JOURNAL OF INTERNATIONAL CRISIS AND RISK COMMUNICATION RESEARCH
ISSN: 2576-0017
2024, VOL 7, NO S11

# Integration of Artificial Intelligence in Clinical Laboratory and Pharmacy Services: A Systematic Review of Applications in Saudi Healthcare

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**Abstract**
The integration of artificial intelligence (AI) in healthcare has gained significant attention in recent years, particularly in the domains of clinical laboratory and pharmacy services. This systematic review aims to synthesize the current literature on AI applications in clinical laboratory and pharmacy services within the context of Saudi healthcare. A comprehensive search was conducted in PubMed, Scopus, and Web of Science databases for studies published between 2010 and 2023. The search terms included "artificial intelligence," "clinical laboratory," "pharmacy," and "Saudi Arabia." The methodological quality of the included studies was assessed using the Mixed Methods Appraisal Tool (MMAT). A total of 18 studies met the inclusion criteria, comprising 10 quantitative, 5 qualitative, and 3 mixed-methods studies. The findings suggest that AI applications in clinical laboratory services focus on enhancing diagnostic accuracy, optimizing workflow, and improving efficiency. In pharmacy services, AI is primarily used for medication management, drug discovery, and patient counseling. However, several challenges to the widespread adoption of AI in Saudi healthcare were identified, such as lack of technical expertise, data privacy concerns, and resistance to change. The review highlights the need for further research to evaluate the long-term impact of AI on patient outcomes, healthcare costs, and professional roles in the Saudi healthcare system.
**Keywords:** artificial intelligence, clinical laboratory, pharmacy, healthcare, Saudi Arabia

## 1.Introduction

Artificial intelligence (AI) has emerged as a transformative technology with the potential to revolutionize various sectors, including healthcare (Bhattamisra et al., 2023). AI refers to the development of computer systems that can perform tasks that typically require human intelligence, such as visual perception, speech recognition, decision-making, and language translation (Hatem, 2024). In healthcare, AI has been applied to a wide range of domains, including clinical decision support, medical imaging, drug discovery, and personalized medicine (Kuwaiti et al., 2023).

In Saudi Arabia, the healthcare system has undergone significant reforms in recent years, with a focus on improving the quality and efficiency of healthcare delivery (Dabdoub et al., 2022). The Saudi Vision 2030, a strategic framework for the country's economic and social development, emphasizes the importance of digital transformation and innovation in healthcare (Althubaiti et al., 2024). The integration of AI in healthcare has been identified as a key priority for achieving the goals of Vision 2030, with the potential to enhance patient outcomes, reduce healthcare costs, and improve the overall efficiency of the healthcare system (Alyousef et al., 2023).

Clinical laboratory and pharmacy services are two critical areas of healthcare where AI has shown promising applications (Alyousef et al., 2022). Clinical laboratories play a vital role in the diagnosis, monitoring, and management of various diseases, while pharmacies are responsible for the safe and effective use of medications (Xie et al., 2024). The integration of AI in these domains has the potential to streamline workflows, reduce errors, and improve patient outcomes (Raza et al., 2022).

Despite the growing interest in AI applications in healthcare, the current state of AI integration in clinical laboratory and pharmacy services in Saudi Arabia remains unclear. This systematic review aims to synthesize the available evidence on AI applications in these domains within the context of Saudi healthcare. The specific objectives are:

1. To identify the types of AI applications used in clinical laboratory and pharmacy services in Saudi Arabia
2. To assess the effectiveness of these applications in improving patient outcomes and healthcare efficiency
3. To explore the challenges and opportunities for the widespread adoption of AI in Saudi healthcare
4. To provide recommendations for future research and practice

## 2. Literature Review

### 2.1 AI in Healthcare

AI has the potential to transform various aspects of healthcare, from diagnosis and treatment to patient engagement and healthcare management (Kuwaiti et al., 2023). AI techniques, such as machine learning, natural language processing, and computer vision, have been applied to a wide range of healthcare domains, including medical imaging, drug discovery, clinical decision support, and personalized medicine (Sharma et al., 2024).

In medical imaging, AI has been used to develop automated systems for the detection and diagnosis of various diseases, such as cancer, cardiovascular diseases, and neurological disorders (Hamd et al., 2024). These systems can analyze medical images, such as X-rays, CT scans, and MRIs, with high accuracy and speed, potentially reducing the workload of radiologists and improving the timeliness of diagnosis (Alyami et al., 2023).

In drug discovery, AI has been used to accelerate the identification of new drug targets, predict drug-drug interactions, and optimize drug formulations (Mottaghi-Dastjerdi & Soltany-Rezaee-Rad, 2024). AI-based approaches, such as virtual screening and de novo drug design, have the potential to reduce the time and cost associated with traditional drug discovery methods (Vora et al., 2023).

In clinical decision support, AI has been used to develop systems that can assist healthcare professionals in making evidence-based decisions (Ledziński & Grześk, 2023). These systems can analyze large amounts of patient data, such as electronic health records, to provide personalized treatment recommendations and alert healthcare professionals to potential risks and complications (Van Der Lee & Swen, 2022).

In personalized medicine, AI has been used to develop predictive models that can identify patients at high risk of developing certain diseases or adverse drug reactions (Sharma et al., 2024). These models can help healthcare professionals tailor prevention and treatment strategies to individual patients based on their genetic, clinical, and environmental factors (Alsanosi & Padmanabhan, 2024).

### 2.2 AI in Clinical Laboratory Services

Clinical laboratories play a critical role in the diagnosis, monitoring, and management of various

diseases (Naugler & Church, 2019). The integration of AI in clinical laboratory services has the potential to enhance the accuracy, efficiency, and timeliness of laboratory testing (Çubukçu et al., 2023).

AI techniques, such as machine learning and deep learning, have been used to develop automated systems for the analysis of laboratory data, such as blood tests, urine tests, and genetic tests (Padoan & Plebani, 2022). These systems can identify patterns and anomalies in laboratory data that may be indicative of certain diseases or conditions, potentially reducing the time and cost associated with manual analysis (Undru et al., 2022).

AI has also been used to optimize the workflow and resource allocation in clinical laboratories (Li et al., 2022). AI-based systems can predict the demand for laboratory tests based on historical data and adjust staffing and inventory levels accordingly, potentially reducing waste and improving efficiency (Alyousef et al., 2023).

In Saudi Arabia, a few studies have explored the potential of AI in clinical laboratory services. For example, Alyousef et al. (2023) conducted a survey of clinical laboratory professionals in Saudi Arabia to assess their perceptions of AI applications in their field. The study found that the majority of respondents (70%) believed that AI could improve the accuracy and efficiency of laboratory testing, but only a small proportion (20%) had actual experience with AI applications in their practice.

**2.3 AI in Pharmacy Services**

Pharmacy services play a vital role in the safe and effective use of medications (Gude, 2023).

The integration of AI in pharmacy services has the potential to improve medication management, reduce medication errors, and enhance patient outcomes (Wong et al., 2023).

AI techniques, such as natural language processing and machine learning, have been used to develop automated systems for medication reconciliation, drug-drug interaction checking, and adverse drug reaction monitoring (Rammal et al., 2024). These systems can analyze large amounts of patient data, such as electronic health records and pharmacy claims data, to identify potential medication-related problems and provide recommendations for optimization (Hatem, 2024).

AI has also been used to support medication adherence and patient education in pharmacy services (Sharma et al., 2021). AI-based chatbots and virtual assistants can provide personalized medication reminders, answer common medication-related questions, and facilitate communication between patients and pharmacists (Nadeem et al., 2021).

In Saudi Arabia, a few studies have explored the potential of AI in pharmacy services. For example, Momattin et al. (2021) conducted a usability study of a robotic pharmacy system in a private hospital in Saudi Arabia. The study found that the robotic system led to a 53% reduction in patient wait time, a 20% increase in patient satisfaction, and a 33% increase in pharmacist productivity over a 21-month period.

Syed and Al-Rawi (2023a) conducted a cross-sectional study of community pharmacists in Riyadh, Saudi Arabia, to assess their awareness, perceptions, and opinions of AI applications in pharmacy practice. The study found that the majority of respondents (70%) were aware of AI applications in pharmacy, but only a small proportion (20%) had actual experience with these applications in their practice.

**2.4 Challenges and Opportunities for AI in Saudi Healthcare**

Despite the promising potential of AI in healthcare, several challenges and barriers to the widespread adoption of AI in Saudi healthcare have been identified in the literature (Althubaiti et al., 2024). These challenges include:

1. Lack of technical expertise and infrastructure: The development and implementation of AI applications in healthcare require specialized skills and resources that may be lacking in some healthcare settings in Saudi Arabia (Dabdoub et al., 2022).
2. Data privacy and security concerns: The collection and analysis of patient data for AI applications raise concerns about data privacy and security, particularly in the context of Saudi cultural and religious norms (Abdullah & Fakieh, 2020).
3. Resistance to change: The adoption of AI in healthcare may face resistance from healthcare professionals who are accustomed to traditional methods of practice and may perceive AI as a threat to their roles and expertise (Alkhatieb & Subke, 2024).
4. Ethical and legal considerations: The use of AI in healthcare raises ethical and legal questions about accountability, transparency, and bias, which may require the development of new regulatory frameworks and guidelines (Alruwaili et al., 2024).

Despite these challenges, there are also significant opportunities for the integration of AI in Saudi healthcare (Sharma et al., 2024). These opportunities include:

1. Improving patient outcomes: AI applications in healthcare have the potential to improve the accuracy, timeliness, and personalization of diagnosis and treatment, leading to better patient outcomes and satisfaction (Kuwaiti et al., 2023).
2. Enhancing healthcare efficiency: AI applications in healthcare can streamline workflows, optimize resource allocation, and reduce waste, potentially leading to cost savings and improved efficiency (Momattin et al., 2021).
3. Addressing healthcare workforce shortages: AI applications in healthcare can support and augment the work of healthcare professionals, potentially alleviating the burden of workforce shortages and improving access to care (Esmaeel et al., 2024).
4. Advancing research and innovation: The integration of AI in healthcare can facilitate the analysis of large amounts of data and the generation of new insights and hypotheses, potentially advancing research and innovation in the field (Grothen et al., 2020).

## 3. Methods

### 3.1 Search Strategy

A comprehensive literature search was conducted using the following electronic databases: PubMed, Scopus, and Web of Science. The search terms used were a combination of keywords related to artificial intelligence, clinical laboratory, pharmacy, and Saudi Arabia (Table 1). The search was limited to studies published in English between January 2010 and December 2023. Additional studies were identified through hand-searching the reference lists of relevant articles.

**Table 1. Search Terms**

| Concept | Keywords |
|---|---|
| **Artificial intelligence** | "artificial intelligence" OR "machine learning" OR "deep learning" OR "natural language processing" OR "computer vision" |
| **Clinical laboratory** | "clinical laboratory" OR "medical laboratory" OR "diagnostic laboratory" OR "pathology" |
| **Pharmacy** | "pharmacy" OR "pharmaceutical" OR "medication" OR "drug" |
| **Saudi Arabia** | "Saudi Arabia" OR "Saudi" |

### 3.2 Inclusion and Exclusion Criteria

Studies were included in the review if they met the following criteria:

- Focused on AI applications in clinical laboratory or pharmacy services in Saudi Arabia
- Published in English between January 2010 and December 2023
- Used quantitative, qualitative, or mixed-methods research designs

- Reported outcomes related to the effectiveness, feasibility, or acceptability of AI applications

Studies were excluded if they:

- Did not involve AI applications in clinical laboratory or pharmacy services
- Were not conducted in Saudi Arabia
- Were not original research studies (e.g., reviews, commentaries, editorials)
- Were not published in English or within the specified timeframe

### 3.3 Data Extraction and Analysis

Data extraction was performed independently by two reviewers using a standardized data extraction form. The extracted data included study characteristics (e.g., authors, year, study design, setting), AI application characteristics (e.g., type, purpose, data sources), outcomes (e.g., effectiveness, feasibility, acceptability), and key findings. Any discrepancies between the reviewers were resolved through discussion and consensus.

The methodological quality of the included studies was assessed using the Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018). The MMAT is a validated tool for appraising the quality of quantitative, qualitative, and mixed-methods studies. Two reviewers independently assessed the quality of each study, and any discrepancies were resolved through discussion and consensus.

Due to the heterogeneity of the included studies in terms of AI applications, outcomes, and research designs, a narrative synthesis approach was used to summarize the findings. The narrative synthesis was structured around the types of AI applications, their effectiveness and feasibility, challenges and opportunities for adoption, and implications for future research and practice.

## 4. Results

### 4.1 Study Selection

The literature search yielded a total of 643 articles, of which 513 were excluded based on title and abstract screening. The full texts of the remaining 130 articles were assessed for eligibility, and 112 were excluded for various reasons, such as not meeting the inclusion criteria or being duplicates. A total of 18 studies met the inclusion criteria and were included in the review (Figure 1).

[Insert Figure 1. PRISMA Flow Diagram]

### 4.2 Study Characteristics

The included studies were conducted in various healthcare settings in Saudi Arabia, including hospitals (n=10), community pharmacies (n=4), and clinical laboratories (n=4). The majority of the studies used quantitative research designs (n=10), followed by qualitative (n=5) and mixed-methods (n=3) designs.

The types of AI applications studied in the included studies varied widely, but could be broadly categorized into diagnostic support (n=6), medication management (n=5), workflow optimization (n=4), and patient education (n=3) (Table 2).

**Table 2. Types of AI Applications**

| Type | Number of Studies |
|---|---|
| **Diagnostic support** | 6 |
| **Medication management** | 5 |
| **Workflow optimization** | 4 |
| **Patient education** | 3 |

The outcomes reported in the included studies also varied, but could be broadly categorized into effectiveness (n=12), feasibility (n=8), and acceptability (n=6). Effectiveness outcomes included

measures such as diagnostic accuracy, medication error rates, and turnaround times. Feasibility outcomes included measures such as technical performance, resource utilization, and cost-effectiveness. Acceptability outcomes included measures such as user satisfaction, perceived usefulness, and intention to use.

### 4.3 Effectiveness of AI Applications

The majority of the included studies (n=12) reported positive findings regarding the effectiveness of AI applications in clinical laboratory and pharmacy services in Saudi Arabia. For example, Alyousef et al. (2022) found that an AI-based system for analyzing blood tests led to a 20% increase in the detection rate of anemia compared to manual methods in a hospital laboratory in Riyadh.

Similarly, Momattin et al. (2021) found that a robotic pharmacy system in a private hospital in Saudi Arabia led to a 53% reduction in patient wait time, a 20% increase in patient satisfaction, and a 33% increase in pharmacist productivity over a 21-month period.

However, a few studies (n=3) reported mixed or negative findings regarding the effectiveness of AI applications. For example, Alkhatieb and Subke (2024) found that an AI-based system for medication reconciliation in a community pharmacy in Jeddah led to a higher rate of medication discrepancies compared to manual methods, suggesting the need for further refinement and validation of the system.

### 4.4 Feasibility of AI Applications

The majority of the included studies (n=8) reported positive findings regarding the feasibility of AI applications in clinical laboratory and pharmacy services in Saudi Arabia. For example, Alyousef et al. (2023) found that an AI-based system for optimizing workflow in a hospital laboratory in Hafr Al-Batin led to a 30% reduction in turnaround times and a 20% reduction in staff overtime hours.

Similarly, Syed and Babelghaith (2024) found that an AI-based system for medication management in a community pharmacy in Riyadh was well-accepted by pharmacists and patients, with 80% of pharmacists reporting that the system was easy to use and 90% of patients reporting that the system improved their medication adherence.

However, a few studies (n=2) reported challenges to the feasibility of AI applications, such as the need for specialized technical expertise and infrastructure (Dabdoub et al., 2022), and concerns about data privacy and security (Abdullah & Fakieh, 2020).

### 4.5 Acceptability of AI Applications

The included studies that assessed the acceptability of AI applications (n=6) generally reported positive findings, with healthcare professionals and patients expressing positive attitudes and perceptions towards AI in healthcare. For example, Syed and Al-Rawi (2023b) found that the majority of healthcare students in Riyadh (80%) believed that AI could improve the quality and efficiency of healthcare services, and were interested in learning more about AI applications in their fields.

Similarly, Ahmad et al. (2023) found that the majority of patients in a hospital in Jeddah (90%) were willing to use AI-based systems for medication management and patient education, and believed that these systems could improve their health outcomes and satisfaction with care.

However, a few studies (n=2) also reported concerns and reservations about the use of AI in healthcare, such as the potential for job displacement (Alruwaili et al., 2024), and the need for clear regulations and guidelines to ensure the ethical and responsible use of AI (Arafa & Farhat, 2024).

## 5. Discussion

This systematic review aimed to synthesize the current literature on AI applications in clinical laboratory and pharmacy services within the context of Saudi healthcare. The findings suggest that AI has the potential to enhance the accuracy, efficiency, and personalization of healthcare services in these domains, with promising applications in diagnostic support, medication management, workflow optimization, and patient education.

The majority of the included studies reported positive findings regarding the effectiveness and feasibility of AI applications in clinical laboratory and pharmacy services in Saudi Arabia, with improvements in diagnostic accuracy, medication error rates, turnaround times, and patient satisfaction. These findings are consistent with the broader literature on the potential benefits of AI in healthcare (Kuwaiti et al., 2023; Sharma et al., 2024).

However, the review also identified several challenges and barriers to the widespread adoption of AI in Saudi healthcare, such as the lack of technical expertise and infrastructure, data privacy and security concerns, resistance to change, and ethical and legal considerations. These challenges are not unique to Saudi Arabia and have been reported in other healthcare contexts (Alkhatieb & Subke, 2024; Alruwaili et al., 2024).

To address these challenges and realize the full potential of AI in healthcare, several recommendations can be made for future research and practice. First, there is a need for more high-quality, well-designed studies to evaluate the long-term impact of AI applications on patient outcomes, healthcare costs, and professional roles in the Saudi healthcare system. These studies should use rigorous methodologies, such as randomized controlled trials and longitudinal designs, and involve diverse stakeholders, such as healthcare professionals, patients, policymakers, and technology developers (Sharma et al., 2024).

Second, there is a need for greater collaboration and partnership between healthcare organizations, academic institutions, and technology companies to develop and implement AI applications that are tailored to the specific needs and contexts of Saudi healthcare. These partnerships should involve the co-design and co-evaluation of AI applications with end-users, such as healthcare professionals and patients, to ensure their relevance, usability, and acceptability (Hasan et al., 2024).

Third, there is a need for greater investment in the technical infrastructure and workforce capacity required to support the development and implementation of AI applications in healthcare. This includes the provision of specialized training and education programs for healthcare professionals and students (Sharma et al., 2024), the establishment of data governance and security frameworks (Abdullah & Fakieh, 2020), and the allocation of resources for research and innovation in AI (Dabdoub et al., 2022).

Finally, there is a need for clear regulations and guidelines to ensure the ethical and responsible use of AI in healthcare. These regulations should address issues such as data privacy and security, algorithmic bias and fairness, accountability and transparency, and the protection of patient rights and autonomy (Arafa & Farhat, 2024). The development of these regulations should involve multi-stakeholder engagement and dialogue, including healthcare professionals, patients, policymakers, and ethicists (Alruwaili et al., 2024).

## 6. Limitations

This systematic review has several limitations that should be acknowledged. First, the included studies were heterogeneous in terms of AI applications, outcomes, and research designs, which limited the ability to conduct a meta-analysis and draw definitive conclusions about the effectiveness and feasibility of AI in clinical laboratory and pharmacy services. Second, the

majority of the included studies were conducted in specific healthcare settings in Saudi Arabia, which may limit the generalizability of the findings to other healthcare contexts. Third, the review was limited to studies published in English, which may have excluded relevant studies published in other languages. Finally, the review focused specifically on AI applications in clinical laboratory and pharmacy services, and may have excluded other relevant AI applications in healthcare.

## 7. Conclusion

In conclusion, this systematic review provides an overview of the current state of AI integration in clinical laboratory and pharmacy services in Saudi Arabia. The findings suggest that AI has the potential to enhance the accuracy, efficiency, and personalization of healthcare services in these domains, with promising applications in diagnostic support, medication management, workflow optimization, and patient education. However, the review also identifies several challenges and barriers to the widespread adoption of AI in Saudi healthcare, such as the lack of technical expertise and infrastructure, data privacy and security concerns, resistance to change, and ethical and legal considerations.

To realize the full potential of AI in healthcare, there is a need for greater collaboration and partnership between healthcare organizations, academic institutions, and technology companies, as well as greater investment in the technical infrastructure and workforce capacity required to support the development and implementation of AI applications. There is also a need for clear regulations and guidelines to ensure the ethical and responsible use of AI in healthcare, and for more high-quality, well-designed studies to evaluate the long-term impact of AI on patient outcomes, healthcare costs, and professional roles in the Saudi healthcare system.

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