REVOLUTIONIZATION HOSPITAL PHARMACY: THE INTEGRATION OF ROBOTICS AND ARTIFICIAL INTELLIGENCE

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ABSTRACT

This study explores the transformative impact of robotics and artificial intelligence (AI) on hospital pharmacy operations. The integration of robotic systems and AI algorithms has the potential to optimize medication management, improve patient safety, and enhance the overall efficiency of hospital pharmacy services. Our research examines the current state of robotic and AI adoption in hospital pharmacies, their applications in automating tasks such as dispensing and inventory management, and their potential to improve patient outcomes. We also discuss the methodological approaches used to evaluate the effectiveness of robotic and AI systems in hospital pharmacies. Our findings suggest that the strategic integration of robotics and AI can significantly enhance the quality and safety of hospital pharmacy services, while also reducing costs and improving patient satisfaction. As the healthcare industry continues to evolve, our research highlights the importance of embracing innovative technologies like robotics and AI to drive transformative change in hospital pharmacy operations.

KEYWORDS: Hospital Pharmacy, Robotics, Artificial Intelligence (AI), Medication Management, Patient Safety, Healthcare Innovation.

1. INTRODUCTION

1.1 What is Hospital Pharmacy?

A hospital pharmacy's goal is to fill prescriptions for patients when they are scheduled in accordance with medical professionals' guidelines. However, given the increasing patient population, this is not a simple undertaking. While patient safety and care are the most important factors—possibly the only ones—human mistake can sometimes have fatal consequences when it comes to administering medication to patients. These mistakes can take many different forms, such giving out the wrong dosage or the prescription at the wrong time. However, all of these have the potential to have detrimental effects. Furthermore, the pharmacy distributes medications to every hospital unit using a variety of delivery routes and dispensing techniques, which presents a significant logistical challenge.[1,2] Within the framework of a hospital pharmacy, a variety of technologies are available to improve patient safety by lowering prescription errors and medication missing. One of the most important technologies contributing significantly to the development of hospital pharmacy systems is the pharmacy robot.[1-5]

According to a study, the pharmacy robot administers medications almost perfectly, and the right algorithm permits the application of the five rights. By making sure the proper patient receives the right medication and dosage in the right administration at the right time, these rights allude to the sole way to prevent errors.[6]

1.2 What is Robotics & Artificial intelligence?

1.2.1 Robotics

Technology that deals with the creation, maintenance, use, and control of robots as well as computer systems for information processing, sensory feedback, and control is known as robotics. In applications related to laboratories, life sciences, and pharmaceuticals, robots accomplish tasks faster than humans could. These robots operate in potentially dangerous environments where they are in close contact to radioactive contaminants, biological hazards, and toxic chemotherapeutic ingredients. For example, the first ABB robot was implemented in the automotive industry in 1974. More than 150000 have been installed since then, with a significant share occurring in the pharmaceutical industry worldwide.[7] In the domains of pharmaceuticals and other biological research, the use of robots guarantees a significant reduction in the amount of time,

money, and waste generated overall.[2,8] Another important benefit of adopting robotic technologies is the reduction in preparation time for the prescription.[8] Additionally, robotics lowers the proportion of drug errors.[9]

1.2.2 Artificial intelligence (AI)

Artificial intelligence (AI) has revolutionized the healthcare sector by enabling computers to carry out activities that previously required human intelligence. AI has accelerated clinical workflows, improved patient care, and increased diagnostic precision.[10] AI has proven to be useful in a number of medical applications, such as image interpretation, disease detection, and tailored medication, according to recent studies. For example, medical pictures like MRIs and X-rays may now be interpreted by AI-powered algorithms with amazing accuracy, improving diagnosis accuracy and lowering the need for repeat testing. In the medical field, AI has also increased natural language processing, boosted drug discovery, and enhanced genomics. AI in drug discovery has made it possible for scientists to swiftly evaluate vast volumes of data, find possible therapeutic targets, and forecast the effectiveness of novel therapies. AI has advanced genomics by expanding our knowledge of the composition and actions of biomolecules, which has resulted in advances in the identification and management of disease.[11] Additionally, healthcare workers can now swiftly glean insights from vast volumes of medical material thanks to Al-powered natural language processing, which has enhanced patient care and results. Additionally, the use of Al in healthcare has enhanced population health management, tailored medication, and patient engagement.[12] Healthcare providers can now customize

treatment regimens to meet the needs of each patient thanks to Al-powered analytics, while patients may now participate more actively in their care thanks to Al-powered catboats and virtual assistants. Furthermore, by empowering medical practitioners to recognize high-risk individuals, anticipate disease outbreaks, and create focused interventions, Al has enhanced population health management.[13] Al has the ability to transform healthcare by raising the quality of treatment, cutting costs, and increasing patient outcomes. The future of healthcare is probably going to be shaped by Al more and more as it develops and advances.[14]

"The purpose of this article is to review pharmacy robot technology as one of the most important applications of AI in pharmacy."

1.3 How Robotics in Hospital Pharmacy works[15]?

The most effective fit across several domains is typically custom. From the perspective of the system architecture, every robot, application, and system is uniquely created and constructed according to the requirements and features of the system. When developing an automated system, all application-related factors are carefully taken into account. In this section, we will provide a detailed explanation of the pharmacy robot system architecture using an example of a robot that was introduced by some authors in order to help you understand the architecture. The robot can speak with a doctor, assistant, or middleman directly and independently, as seen in Figure 1, 1. The robot then evaluates whether the required prescription is available by scanning the stock inventory. The robot will fill the container with the medication and store it once the appropriate prescription is available.
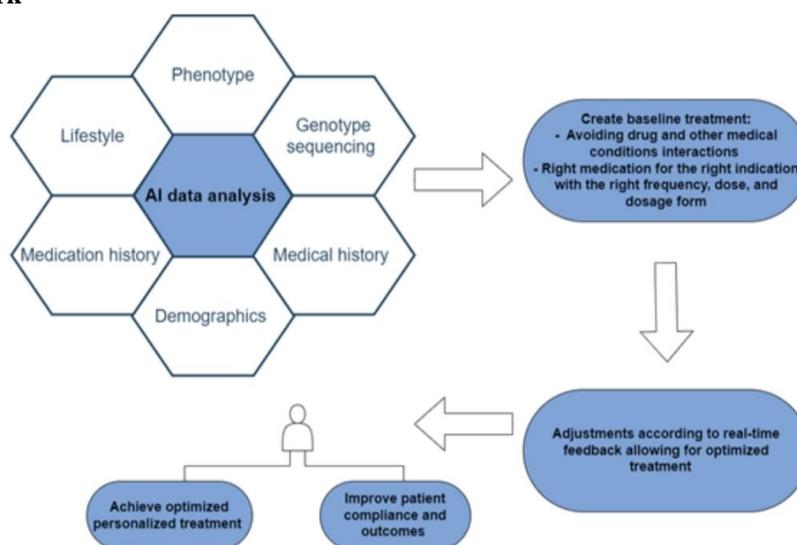
1.3.1 AI powered work

Figure 1.1: Flow chart of working of AI in hospital pharmacy.[16-18]

All of these AI work is combined and regulated by the robot using the internal map that the map-making algorithm produced to reference and interact with its

surroundings. This particular robot utilizes simultaneous localization and mapping (SLAM). The robot will authenticate the identification of the person getting the

medication when the patient or representative shows up to pick it up. The robot will next give the patient the prepared medication after the patient or their representative provides the prescription. As was already noted, this particular robot uses SLAM and AI to interact with a range of objects. SLAM not only gives the robot a precise and clear image of its environment, but it also enables it to update the map as needed, maintaining a precise and up-to-date "vision" of the inventory's current locations.
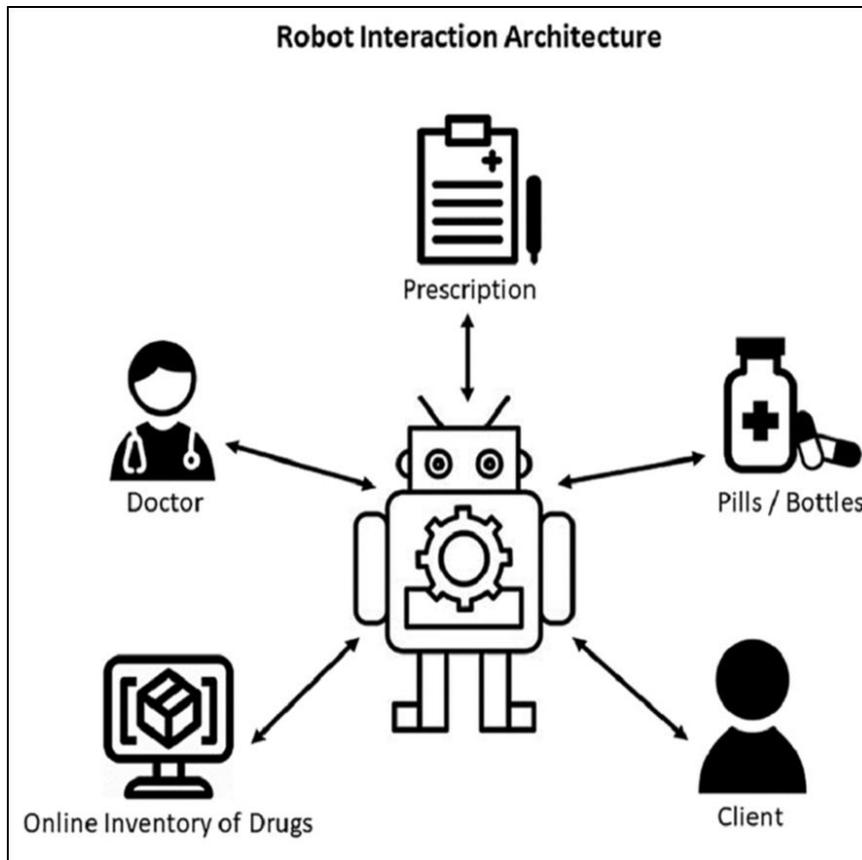

Figure 1.2: Robot Interaction Architecture.[15]

1.4 What are the types of Robots & AI Interfaces used for Hospital Pharmacy?
1.4.1 Types of Robots[19, 20 & 1]

Name of Robot	Year	Advantages	Disadvantages
Pyxis automation system	2019	Workload moved from the pharmacy to the clinic floors. Fingerprint verification ensures that only authorized individuals have access to the medicine. Allows keeping track of stock. Receives all drug-related reports. Ensures that the proper medicine is available at the right moment.	Unable to track lots as a unit dose. Mistakes could occur as a result of reinstalling the returned medication. The inability of checking the expiration dates of the same medications in the same drawer. Issues with data transmission. Barcode verification of tablet medications is performed only at the bedside. The inability of preventing medication mistakes completely.
Rowa Speedcase system	2008	Decreased department costs, medication mistakes, and patient drug distribution times. Improved service efficiency. Stock control is relatively easy.	This technology is unable to package unit doses and deliver medications to the clinic.

Figure 1.3: Table of Robots used in hospital pharmacy.

1.4.2 Types of Artificial intelligence interface [21]

Algorithm	Advantage	Disadvantage	Ideal use
Linear regression	Simple interpretation that can be applied to continuous data	Assumptions of linearity and independence	Dose prediction, dosing adjustments
Support vector machine	Effective in high-dimensional spaces	Sensitive to the selection of parameters and outliers	Classification of side effects; risk management
Decision tree	Simple interpretation, management of complex datasets	Prone to overadjustment, scarce generalization	Dose optimization, clinical decision-making
Random forest	High accuracy with less overadjustment	Greater complexity and longer training times	Personalized therapy selection; stock management
Neural networks	Able to capture complex patterns	Greater complexity, requires abundant data	Drug–drug interaction analysis, prediction of treatment outcomes
Naïve Bayes	Effective management of text and categorical data	Excessive simplification, sensitive to noisy data	Classification of drug records, therapeutic follow-up
K-nearest neighbors	Intuitive, does not make assumptions on data distribution	Sensitive to the distance metric used	Detection of drug response patterns; pharmacovigilance analysis

Figure 1.4: Table of AI used in hospital pharmacy.

1.5 What are the impacts of Robotics in Hospital Pharmacy[22-24]?

At the moment, robots are limited to using either the packed down unit dosages method or the original packs approach, which is also referred to as "one stop dispensing." A hospital should decide which approach to automate and which to use for the majority of dispensing in order to reap the greatest benefits. The majority of US and European hospitals had previously delivered medications mostly in their original packaging or via unit dose dispensing before the introduction. But because the UK combined these approaches, most of the supply chain needed to be reformed in order to adopt a "one-stop" or original pack approach before robotics could be implemented. With the implementation of this reform, there are currently more than 150 operational hospital robot installations in the UK.

Table 1.1 Impacts of Robotic intelligence in hospital pharmacy.

Safety & Quality	Financial	Process Efficiencies
Error in dispensing reduced	Stock holding reduced	dispensing time is faster which reduce the waiting time of patient
The released staff from dispensing field for direct patient care establishing new Clinical Pharmacy Model	Rotation in stock increased resulting reduction in wastage by expired stock	• 24/7 activity • Remote working on call • Better utilization of space

Transaction data: Many larger UK hospitals utilize tandem systems of two to three robots since robot capacity varies from around 8,000 to 11,000 packs. Data on capacity and throughput, both current and projected, is required to determine the needs of specific institutions. This needs to be utilized with the kinds of products that the scope of services covers.

Artificial Intelligence

Prescription Verification
➢ Right medication to the right patient
➢ Right dose, frequency & Dosage form
➢ Detect drug interaction

Counselling
➢ Create personalized diet plan
➢ Council on how to take a medication
➢ Monitor adherence
➢ Follow up plan

Dispensing technique: Full pack dispensing and impress management are the main advantages of robotic dispensing that are observed in the UK. Although individual patient dispensing was once the more typical method, whole pack distribution has not always been as common, and pharmacy in the UK has developed when practicable. The UK Audit Commission Report, "A Spoonful of Sugar," supported the practice modification to lower overall costs and inefficiencies in the discharge and post-discharge processes, as well as to make it easier to introduce robotic dispensing. Although the complexity of Australia's state and commonwealth divide is

recognized, this does not mean that the task is impossible to complete. There will probably be additional process efficiencies as a result of the trend towards polypharmacy. Robotic dispensing has also shown better time efficiencies on prescriptions with multiple packs.

1.6 What is The Future of Automated Dispensing[25, 26]?

Robotic dispensing business case: - Savings must outweigh the cost of the equipment and related expenses (such as inventory, employee turnover, and savings). It's also important to take employee morale, space usage, and risk reduction into account. The extent of the "to be" processes that will make the Pharmacy Reform Program possible should be determined by the business case.

AI based management: The potential for AI to transform the pharmaceutical sector is demonstrated by the most recent advancements in this field. Patients and subject-matter experts will gain from further refinement of these instruments. AI technology may be able to remove risk factors related to clinical trials and drug research. Furthermore, AI enhances patient outcomes and expedites certain aspects of the medication development process. Increased productivity and fewer errors will result from its broader adoption, which will lower production costs. When applied correctly, AI integration can overcome its present limits and possible disadvantages. The value of the pharmaceutical AI products market worldwide was $908 million. This amount is anticipated to increase to almost $11.8 billion by 2032. These figures show that the market will expand at a CAGR of 29–30%. This figures shows future investment of pharmaceutical sectors in AI field.

Design, Organization, and Requirements: - Completely rework the dispensing procedure to prevent acquiring inefficiencies. Increase patient responsiveness and staff efficiency. To avoid transportation, cluster dispensing computers around the robot's output point. To guarantee greater efficacy and efficiency, map "current state" processes against "to be" processes.

Installation and Implementation Planning: - When working with suppliers, strategic sourcing and procurement are crucial. Make use of an organized and structured project management approach. Break the project down into flexible, manageable stages to reduce interference with patient care and pharmacy services.

Change management: - Identify change leaders and involve stakeholders from all relevant departments, organizations, and supplier groups to ensure trust and motivation for the change. Implement a centrally coordinated program of awareness, training, education, SOP integration, adoption support, go-live assistance, and compliance reviews.

Benefit Realization: - Evaluate the effects of robotic pharmacy dispensing and compare the actual benefits to those projected in the original business case. Apply a blend of quantitative and qualitative assessment methods. A comprehensive analysis of the business case and benefits is necessary to obtain internal knowledge and funding for the project. Simplify the specification process to take advantage of prior implementation's experience and offer the advantages of a standard configuration.

Cost Savings:- Major stock holding reductions can result from automated dispensing cabinets at the ward level (e.g., 20% savings at Guy's and St Thomas' NHS Trust). To guarantee service continuity, take into account enabling work, infrastructure, interfaces, hardware, project management, overtime, and backup plans. Use lean methodologies to evaluate the efforts that bring value and those that don't. Apply lean methodologies to evaluate initiatives that create value and those that don't in the pharmacy supply chain.

Enhancing Services: - Using robotics and "e-health" solutions in the pharmacy division can have a significant positive impact, as demonstrated by the Forth Valley Royal Hospital.

1.7 What are the obstacles in use of Robotics & AI in Hospital Pharmacy[26, 27]?

Robots can handle pharmaceuticals without human supervision, but they still require human supervision because machine errors can still happen, albeit infrequently. Therefore, a major worry is that artificial intelligence (AI) will replace humans in their jobs. Artificial Intelligence (AI) has the potential to revolutionise healthcare delivery when integrated into the pharmacy industry, but there are a number of issues that need to be resolved for deployment to be safe and successful. One of the main issues is bias in data collecting, which can provide erroneous results and reinforce pre-existing prejudices in the healthcare system also the efficacy and safety of AI-powered pharmacy systems are difficult to evaluate due to the dearth of evidence-based research. Since sensitive medical data is frequently necessary for AI systems to operate efficiently, data privacy and security issues are also crucial. It is understandable that patients and clinical trial participants are worried about AI datasets compromising or leaking their personal information. Additionally, when AI systems discover unrelated relationships between patient characteristics and outcomes, it may trigger problems with data integration and produce predictions with unsuitable features.

Also mechanical errors were documented as a variety of issues, including material issues (e.g., vials or fluid bags that did not meet weight specifications, crooked needles, or the robot's incapacity to grasp or hold a vial in succession as a result of manufacturing errors in the robot's assembly). Changes in the production process also led to other problems, such as syringe readings that were off. Failures with barcode and vial recognition have also been recorded; these can be attributed to the robot's

limited capacity to handle many simultaneous versions of a task. The pharmacist or technician had to step in to correct all of these problems in order to confirm the relevant information, change the parameters, or fix manufactured defaults.

1.8 Why we must imply Robotics in Hospital Pharmacy[28]?

A website called www.youhaverights.com estimates that 30 million pharmacy errors happen in the US every year. Each year, these errors result in thousands of serious consequences and an estimated 7,000 patient deaths. These mistakes happen when the pharmacist reads the prescription incorrectly, misjudging the medication's name or dosage, for example. These mistakes typically appear to be the result of overburdened pharmacy staff members. These workers have ever-growing workloads and operate under tremendous strain. The staff has less time to devote to each prescription as a result of the growing quantity of prescriptions that must be filled each day. The most frequent pharmacy mistakes include giving patients the wrong prescription at the wrong dosage because employees neglected to advise them on how to use certain medications, and giving IV (intravenous) pharmaceuticals to hospital patients in the wrong way.

CONCLUSION

This research study explored the transformative potential of robotics and artificial intelligence (AI) in hospital pharmacy operations. The findings suggest that the strategic integration of robotic systems and AI algorithms can significantly enhance the quality and safety of hospital pharmacy services, while also reducing costs and improving patient satisfaction. The study highlights the importance of embracing innovative technologies like robotics and AI to drive transformative change in hospital pharmacy operations. Future research directions include exploring the scalability and sustainability of robotic and AI systems, investigating their impact on patient outcomes, and developing frameworks for evaluating their effectiveness. The study recommends that hospital pharmacies invest in robotic and AI systems, develop evaluation frameworks, and support initiatives that promote their adoption. Overall, the research contributes to the growing body of evidence supporting the use of robotics and AI in hospital pharmacies, and highlights their potential to improve patient care, reduce costs, and enhance the overall quality of hospital pharmacy services.

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