CLOSED-LOOP MEDICATION MANAGEMENT SYSTEM BASED ON INFORMATION SYSTEMS IN HEALTHCARE INSTITUTIONS

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ABSTRACT

The implementation of a closed-loop medication management system (CLMMS) in healthcare institutions holds great importance in improving patients' safety and minimizing medication errors. CLMMS systems ensure the automation and integration of every step in the medication process, from writing the prescription based on accurate clinical data to administrating medication to the right patient, therefore improving the accuracy and efficiency of the treatment process. While the digitalization of medication management supports data management and the analytical aspect of healthcare facilities, it also presents challenges, such as requiring significant investment in infrastructure and training. This article will include a systematic review of closed-loop medication management systems.

Keywords: Hospital Information Systems, Closed-Loop System, Medication Management.

ÖZET

Sağlık kurumlarında kapalı döngü ilaç yönetim sisteminin (KDİYS) uygulanması, hastaların güvenliğinin artırılması ve ilaç hatalarının en aza indirilmesi açısından büyük önem taşımaktadır. KDİYS sistemleri, reçetenin doğru klinik verilere dayanarak yazılmasından ilacın doğru hastaya verilmesine kadar ilaç sürecindeki her adımın otomasyonunu ve entegrasyonunu sağlayarak tedavi sürecinin doğruluğunu ve verimliliğini artırır. İlaç yönetiminin dijitalleştirilmesi veri yönetimini ve sağlık tesislerinin analitik yönünü desteklerken, altyapı ve eğitim için önemli yatırımlar gerektirmesi gibi zorlukları da beraberinde getirmektedir. Bu makale, kapalı döngü ilaç yönetim sistemlerinin sistematik bir incelemesini içerecektir.

Anahtar Kelimeler: Hastane Bilgi Sistemleri, Kapalı Döngü Sistem, İlaç Yönetimi.

1. INTRODUCTION

Over the years, medical information processing in hospitals has developed rapidly due to international and national health reforms and the urgent need to improve information structures to cope with the rapid development of computer communication technology. Hospital information systems (HIS) have been implanted in many hospitals where computers are used to store, process, and manage large medical data. These systems are essential not only for daily operations but also for supporting healthcare institutions' administrative and clinical functions.

Pharmacy management systems are a key component of HIS and play a vital role in the safety and efficiency of medication processes. Digitalized hospital pharmacy management imposes a higher requirement for normalization and rationality (resembled in safety, efficiency, and scientific rigor),

which can be achieved by implementing a closed-loop medication management system (Hong et al., 2012).

2. INFORMATION SYSTEMS IN HEALTHCARE INSTITUTIONS

Hospital Information Systems consist of tools that manage administrative and clinical functions within healthcare institutions. HIS records and manages daily transactions facilitate operations and coordinates hospital management, supervision, and planning functions. HIS can be divided into administrative systems, which handle finance, human resources, and inventory management, and clinical systems, which support patient care through managing records, clinical services, and medication. Complete and integrated information systems ensure effective and efficient hospital operations and support the achievement of the hospital's strategic goals.

2.1. Administrative Information Systems

Administrative Information Systems provide the necessary data and manage the transaction of information to help health providers make effective decisions in managing and planning administrative processes. These systems analyze data obtained from various activities of healthcare institutions to present them to managers and generate reports. Administrative information systems effectively solve structural problems by processing a wide range of information. However, they are not effective enough in less frequent situations requiring specific and complex responses. These systems are subsystems of hospital information systems, focusing on administrative decision-making and solving organizational and environmental challenges (Yılmaz, 2013).

2.1.1. Material Management Systems

Hospital's Material Management System, also known as hospital supply chain management system, is designed to facilitate the process of managing and tracking medical supplies and equipment within a hospital. This system ensures that the healthcare providers have the necessary supplies when needed while also focusing on minimizing waste and reducing costs (Neve and Schmidt, 2022).

2.1.2. Information Management, Statistics and Reporting Systems

Information Management, Statistics, and Reporting Systems enable hospital administrators to monitor all medical and financial resources in the hospital and make inquiries, evaluations, and analyses to make administrative and strategic decisions. (T.C. Ministry of Health, Department of Administrative and Financial Affairs, 2010).

2.1.3. Office Automation Systems

Office Automation Systems enable computers to do repetitive tasks automatically instead of using manpower. These systems include computer systems and software that digitally collect, store, transfer, modify, and use office information (Republic of Turkey Ministry of Health, Department of Administrative and Financial Affairs, 2010).

2.1.4. Human Resources Management Systems

The Human Resources Information Management System is designed to improve the efficiency of hospital human resources management by integrating various functions such as personnel management, recruitment, and patient medical information management. (Yu, et al., 2022)

2.1.5. Accounting and Financial Management Systems

Accounting and Financial Management systems monitor the financial situation to generate information that is essential for reporting and long-term strategic planning (Alagöz et al., 2013).

2.1.6. Other administrative information systems

The hospital procurement guide published by the Turkish Ministry of Health lists the administrative software modules required to implement an efficient HIS as follows:

- Cashier module
- Inventory tracking, purchasing, and inventory transactions module
- Revenue, invoice, and finance module
- Personnel operations module
- Information management, statistics, and reporting operations module
- Health board module
- File and archive module

2.2. Clinical Information Systems

Clinical information systems enable data collection, storage, and reuse in diagnosis and treatment processes. These systems are central to patient care and clinical practices, ensuring that all medical information and visuals are collected, processed, stored, and available to healthcare providers (Yılmaz, 2013).

2.2.1. Outpatient Clinic Information Systems

Outpatient Information Systems are designed to collect, store, process, and provide access to clinical information crucial for healthcare delivery. Outpatient information systems provide clinical data that stores patient histories and interactions with care providers, assisting physicians in making decisions about patient conditions and treatment options and monitoring the effectiveness of decisions and actions taken (Donte, 2018).

2.2.2. Electronic Medical Records

The patient record system manages all aspects of a single patient's data, including the creation, usage, storage, and access of these records. This system encompasses both administrative details, such as lists of doctors and consent forms, and clinical information, including previous procedures and medications. By documenting standard practices at the time the records were created, this data serves as a foundation for making future medical decisions (Ambinder, 2007).

2.2.3. Patient Monitoring Systems

In the Patient Monitoring System, the computer continuously monitors the patient's vital functions and periodically displays their pathological data. In this system, functions such as heartbeat, blood pressure, and patient temperature can be monitored instantly on the computer screen. These systems are extremely important to operate in intensive care units (Şahin, 2010).

2.2.4. Clinical Decision Support Systems

Clinical decision support (CDS) systems enhance decision-making by linking patient data to an electronic database. CDS tools are categorized as drug dosage support, medication ordering facilitators, point-of-care alerts and reminders, e-authorization, physician systems, and workflow support. Clinical decision support systems have improved processes such as the adoption of guidelines, increased vaccination use, and reduced rates of serious medication errors (Beeler et al., 2014).

2.2.5. Medical Image, Archive and Communication Systems

A Picture Archiving and Communication System (PACS) is a medical imaging technology that provides economical storage and easy access to visuals from various imaging modalities such as X-ray, CT, MRI, and ultrasound. It allows electronic images and reports to be transmitted digitally, eliminating the need to manually file and transport film. This system increases efficiency by reducing the physical and time barriers associated with traditional film-based imaging and image retrieval (Costanza, 2021).

2.2.6. Pharmacy Information Systems

Pharmacy Information Systems should include functionalities such as drug dispensing, pharmacy warehouse management, drug ordering, and pharmaceutical reporting. The primary purpose of these systems is to manage patient medication requests, maintain comprehensive pharmacy records, and track drug stock levels, including minimum and maximum stock levels. These systems are integrated with the hospital's warehouse and the Material Resources Management System (T.C. Ministry of Health, Department of Administrative and Financial Affairs, 2010).

The main functions of pharmacy information systems include (Şahin, 2010):

- Display medication requests and perform necessary screenings.
- Record any changes in treatment made by doctors, such as stopping or returning medications.
- Support barcode applications within the system.
- Check physician request dates, treatment durations, and patients' allergies.
- Enable medication tracking on a department-by-department basis.
- Activate warning systems when drug interactions are detected, while allowing user flexibility for specific interactions.
- Provide access to patient medication data.
- Automatically update price information and reflect it on invoices.
- Record information on prescriptions given to discharged patients.
- Ensure the entire medication ordering process is accessible.
- Reflect returned medications on invoices.
- Record data on drug interactions and side effects.
- Track medications consumed in unit doses or tablets and accurately transfer them to financial records.
- Allow the pharmacy to access and transcribe data from specific dates as needed.

2.2.7. Medication Information Systems

Medication Information Systems store and coordinate all treatment-related functions, from medication requests to administering it to the patient. Integrating these systems into HIS enhances the accessibility of medication tracking and records (Şahin, 2010).

2.2.8. Other Clinical Information Systems

In addition to those systems, there are many important systems that need to be integrated into the hospital's clinical information management systems (Dikmetaş, 2022).

- Consultation module
- Emergency service module
- Patient registration module
- Polyclinic module
- Operating room module
- Diet and Ration module
- Patient appointment management module
- Blood collection and blood center module
- Other outpatient specialty systems such as dialysis, audiology, psychology, etc.

3. CLOSED-LOOP MEDICATION MANAGEMENT SYSTEM

Closed-Loop Medication Management Systems (CLMMS) are used to automate and monitor the entire medication processes in healthcare facilities. Medication Management Systems include several functions such as decision support, prescribing, dispensing and medicine storage, administration, and monitoring. When feedback from each step influences the subsequent steps in the process, this is referred to as a "closed loop." In a hospital based CLMMS, these steps are automated, ensuring accurate administration of medicines and proper documentation throughout the entire cycle. CLMMS encompass electronic prescribing, automated dispensing and barcoded unit doses linked to electronic medication records. Some systems also automate the administration of specific drugs, such as anesthesia or oxygen, by monitoring patient variables (Gates PJ, 2021).

3.1. Closed-Loop Medication Management Systems Definition

According to Fruzsina, a director at the Canadian pharmaceutical company LMC, closed-loop medication management is a fully electronic process that ensures seamless documentation of all relevant information. This system electronically supports each step of the medication cycle, starting from ordering, verification, and preparation to medicine administration, while emphasizing safety through integrated decision support in all treatment processes. CLMMS relies on four key components: an active medication order, an electronically identified provider (such as a nurse), a barcoded medication, and an electronically identified patient (Pataky, 2017).

A closed-loop medication management system is a comprehensive process designed to ensure a safe and accurate administration of medications to patients. It involves steps such as prescribing, transcribing, dispensing, administration, and monitoring the effects of the medication. The system aims to create a seamless flow of information that minimizes errors and improves patient safety. Technologies like electronic prescribing and barcoding are often utilized to verify that the correct patient receives the right medication, in the proper dose, and at the appropriate time which ensures keeping medication errors at a minimal level (Lenderink and Egberts, 2004).

In summary, CLMMS integrates technology and process management to systematically reduce medication errors and improve patient care outcomes. It is an important measure in the healthcare sector for addressing public health concerns related to medication errors.

3.2. Closed Loop Medication Management System Mechanism

CLMMS operates through an integrated, electronic process that ensures accurate and efficient medication administration from prescription to patient follow-up. The process begins with electronic medication ordering, where healthcare providers enter prescriptions directly into an Electronic Health Record (EHR) or a Computerized Physician Order Entry (CPOE) system. This step is supported by a Clinical Decision Support System (CDSS) that checks for potential drug interactions, allergies, and potential contraindications and then generates alerts and recommendations to optimize patient safety. The electronic order is then transformed to the pharmacy, where a pharmacist reviews it for accuracy and prepares the medication, labeling it with a barcode containing all the necessary tracking information.

During the dispensing phase, Automatic dispensing cabinets (ADC) play a critical role. These cabinets use barcoding technology to assure the correct medication is dispensed and to maintain an accurate inventory. When it is time to administer the medication, the healthcare provider scans the patient's wristband and the medication's barcode to verify that the right patient has received the right medication at the right dose and time. This verification process significantly reduces the risk of medication errors. Administration details are automatically recorded in the same time in the patient's electronic medical record, ensuring accurate and up-to-date documentation.

Following administration, the system continues to monitor the patient for any reaction or response to the medication, providing a feedback loop to the healthcare team. This continuous monitoring allows for timely interventions and adjustments to the treatment plan as needed. CLMMS' comprehensive documentation and reporting capabilities ensure that every step of the medication management process is properly recorded, enhancing patient safety and facilitating effective healthcare delivery. Overall,

CLMMS improves the accuracy, efficiency and safety of medication management through an integrated and automated approach.

A study conducted in the hospitalization wards of hospitals demonstrated the main steps of CLMMS used in inpatient facilities as follows (Ozturk et al., 2020):

1. Stock Management:

- Verifying medicines using technology (e.g. barcodes, RFID).
- Monitoring medication details (name, type, quantity, expiration date).
- Disposing of expired medicines following appropriate procedures.

2. Ordering:

- Physicians ordering medicines electronically.

3. Pharmacist Approval:

- Pharmacists review prescriptions for accuracy.
- Packaging and labeling approved medicines (using barcodes or RFID).
- Verifying unit doses of medicines before dispensing to patient wards.

4. Medication Administration, Return and Disposal:

- Nurses administer medicines, ensuring five administration rights.
- Returning unused medicines to the pharmacy using automatic cabinets.
- Dispose of unusable medicines according to established procedures.

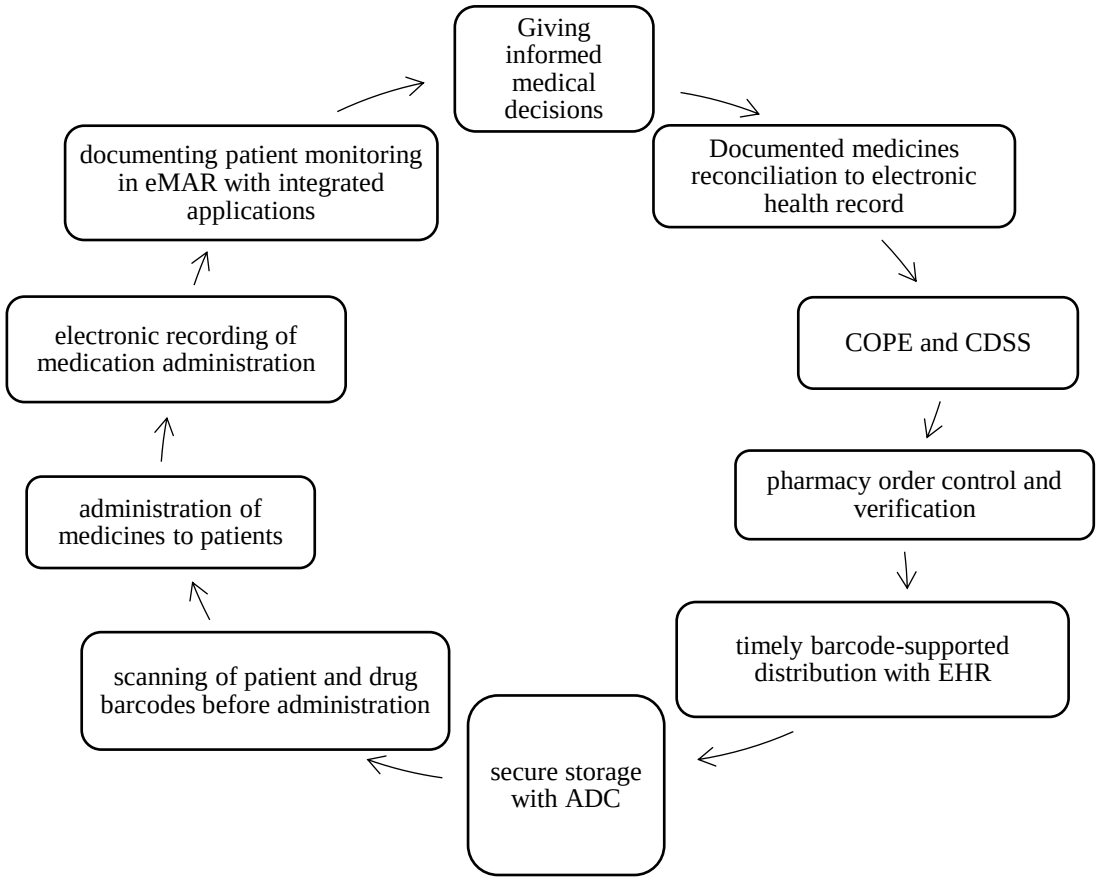

Figure 1. Closed Loop Medicines Management System Mechanism (Pataky, 2017)

Components of CLMMS according to Figure 1:

- Computerized Physician Order Entry (CPOE): Ensures accurate medication orders.
- Electronic Health Records (EHR): Ensures integration of all data.
- Pharmacy Information Systems (PIS): Facilitates the management of drug inventory and dispensing.
- Automated Dispensing Cabinets (ADC): Contributes to reducing medication errors.
- Barcoding and RFID: Allows tracking of medicines through the system.
- Smart Drug Administration Devices: Ensuring correct dosages and correct application.
- Patient Monitoring Systems: Allows monitoring of patients' reactions to medicines.

3.3. The Advantages and Disadvantages of CLMMS

A socio-technical study of closed-loop documentation systems by London's Digital Health Institute found that these systems provide a range of benefits, notably improving patient safety and streamlining the medication administration process (Furniss et al., 2020).

An overview of the advantages of closed-loop medication systems is as follows:

- Improves safety, the order reduces medication errors by ensuring that the right medication is given to the right patient at the right time in the right dose.
- Improves efficiency, entering orders directly into the computer speeds up the process, eliminating delays associated with faxing and manual processing.
- Ensures accuracy, barcoding improves accuracy in medication dispensing by eliminating readability problems in handwritten prescriptions.
- Facilitates documentation, scanning barcodes automatically enters the correct documents into the clinical information system, ensuring accurate records are made.

However, there are also potential disadvantages to consider:

- High cost of implementation. The initial setup of a CLMMS can be expensive due to the need for new technology and training.
- The complexity of CLMMS may require significant training for staff and may lead to resistance or errors during the transition period.
- Ongoing maintenance of electronic systems and hardware is required, which can be costly and resource intensive.

3.4. Examples and Application Areas of Closed Loop Medicines Management Systems in Turkey and the World

3.4.1. Turkiye: Yozgat City Hospital

In Yozgat City Hospital, which has HIMMS EMRAM Level 7 certification, the procurement process, verification, and timely administration of medicines are carried out within the scope of the standard closed-loop medication system (Uysal & Semiz, 2022, p. 157).

The functioning of the CLMMS of Yozgat City Hospital is as follows (Yozagat City Hospital, 2022):

1. Stock Acceptance and Addition to the System
2. Unit Dose Drug Packaging
3. Expiration Control and Unit Dose Barcode Printing
4. Fulfillment and PPE
5. External Stock Control: The system gives a warning in case there is a patient waiting for external stock approval and the approval must be made by the pharmacist.
6. Preparation of Medicine Bags: After the barcodes of the bags are printed, they are handled from the medicine storage cabinets and patient-based medicines are verified before they are

packaged. In case of incorrect medication scanning, the system gives an audible and visual warning.

7. Delivering Medicines to Services: Medicines are sent to the wards via carrier personnel and are verified by barcode before any medication is administered to patients.

3.4.2. China: Beijing Jishuitan Hospital

Beijing Jishuitan Hospital is a large-scale high-end hospital in China and the first orthopedic hospital in the country. In this hospital, Orthopedic Medical Supply Management is Automated With the Intelligent closed-loop medical Supply Management System, every process of medical supply activities is more effectively monitored and planned, including suppliers' stock replenishment, access procurement for surgery, post-operative return, and inventory counting Barcode Scanning and RFID systems are implemented (Nobumed, 2022).

1. Receiving Orders and ADC
2. Integration of Decision Support Systems: Surgeons and doctors can use the system as a guide and can see the appropriate drugs and surgical instruments by selecting the operation site in the system before surgery.
3. Verification of Medicines and Instruments: Before the operation, the barcodes of the medicines are verified via RFID and semi-automatic inventory output detection is performed.
4. Medicine Returns and Inventory Control: Unused and unpackaged medicines are returned, and periodic inventory checks are carried out for control purposes.

3.5. Future Perspectives and Potential Innovations

Data obtained from the implementation of closed-loop medication management systems can enhance several critical functions in healthcare.

Firstly, analyzing this data allows healthcare providers to predict the potential side effects of specific medications, improving patient safety and enabling more personalized treatment plans. These predictive insights can be integrated into clinical decision support systems, enhancing their ability to assist healthcare professionals in making more informed and accurate decisions.

Additionally, this data is valuable for evaluating the effectiveness of medications and treatments provided to patients. By continuously monitoring and analyzing treatment outcomes, healthcare providers can adjust and optimize treatment strategies in real time, leading to improved patient outcomes. Furthermore, comprehensive analysis of this data contributes to broader clinical research

efforts, helping to identify trends, improve treatment protocols, and assess the efficacy of both new and existing medications.

In summary, utilizing data from closed-loop medication systems can significantly advance predictive analytics, improve decision-making, and enhance the evaluation of treatment efficacy in hospital settings. This whole approach to data integration and analysis represents a promising direction for the future of healthcare innovation.

4. CONCLUSION

In conclusion, the implementation of Closed-Loop Medication Management Systems (CLMMS) is a very important advancement in hospital information systems. These systems significantly improve patient safety and reduce medication errors by automating and integrating every step of the medication process, from prescription and verification to dispensing and administration. This automation guarantees accuracy, increases efficiency, and provides comprehensive documentation, therefore minimizing human errors and automating healthcare workflows.

One of the key benefits of CLMMS is ensuring that the correct treatment is administered to the right patient, at the right dosage and time, effectively limiting medical errors. Real time monitoring and alert mechanisms, which could be integrated into CLMMS, allow healthcare professionals to notice and deal with discrepancies in a timely manner, further protecting patient health. Additionally, the digital nature of CLMMS improves data management and analytics, facilitating continuous monitoring and optimization of medical practices. The economic advantages of CLMMS are also substantial. By reducing medication errors and related complications, hospitals can lower costs associated with extended hospital stays, additional treatments, and legal liabilities. Increased efficiency in medication processes also frees up healthcare providers to focus more on patient care.

To fully realize the benefits of CLMMS, healthcare institutions should implement several strategies. Starting with a phased implementation approach can reduce resistance to change and ensure smoother adoption. Institutions should conduct thorough cost-benefit analyses to assess the feasibility of investment and plan for necessary infrastructure upgrades. Additionally, providing comprehensive training programs for healthcare professionals is essential to ensure familiarity and comfort with the system’s functionalities and, therefore, the full integration of the system.

Governments and policymakers also play a critical role in encouraging the adoption of CLMMS. By establishing incentives, such as grants or subsidies, the financial burden on healthcare facilities can alleviated, particularly in under-resourced settings. Regulatory frameworks should also be developed to standardize the use of these systems and ensure uniform safety and efficiency standards across institutions.

Despite the obvious benefits, challenges remain, such as the significant investment in technology and staff training. However, the long-term advantages in terms of patient safety, cost savings, and operational efficiency make this investment worthwhile. Addressing potential resistance to change through comprehensive training and emphasizing the positive impact on daily operations is essential. It is also important to recognize that implementing CLMMS requires a high-tech infrastructure, which may not be applicable for all hospitals.

From a future aspect, the integration of emerging technologies such as artificial intelligence (AI) and machine learning offers promising opportunities to enhance CLMMS functionalities. Predictive analytics can improve treatment personalization and patient outcomes by enabling healthcare providers to predict potential drug side effects or interactions. Furthermore, global trends indicate a move towards international standardization of medicines management practices, which could further harmonize patient safety measures and optimize healthcare delivery.

Integrating CLMMS is not only a technological enhancement but a crucial step toward improving patient safety and care quality overall. As the healthcare industry evolves, adopting such systems is essential to meet increasing demands for safety, efficiency, and cost-effectiveness. Healthcare providers must prioritize CLMMS adoption to create a safer, more reliable medication management environment, ultimately improving patient outcomes and the overall healthcare experience.

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