty of implementation. From within the anesthesiology department, some managers still understand informatization management at the level of "equipment procurement" or "electronic ledgers," neglecting the importance of process reengineering, data governance, and continuous operation and maintenance, and tend to adhere to traditional experience-based management. Frontline medical staff may also develop resistance due to insufficient information literacy, inadequate training, complex user interfaces, or concerns that system documentation increases accountability pressure. If feedback is not promptly addressed and processes are not optimized after

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system launch, users tend to perceive informatization as an "additional burden," resulting in phenomena of "built but not used" or "used but not deeply," further reducing the actual effectiveness of informatization investment [17,19]. Meanwhile, changes in the policy environment also bring continuous challenges to informatization construction. In recent years, national requirements for refined management of pharmaceuticals and consumables in medical institutions have been continuously strengthened, especially in the field of narcotic and psychotropic drugs, where the regulatory hierarchy has been continuously expanded, regulatory content has been deepened, management methods have been frequently updated, and responsibility divisions have become increasingly clear [9]. However, software and hardware design exhibits obvious lag. Taking the waterfall model commonly used in the domestic software industry as an example, it strictly divides the development process into stages such as requirements analysis, outline design, detailed design, coding, software testing, and operation and maintenance, requiring each stage to be completed before moving to the next, and any problem identified must be traced back to the previous stage before correction [20]. This rigid development model struggles to cope with the constantly changing policy and process demands in hospital informatization construction, further widening the gap between ideal and reality..

4. Innovative Ideas and Recommendations

In response to the above problems, breakthroughs in informatization management of pharmaceuticals and consumables in anesthesiology departments should not rely on a single grand plan. Instead, they should proceed from the actual conditions of the department and adopt a progressive strategy of "from internal to external and from lightweight to heavyweight," making coordinated efforts at three levels: technological pathways, system architecture, and institutional ecology.

At the technological pathway level, departments can actively explore low-cost self-development solutions. For a long time, informatization construction in anesthesiology has been constrained by limited budgets, lengthy procurement processes, and delayed vendor responses. In addition, system development lacks the participation of end users, resulting in insufficient software user-friendliness [20]. With the increasing maturity of AI-assisted programming and low-code platforms [21], the technical barriers to software development have been significantly lowered. Anesthesiology departments are fully capable of independently developing lightweight management tools based on their own operational pain points, such as drug base quantity management, near-expiration warnings, consumable usage registration, shift scheduling queries, equipment borrowing and returning, and adverse event reporting. The advantages of self-development lie in precise understanding of requirements, short development cycles, and flexible modification. Users are also developers, making it easier to ensure that functions fit actual needs, effectively improving satisfaction among medical and nursing staff, and turning informatization tools into burden-reducing assistants rather than workload-increasing burdens. In addition, the massive data generated in perioperative scenarios and anesthesia clinical work can be secondarily utilized to support clinical decision-making, research, and process improvement [22]. Self-developed systems can achieve more comprehensive and efficient data collection and utilization. Of course, self-development solutions also need to strengthen data security, access control, and system stability through means such as QR codes, NFC, and MD5 encryption. At the current stage, they should serve as supplements or pilot projects in areas not yet covered by core systems, rather than hastily replacing core pharmaceutical and consumable business systems. After operational effectiveness has been verified, application can be made to the hospital information department for interface integration or unified operation and maintenance.

At the system architecture level, efforts should be made to promote modular integration and build an integrated management platform. As a platform department, the Department of Anesthesiology not only faces information silo problems among clinical systems, but also has numerous fragmented applications in personnel, materials, equipment, and other management areas[24]. The ideal solution is to build a modular integrated management platform based on unified data standards and a unified user permission system, integrating functions such as pharmaceutical and consumable warehousing, storage management, instrument circulation, fixed asset management [25], staff scheduling and attendance/leave approval and performance management [26], adverse event registration [27], quality control indicator reporting [28], equipment borrowing and returning [29], and on-duty meal registration into separate modules. The advantage of modular design is that it can be constructed in phases and launched gradually, effectively reducing the risk of one-time construction. After data connectivity among modules is achieved, it can not only reduce duplicate data entry and unify statistical standards, but also provide reliable data support for departmental operational decision-making. During implementation, integration with the hospital's existing HIS, HRP, and surgical anesthesia systems is needed. It is recommended to prioritize the adoption of standard interfaces and master data management strategies to avoid creating new "platform

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silos."

At the institutional ecology level, efforts should be made to build a regulatory system that dynamically balances safety and efficiency while coordinating internal and external resources. Informatization construction in anesthesiology must simultaneously address the continuous updating of narcotic and psychotropic drug management, quality control safety, and performance regulatory requirements, as well as the constraints of limited departmental human and financial resources. The traditional waterfall model, due to frozen requirements and excessively long cycles, cannot respond quickly to policy and process adjustments. In contrast, the test-driven development, small-scale releases, simple design, and continuous integration advocated by Extreme Programming (XP) can transform new rules into system functions in a more agile manner, significantly reducing change costs [30]. On this basis, management systems can be parameterized and processes configurable, so that safety bottom lines are solidified through system rules while retaining reasonable operational flexibility, thereby achieving a dynamic balance between safety and efficiency. In terms of funding, multiple approaches can be explored to share costs, including internal special informatization investment, research project funding, equipment placement, cooperation with third-party SPD services, and regional platform sharing. The effectiveness of informatization should also be continuously evaluated through dimensions such as quality and safety indicators, inventory turnover rate, error rate, and medical staff satisfaction, ultimately forming a virtuous cycle of "investment–construction–evaluation–optimization" and moving pharmaceutical and consumable management in anesthesiology from passive response to inspections toward active governance.

5. Conclusion

In summary, current informatization management of pharmaceuticals and consumables in the Department of Anesthesiology has formed a basic consensus in the field around core pathways involving ADCs, SPD systems, and information system integration. Although these means have demonstrated significant advantages in improving work efficiency, reducing error events, and strengthening full-process traceability, their overall deployment rate remains low, and there is a clear imbalance in development among different regions and medical institutions. The factors constraining the deep coverage of informatization at the grassroots level and across the entire process are characterized by diversity, mainly including imbalances in funding and talent allocation, prominent information silo effects, insufficient matching between system practicality and clinical needs, an incomplete information security guarantee system, lagging cognitive levels and training intensity among relevant personnel, and the structural contradiction between rapid policy updates and long software development cycles.

Looking ahead, the key to resolving the above dilemmas lies in constructing a multi-dimensional collaborative promotion mechanism. At the departmental level, active exploration should be made of effective integration between low-cost self-developed solutions and modular platforms. At the technological development level, agile development concepts should be introduced to improve system response speed and iteration efficiency. At the management mechanism level, efforts should be made to build a virtuous operational ecosystem that balances safety and efficiency while coordinating internal and external resources. Through these systematic efforts, it is expected that pharmaceutical and consumable management in the Department of Anesthesiology can achieve a paradigm shift from "passive recording" to "active governance."

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