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Revolutionizing Pharmacy Practice: The Role of Automation and AI in Enhancing Patient Safety and Efficiency

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ABSTRACT

Pharmacy automation is emerging as a transformative tool in healthcare and improving patient outcomes, using digital technologies and artificial intelligence (AI) such as robotics and automated dispensing systems to improve medication distribution, reduce errors, manage inventory, and patient safety, thereby enhancing healthcare outcomes. Automated systems such as robots, AI-based algorithms, and remote dispensing services enable pharmacies to handle medication operations more efficiently and provide better patient services, especially in peripheral areas. Population growth and the rise of infectious and chronic diseases have led to increased demand for medicines and pharmaceutical services, which strongly drives the trend towards pharmacy automation and its effective role in reducing medication errors, improving efficiency, and meeting global needs. This review explores the benefits, challenges, and evolving role of pharmacists in a highly automated pharmacy environment. It also examines the integration of AI and robotics, highlighting their potential to reshape pharmacy practices and the overall health landscape.

Keywords: Pharmacy, Pharmacy Automation, Artificial Intelligence, Robotics, Healthcare.

Introduction

Pharmacy automation is a recent technological development that is transforming the way medications are dispensed, managed, and administered within healthcare settings [1]. Pharmacy automation uses a variety of automated hardware and software to streamline and improve pharmacy operations [2]. Medications are dispensed accurately and efficiently through automated dispensing systems, such as robotic prescription filling systems, to ensure accurate dosage measurement and reduce human error, improving patient safety and speeding up prescription fulfillment [2,3].

Additionally, inventory tracking software is included, allowing pharmacies to monitor medication stock levels in real time, reducing the likelihood of running out of essential medications and minimizing waste due to expired medications. As a result, pharmacy automation is gaining immense traction across the globe [3,4].

Patient safety and improved healthcare are the primary goals of healthcare systems, so there is a growing demand for pharmacy automation that helps reduce medication errors and improve patient safety [5]. The pharmacy automation market is primarily driven by the growing demand for improved patient safety. Furthermore, pharmacy automation reduces the possibility of medication errors by accurately measuring and dispensing medications, protecting patients and reducing pharmacists' legal liabilities [6].

Furthermore, the integration of robotics and artificial intelligence (AI) is at the forefront of innovation in pharmacy automation, which is another key growth factor [7]. Robotic dispensing systems can efficiently handle multiple medications, improving accuracy and speed. AI algorithms help in predictive analysis, suggesting appropriate drug dosages and alerting pharmacists to potential drug interactions to enhance efficiency and reduce the risk of medication-related errors [7,8]. Pharmacy automation has contributed to enhancing the efficiency of operations using barcodes and AI, in recognizing the drug package through its dimensions as a tool to reduce medical errors, in addition to monitoring the validity of drugs, alerting when they are about to expire, monitoring the availability of drugs and alerting when quantities are about to expire, and automating inventory and stock management processes [9].

In addition, the demand for drug sales in the pharmaceutical industry is accelerating due to the increase in the elderly population and the spread of chronic diseases [10]. Pharmacy automation systems can efficiently handle large quantities of drugs, ensuring that patients receive their prescribed treatments quickly. Moreover, pharmacy automation is transforming the delivery of pharmaceutical services, and remote dispensing systems allow pharmacists to provide services to underserved or remote areas, ensuring access to medications for all patients, regardless of their location, thus improving healthcare [10,11].

Artificial Intelligence (AI) in Pharmacy

With the increasing use of AI in healthcare, AI technology has been integrated into pharmacy. This is for healthcare system analysis, drug discovery, medicine accuracy, research and development, healthcare support and medical assistance, treatment plan design, assistance with repetitive tasks, and more [7]. AI offers opportunities for various other industries and fields. For example, AI can also be implemented through telehealth partnerships, inventory management, and the use of chatbots to mimic patient-pharmacist interactions. In retail and hospital pharmacies, AI is being used to track the preparation of injectable medications, scan barcodes, and more [12]. These features will improve patient outcomes, reduce the burden on pharmacists, and improve healthcare.

Robotic Drug Delivery Systems

Innovative automated drug delivery systems are being developed to improve the efficiency, safety, and patient experience of drug administration [13]. These systems often incorporate advanced technologies such as artificial intelligence, machine learning, and automation to improve treatment outcomes. The development of innovative automated drug delivery systems promises to revolutionize the way medications are administered to patients, delivering more precise and personalized treatments [14].

The Role of Automation and Technology in Modern Pharmaceutical Services

The smart pharmacy is one of the most important advanced technologies in the field of pharmaceutical services through the application of advanced software solutions, artificial intelligence and modern technological systems related to the process of dispensing medicine [11,14].

The Coived-19 pandemic imposed many precautionary measures aimed at reducing human contact, which led to shedding light on this smart pharmacy and the growth of the software solutions market specialized in pharmacy automation and increasing demand for the use of modern technologies [15]. Automation in pharmacies is divided into several sections, including the filling and storage mechanism, methods of retrieving medicine, packaging, automated counters and other programmed services to reach the patient in record time [16]. The use of automation in smart pharmacies to dispense prescriptions contributes to reducing the burden on the pharmacist, giving him more time to work closely with patients [11]. In addition, to reducing costs, reducing the time of dispensing medicines and increasing their level of accuracy, which has positively reflected on the pharmacy [17].

In the smart pharmacy, the medicine is dispensed through a robot that picks up the medicine and prints the label containing the patient's information and the prescription, then delivers it to the pharmacist's counter in seconds [18]. The robotic pharmacy also uses advanced technological techniques by designing specialized software, operating it, and applying robots in pharmacies, in addition to the computer systems needed to manage it [18,19].

Types of Pharmacy Automation and Robotics

Automated Dispensing Cabinets:

Automated dispensing cabinets are decentralized medication dispensing systems that manage the storage and dispensing of medications near the point of care. Automated dispensing cabinets aim to enhance medication security, enable accurate tracking, reduce medication errors, and improve inventory management [20].

Centralized automated dispensing systems:

These systems are primarily used in hospital pharmacies and large community pharmacies to automate the dispensing process from a central location. They include robotic arms, conveyors, and automated labeling systems to ensure efficiency and accuracy [21].

Uniform and multi-dose packaging systems:

These systems automate the preparation of uniform or multi-dose medication packages, ensuring dosage accuracy and significantly reducing the risk of medication errors [22].

Automated compounding systems:

These systems are designed to prepare sterile and non-sterile compounded medications, ensuring accuracy in compounding and sterility throughout the compounding process [20,21].

The main role of the pharmacist:

To maintain the vital role of the pharmacist in pharmacy automation, he must ensure the provision of effective care to the patient. When the patient enters and submits the prescription, it is necessary for the pharmacist to answer the patient's questions and inquiries. After that, the pharmacist gives the order to the robotic arm to bring the prescribed medications, print the patient's data and the prescription, attach it to the box, and then send it to the pharmacist via a special tape (barcode) [23].

A pharmacist who has the skills to work on advanced computerized systems can manage medications using the barcode through electronic verification to ensure several basic things: the correct medication, the correct dose, the correct path, and the correct time. The pharmacist also verifies the accuracy of the data and implements the guarantees achieved by the patient's barcode technology, which ensures that the prescribed medication is consistent with the treatment condition, that the dose is appropriate for the patient, and that the new medication does not interact negatively with other medications used by the patient [23,24].

Impact on Pharmacy Practice

- **Improved work efficiency:** Pharmacy automation helps streamline pharmacy tasks, reducing manual tasks, allowing pharmacists to focus on clinical services such as medication management, patient counseling, and health screenings [25].
- **Efficiency:** Pharmacy automation makes it easier for pharmacists to perform repetitive tasks, reducing time spent on tasks and patient wait times, thus enhancing the patient's experience and facilitating pharmacists' tasks [25].
- **Role evolution:** Pharmacists' roles are shifting from traditional dispensing to more patient-centered care, including medication management and direct patient interaction [25].
- **Reduced errors:** Pharmacy automation enhances medication accuracy, reducing the risk of human error in dispensing and compounding [26].
- **Improved accuracy:** Robots ensure accurate measurements and labeling, reducing dispensing errors [26].
- **Enhanced patient safety:** Automated systems track and verify medications, preventing dispensing errors and enhancing patient safety [25].

- **Inventory Management and Cost Reduction:** Pharmacy automation helps enhance inventory control by providing real-time tracking of medication stock levels, expiration dates, and usage patterns. Improved inventory management saves costs by improving inventory turnover and reducing expired medications [26].

Challenges and Considerations

- **High Cost:** Pharmacy automation requires expensive infrastructure and technology tools, in addition to ongoing maintenance costs [27].
- **Pharmacy Automation Integration:** There is difficulty in integrating existing pharmacy management systems and electronic health records with pharmacy automation.
- **Training and Adaptation:** Training employees and adapting to new technologies is critical to the successful implementation of automated systems. Managing the transition to automated systems also requires addressing employee resistance and ensuring seamless workflow integration [28].
- **Regulatory Compliance:** Automated dispensing systems must comply with regulatory standards and guidelines to ensure patient safety and medication accuracy [28].
- **Quality Control:** Regular audits and quality control measures are essential to ensure compliance with regulatory requirements

Future trends in the application of automation and artificial intelligence in pharmacy

- **Developing robotic systems:** future robots operate faster and more accurately, while reducing the need for human intervention [3]. In addition to designing robots capable of handling diverse and complex medications.
- **Artificial intelligence:** Artificial intelligence can analyze patients' medical records, analyze drug interactions, and search for optimal therapeutic alternatives, which contributes to improving patient outcomes and reducing medical errors [6].
- **Predictive inventory management:** Artificial intelligence will contribute to the development of smart inventory management systems that predict drug needs based on usage and demand patterns, which helps reduce waste and ensure the continuous availability of medications [6].
- **Expanding telepharmacy:** The importance of telepharmacy is expected to increase as communication technologies improve and automation advances. Doctors and pharmacists will be able to provide remote medical consultations using smart robots, which will enhance access to healthcare in rural areas or areas with limited access to traditional pharmacies [29].
- **Deep analysis of big data:** Artificial intelligence will contribute to the use of big data in the pharmaceutical sector to analyze health information on a large scale, such as drug use, drug interactions, and patient outcomes. These analytics will help identify health patterns and trends that can lead to improved patient care and reduced side effects or medication errors [6].

- **Develop personalized patient solutions using automation:** Automation will enable personalized treatment solutions for patients based on accurate information about their health condition and medical history [30]. AI can be used to determine the best treatment plan or medication for each patient, based on their specific needs.

Conclusion

Pharmacy automation, powered by advanced technologies such as robotics and artificial intelligence, is dramatically transforming the healthcare sector by enhancing the accuracy and efficiency of medication dispensing. These systems not only reduce human error but also enable more effective inventory management and improved patient safety, thus playing a crucial role in modern pharmacy practice. The integration of AI and robotics technologies allows for faster and more accurate dispensing and contributes to improved pharmaceutical care. However, challenges such as high upfront costs, regulatory compliance, and the need for proper training and adaptation remain. The future of pharmacy automation holds immense potential to improve patient outcomes and revolutionize pharmacy services, making it a critical development for the future of healthcare delivery.

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