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Artificial Intelligence in Clinical Medicine: A SWOT Analysis of AI Progress in Diagnostics, Therapeutics, and Safety

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Abstract

Artificial intelligence (AI) is increasingly recognized as a developing driver of innovation in clinical medicine, with reported advancements in diagnosis, treatment, and patient safety. Its capabilities may support new applications in care delivery and quality improvement, though the full extent of its impact remains under investigation. This analysis aimed to explore recent advances in AI across clinical laboratory medicine, infectious disease management, and pharmacovigilance, drawing insights from a peer-reviewed English literature published between 2019 and 2024. The study presented a descriptive literature review using the strengths, weaknesses, opportunities, and threats (SWOT) framework to examine recent AI developments in selected clinical domains, noting its emerging role and potential relevance in clinical settings. In clinical laboratories, AI has been associated with improved diagnostic accuracy and operational efficiency, while in infectious diseases, it has enabled rapid pathogen identification and precision-guided treatments. In pharmacovigilance, AI has been explored for its potential to enhance predictive analytics and real-time monitoring, which may have contributed to reducing medication-related errors and adverse drug events. Despite these reported benefits, AI adoption raised critical concerns, including data privacy, algorithmic bias, and the ongoing need for human oversight. Addressing these challenges is essential to promote ethical, transparent, and appropriate AI integration into clinical medicine. By addressing these complexities, AI may unlock new opportunities in personalized medicine, safety, and care delivery, positioning it as a supportive tool in the

evolving landscape of clinical practice.

Keywords: artificial intelligence, machine learning, clinical medicine, laboratory medicine, infectious diseases, pharmacovigilance

1. Introduction

Artificial Intelligence (AI) has already been reshaping the landscape of clinical medicine (Bajwa et al., 2021; Reali & Femminella, 2024). This AI-driven revolution is marked by the introduction of emerging approaches that are gradually influencing how patient care and outcomes are achieved and optimized (Barracca et al., 2020; Krishnan et al., 2023; Rb et al., 2024; Suh et al., 2022). The capabilities of AI to rapidly and precisely analyze extensive medical data can empower healthcare professionals to make informed, accurate, and timely decisions (Alowais et al., 2023; Bajwa et al., 2021). This progress may contribute to enhancing diagnostic accuracy, tailoring treatments to individual needs, and improving patient outcomes while increasing efficiency in healthcare delivery (Akhter et al., 2024; Alowais et al., 2023; Cesario et al., 2023; Riaño et al., 2019; Salehi, 2024; Saxena & Chandra, 2021; Stafie et al., 2023; Zavaleta-Monestel et al., 2024; Zeb et al., 2024). Additionally, the utility of AI-driven technologies extends to facilitating administrative workflows, enhancing resource allocation, and accelerating the development of groundbreaking medical interventions (Ahmadi & RabieNezhad Ganji, 2023; Alves et al., 2024; Bhagat & Kanyal, 2024; Cutler, 2023). The continued advancements of AI suggest a future where its integration into clinical medicine could support improved effectiveness and efficiency in patient care (Abbaoui et al., 2024; Dutta, 2023).

Clinical medicine involves diagnosing and treating human diseases alongside efforts in disease prevention and promoting health and well-being—key components of the United Nations' Sustainable Development Goals established in 2015 (Kruk et al., 2018). Clinical medicine integrates both primary and specialty care (Romaire, 2020). Primary care serves as the initial point of contact, addressing routine checkups and general health concerns, while specialty care involves advanced treatment provided by physicians with expertise in specific medical disciplines (Wilkinson et al., 2024).

Integrating advanced technologies such as AI into clinical medicine has become increasingly essential to meet the complex demands of modern healthcare (Bajwa et al., 2021; Barracca et al., 2020). Currently, AI is steadily transforming the practice of clinical medicine, redefining various approaches across a wide range of specialties (Bekbolatova et al., 2024; Karalis, 2024). For example, AI-driven predictive analytics have demonstrated potential in enhancing the accuracy, efficiency, and cost-effectiveness of disease diagnosis and clinical laboratory testing, offering advancements in clinical medicine (Khalifa & Albadawy, 2024; Undru et al., 2022). Moreover, AI aids population health management and the development of clinical guidelines by providing real-time, accurate insights and optimizing medication selection (Alowais et al., 2023; Krishnan et al., 2023; Maleki Varnosfaderani & Forouzanfar, 2024). On a specific note and based on the current body of evidence, in fields like clinical laboratory medicine, infectious diseases, and pharmacovigilance, AI-driven tools are being applied to enhance diagnostic accuracy, refine treatment strategies, and provide precise predictions of patient outcomes (Jafri et al., 2024; Lee et al., 2023; Salas et al., 2022; Sarantopoulos et al., 2024; Shamim et al., 2024; Undru et al., 2022; Vora et al., 2023; Xie et al., 2024; Zhao et al., 2024). These domains were selected due to their distinct roles in clinical diagnostics, population-level surveillance, and medication safety, making them important areas for evaluating AI's evolving contributions to patient care.

1.1 An Overview of AI's Development Through the Years

On a historical note, the progress of modern civilization has been profoundly influenced by technological innovation, with the adoption and integration of new tools contributing significantly to societal advancement (Ida, 2024). This development path includes the rise of artificial intelligence, a major technological development of recent decades (Bharadiya et al., 2023). Since the 1940s, AI has undergone notable advancements, evolving into a tool with applications across multiple fields, including clinical medicine (Rashid & Kausik, 2024; Roser, 2022). The evolution of artificial intelligence has been shaped by several decades of technological progress, beginning with its conceptual roots in the 1940s and 1950s. During this time, early computers were introduced, alongside foundational discussions on machine cognition and the Turing Test, proposed as a benchmark for machine intelligence (Haenlein & Kaplan, 2019), including the development of the Turing Test as a benchmark for evaluating machine intelligence (Gonçalves, 2023). A significant milestone was the 1956 Dartmouth Workshop, which formally recognized AI as a research discipline and laid the foundation for future developments (van Assen et al., 2022). Clinical relevance emerged in the 1980s with machine learning (ML) algorithms, such as decision trees and neural networks, which shifted AI from rule-based systems toward data-driven approaches capable of pattern recognition and adaptive learning (Taye, 2023). This transition enabled more adaptive, learning-based systems to identify and respond to data patterns.

A breakthrough followed in the 2010s with the development of a deep convolutional neural network model that demonstrated substantial success in image recognition, marking a key advancement in modern deep learning (DL) and influencing computer vision (Manakitsa et al., 2024; Sarker, 2021). The 2020s witnessed the rapid evolution of generative AI (genAI), with models such as OpenAI's generative pre-trained transformer GPT-3 and GPT-4 demonstrating the ability to generate human-like text and content, with a subsequent huge influence on diverse sectors such as healthcare (Javaid et al., 2023; Sallam, 2023). By 2024, growing interest in AI integration within healthcare was observed, supported by developments in explainable AI, multimodal systems, and evolving regulatory considerations (Pahud de Mortanges et al., 2024; Sadeghi et al., 2024; Tam et al., 2024).

The major milestones in the development of AI, from its early foundations in the 1940s to its advancements in 2024, are illustrated in Figure 1.

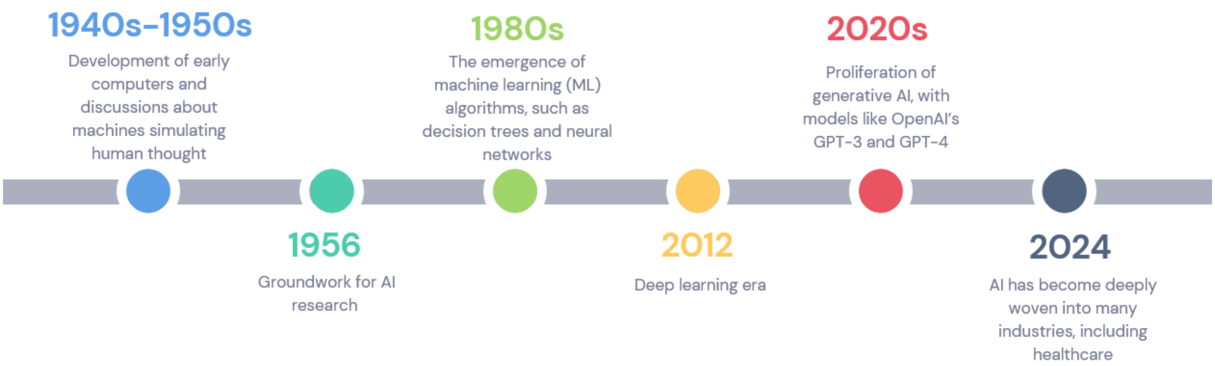

Figure 1. Key Milestones in the Evolution of AI (1940s–2024).

AI: Artificial Intelligence; ML: Machine Learning; genAI: Generative AI; GPT: Generative Pre-trained Transformer.

1.2 Definition and Scope of AI in Healthcare

AI is the branch of computer science focused on simulating aspects of human cognition through machines (Xu et al., 2021). AI encompasses several specialized domains, including ML, natural language processing (NLP), DL, robotics, and process automation, each employing distinct methodologies to address specific challenges (Ahirwal et al., 2022; Soori et al., 2023). ML and DL utilize computational techniques to identify and model complex patterns and decision rules based on data (Taye, 2023). These methods employ supervised, unsupervised, and reinforcement learning, enabling them to perform tasks such as predicting outcomes, classifying diseases, and detecting abnormalities (Asselbergs et al., 2023; Sarker, 2021). The hierarchical relationship between AI, ML, DL, and genAI is illustrated in Figure 2, showing how these fields interconnect in a nested structure.

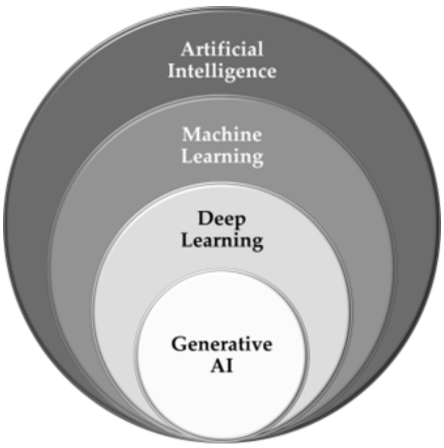

Figure 2. The Nested Structure of Artificial Intelligence, Encompassing Machine Learning, Deep Learning/Artificial Neural Networks, and Generative AI

Building on AI's diverse healthcare applications is considered a potentially valuable approach for interpreting medical texts and developing diagnostic solutions (Bajwa et al., 2021; Demner-Fushman et al., 2009; Locke et al., 2021). For example, NLP has shown practical utility in analyzing electronic health records (EHRs) (Hossain et al., 2023). By analyzing and interpreting unstructured medical texts within EHRs, NLP can extract meaningful insights, streamline diagnostic processes, and enhance clinical decision-making (Sim et al., 2024). This integration supports evidence-based medicine, improves adherence to clinical guidelines, builds knowledge repositories, and facilitates outcome-based research (Shastry & Shastry, 2023; Sheikhalishahi et al., 2019).

Investigating patient specimens is essential in clinical laboratory medicine to aid in diagnosis. Utilizing AI may significantly support the practice of laboratory medicine, enabling the interpretation of laboratory results (Theodosiou & Read, 2023; Undru et al., 2022). Additionally, the use of AI offers advantages compared to traditional clinical analysis, assisting professionals in making faster decisions and improving operational efficiency by reducing delay times and human errors (Baxi et al., 2022; Ephraim et al., 2024; Shafi & Parwani, 2023). In infectious disease management, AI has shown promise in supporting diagnosis, risk stratification, and treatment planning (Cheng et al., 2023; Santangelo et al., 2023; Sarantopoulos et al., 2024). AI's application in pharmacovigilance has been associated with improved detection and monitoring of adverse effects, aiding in detecting and preventing medication-related issues (Gamaleldin et al., 2024). Large language models (LLMs) and genAI enhance interactions, provide accurate and curated information, and improve health service delivery, highlighting the importance of responsible integration to maximize their benefits (Schueller & Morris, 2023; Xu et al., 2021).

These developments reflect AI's emerging influence across the selected domains; however, the effective application of AI continues to face limitations related to data quality, algorithmic bias, cybersecurity risks (Sallam et al., 2024a), patient data privacy and ethical concerns (Bekbolatova et al., 2024), and the limited generation of real-world evidence through clinical trials (Han et al., 2024; Salehi, 2024).

1.3 Study Aims and Objectives

This analysis aimed to explore the developing applications of AI in clinical medicine, focusing on clinical laboratory medicine, infectious disease management, and pharmacovigilance. Specifically, the study objectives included evaluating how AI could contribute to diagnostic accuracy, support decision-making, and improve operational efficiency. The paper also examined the AI's role in analyzing biological specimens, classifying diseases, stratifying risk, planning treatments, and detecting medication-related adverse events. It also highlighted the potential of large language models (LLMs) and genAI to support clinical communication, deliver curated information, and contribute to healthcare delivery (Bedi et al., 2024). Lastly, the paper addressed key challenges associated with AI integration in clinical medicine, such as data quality, bias, interpretability, privacy, and the limited availability of real-world evidence, emphasizing the need for responsible integration and consistent evaluation frameworks to ensure ethical and effective implementation.

2. Materials and Methods

This targeted descriptive literature review examined the integration of AI into three key areas of clinical medicine: clinical laboratory medicine, infectious disease management, and pharmacovigilance. To systematically evaluate current advancements, limitations, and opportunities, a narrative literature review was conducted using five databases: PubMed/MEDLINE, Web of Science, Scopus, EMBASE, and Google Scholar. The search targeted peer-reviewed English-language articles published between January 2019 and September 2024, and the search concluded on October 1, 2024.

The first and second authors collaboratively developed a multidisciplinary search strategy, leveraging AI, healthcare, infectious diseases, and pharmacovigilance expertise. The strategy employed predefined keywords including: "AI in clinical medicine," "machine learning in diagnostics," "AI in infectious diseases," and "AI in treatment optimization," which guided the search. Authors screened abstracts and full texts independently to minimize selection bias, and consensus resolved discrepancies following discussion. Studies were included if they reported on AI's impact on diagnostic accuracy, treatment optimization, patient safety, or clinical outcomes. The evaluated data covered study design, AI methodologies, clinical domains impacted, and reported outcomes. Emphasis was placed on studies detailing AI's role in enhancing diagnostic workflows, reducing medication-related harm, and supporting clinical outcomes. Articles addressing the design, performance, safety profiles, and limitations of AI tools were prioritized. Challenges, such as algorithmic bias, data privacy, security, and the need for human oversight, were systematically analyzed to ensure a balanced evaluation of AI's applications. A Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis was conducted for each domain of clinical laboratory medicine, infectious disease, and pharmacovigilance to provide a structured assessment of AI's capabilities, limitations, and areas for improvement. This analytical approach enabled a nuanced understanding of current practices and identified gaps that warrant future research and development. It provided foundational insights to guide ethical and context-appropriate implementation while addressing potential vulnerabilities in its adoption across the studied clinical domains.

3. AI in Clinical Laboratory Medicine

Integrating artificial intelligence into clinical laboratory medicine may offer advancements in interpreting complex test results, enabling faster, more accurate, and actionable insights that could support timely clinical decision-making (Hou et al., 2024; Xie et al., 2024). The primary technique for increased diagnostic precision and efficiency has been the automation of workflows, thereby reducing turnaround times while improving quality and staff efficiency and providing advanced clinical decision support tools based on complex data patterns (Albahra et al., 2023). Automated identification of pathogens directly from biological specimens to clinical isolates, application of advanced analysis techniques, and enhanced clinical interpretation of casuistry to predict patient results are the key areas of development (Undru et al., 2022; Yang et al., 2022). Various applications of AI in laboratory medicine have been documented in the literature, including instrument automation, error detection, prediction of laboratory test values, result interpretation, optimizing laboratory test utilization, and enhancing laboratory information systems (Haymond & McCudden, 2021; Rabbani et al., 2022).

Recent studies have demonstrated the feasibility of employing text mining and artificial intelligence techniques to extract data from electronic clinical laboratory systems in microbiology. These AI classifiers, which are relatively cost-effective, have been increasingly applied to characterize infectious diseases and identify their causative agents based on laboratory test results (Chaturvedi et al., 2024; Mohseni & Ghorbani, 2024).

Major AI integration challenges in clinical laboratories are associated with a lack of robust data management systems, trained personnel, and insufficient financial and human resources (Xie et al., 2024; Yang et al., 2022). Cadamuro et al. (2023) evaluated ChatGPT's ability to interpret laboratory test results, finding that while it could detect deviations and provide general insights, it lacked the depth and accuracy needed for comprehensive clinical assessments, highlighting the importance of further validation and refinement in medical AI applications (Rabbani et al., 2022). These challenges and other ethical issues are fundamental to any AI-based clinical laboratory service on a global scale (Pennestrì & Banfi, 2022). As AI integration into clinical laboratory medicine advances, it may improve patient outcomes and elevate expectations regarding diagnostic precision and system performance (Imad-Addin, 2024).

Figure 3 presents a SWOT analysis highlighting the strengths, weaknesses, opportunities, and threats associated with implementing AI in clinical laboratory medicine.

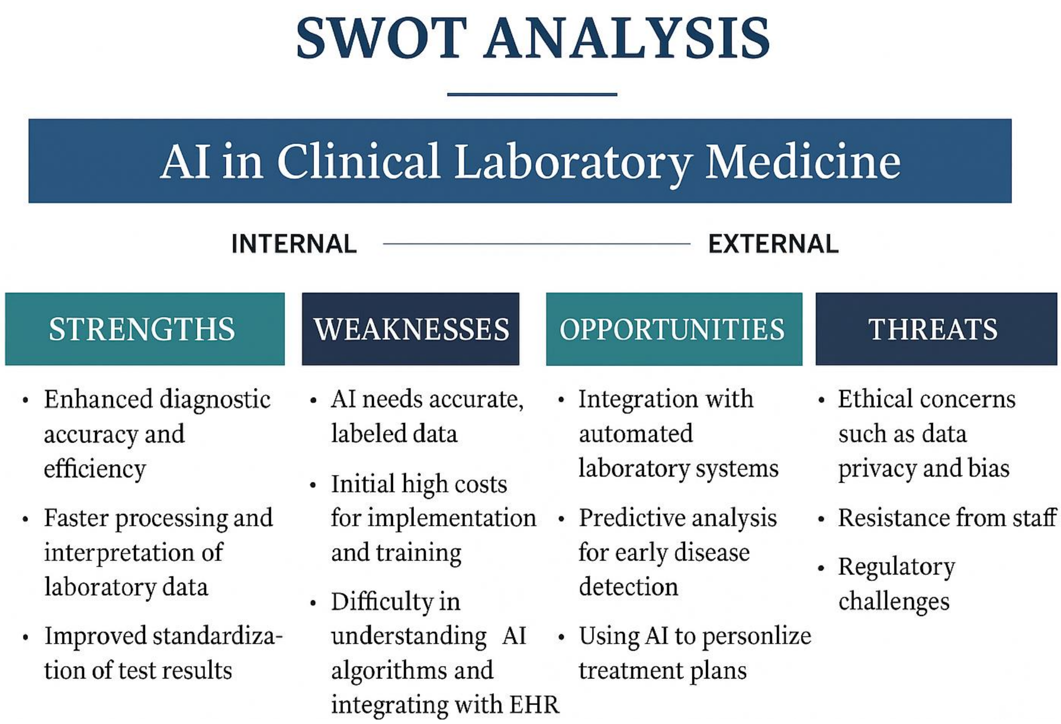

Figure 3. SWOT Analysis of AI in Clinical Laboratory Medicine

4. AI Applications in Infectious Diseases Diagnosis and Management

Despite the recent scientific and technological progress, infectious illnesses still present a notable risk to public health (Rai et al., 2024). These diseases carry the potential of spreading rapidly and causing serious health complications. Furthermore, they manifest as epidemics and impact whole populations (Piret & Boivin, 2021). The challenges of promptly and accurately diagnosing these illnesses and the rising resistance to antimicrobial treatments add complexity to their management (Timbrook et al., 2023).

AI has demonstrated potential in supporting the diagnosis and management of infectious diseases through enhancements in antimicrobial drug discovery, better understanding of infection biology, and refinement of diagnostic tools (Wong et al., 2023), more accurately characterizing patients who present with acute infections, in effectively tracking outbreaks and emerging infectious diseases, and in tailoring antimicrobial therapies to patients and their specific infections (Aslan, 2024). There are many ways in which the infection community is researching methods to improve infectious disease diagnosis, management, and caregiver support (Radaelli et al., 2024). AI enhancements are likely to affect how infection occurs and develops, and it is unlikely that AI itself is directly involved in basic research (Rabaan et al., 2023). AI is used to diagnose and manage infection by analyzing and characterizing clinical and other data associated with patients and their environments—what infections look like and how they progress (Aslan, 2024). According to the literature reviewed, AI-driven data analysis may contribute to more rapid and precise generation of isolation strategies, ICU bed allocation, and antibiotic prescription potentially offering improvements over current diagnostic methods, especially in managing hospital-acquired infections and antimicrobial resistance (AMR) (Ali & Muhammad, 2023; Rabaan et al., 2022), and other outbreak or emerging pathogen scenarios by preventing ongoing disease acquisition. However, more clinical evidence and societal consensus are required to use these cutting-edge tools in infection risk prediction and management tasks (Santangelo et al., 2023). The study by Fatima et al. (2023) proposes a multidisciplinary AI-driven approach to advance precision medicine in infectious diseases, integrating genomics, proteomics, and clinical data to personalize treatment strategies while addressing data privacy and regulatory frameworks. Cheng et al. (2023) explored the rapid adoption of ChatGPT as a tool in infectious disease, emphasizing its potential for clinical practice and research while addressing its societal and ethical implications through an online survey evaluation.

Real-time population infection monitoring will be increasingly driven by data and machine learning in the coming months and years, with the urgent need to track emerging forms of the virus accelerating this transition (Elste et al., 2024). Applying AI and machine learning to environmental data could predict the scope and behavior of emerging infectious diseases months to years before such outbreaks occur (Santangelo et al., 2023). So-called “deep mining” of infectious disease data, combined with the predictive power of AI, opens pathways to preemptive infection prevention (Shausan et al., 2023). Given the resource limitations, if AI rapidly evolves into a credible nosocomial infection prevention tool, it may have the most substantial and demonstrable effect, especially in low- to middle-income settings (Huang et al., 2023). AI is increasingly being explored for its potential to support the management of routine clinical chemistry and microbiology test data, which can be used to develop, validate, and refine machine learning algorithms for diagnosing infections (Kandilci et al., 2024; Sallam, Al-Salahat, et al., 2023). Machine learning is being used to design investigational drugs and vaccines and find existing ones to reposition for tackling the pandemic (Wang et al., 2024). AI-driven systems are currently operational in infectious disease diagnosis and management. However, ethical concerns about patient privacy, data governance, informed consent, and cybersecurity remain critical when deploying AI in infectious disease settings (Isiaka et al., 2024). Healthcare professionals play a major role in fostering patient trust by addressing ethical, privacy, and data security concerns.

4.1 AI-Based Pathogen Detection

AI applications in infectious disease management have recently gained considerable attention (Wong et al., 2023). A key use of AI in infectious disease involves pathogen detection, which aims to identify and subsequently classify pathogens in a clinical sample usually directly isolated from the site of replication (Badidi, 2023; Wang et al., 2024). With increasing demands for bio-surveillance and biosecurity, there has been a steep increase in publications exploring innovative AI methods for pathogen surveillance (Huang et al., 2023; Olaboye et al., 2024; Shausan et al., 2023). Typically, in AI-integrated pathogen detection, some advanced methodologies are applied to ensure higher-dimensional information on the potential threats is collected and subsequently analyzed to ensure high accuracy and that single or multiple pathogen identifications are fast and versatile (Khan et al., 2024). Currently, machine learning models conduct most of the work presented in published research to utilize AI for pathogen surveillance (Keshavamurthy et al., 2022). While many different strategies are used to interpret and present the results to indicate a pathogen detected based on predictive analysis using machine learning, most reports present either image recognition or real-time Polymerase Chain Reaction (PCR) data modeled using a novel type of machine learning techniques (Zhao et al., 2020).

Early pathogen detection remains critical for outbreak containment worldwide (Shausan et al., 2023). Examples include the outbreak of severe acute respiratory coronavirus that was transmitted to humans from animals in China and Ebola in West Africa. AI may support timely pathogen identification and assist in delivering accurate, cost-effective diagnostic tools to enhance public health measures. Moreover, AI in infectious diseases may be utilized to predict outbreaks of emerging and zoonotic infections by facilitating the development of models that forecast future outbreaks, provide insights into new infectious threats (Guo et al., 2023; Isiaka et al., 2024), where accurately forecasting emerging infections is vital for enabling proactive, timely disease prevention strategies with global health and economic implications (Rai et al., 2024; Shausan et al., 2023). However, it may be challenging to act proactively owing to the wide variability in the features determining whether a given pathogen can survive in a new host. Consequently, the translation of animal-to-human and human-to-human pathogens can often be overlooked until the first indications become evident (Rahman et al., 2020).

In parallel to these forecasting applications, developing sensitive, rapid, and portable pathogen diagnostics can improve rather than replace pathology's front line, healthcare services, and clinical pharmacologists in diagnosis and treatment-related activities (Montastruc et al., 2023). However, technical and regulatory challenges are associated with developing and deploying AI-based pathogen diagnostics (Archana & Rohan, 2021; Zhao et al., 2020).

Figure 4 outlines the strengths, weaknesses, opportunities, and threats associated with the application of AI in infectious disease management.

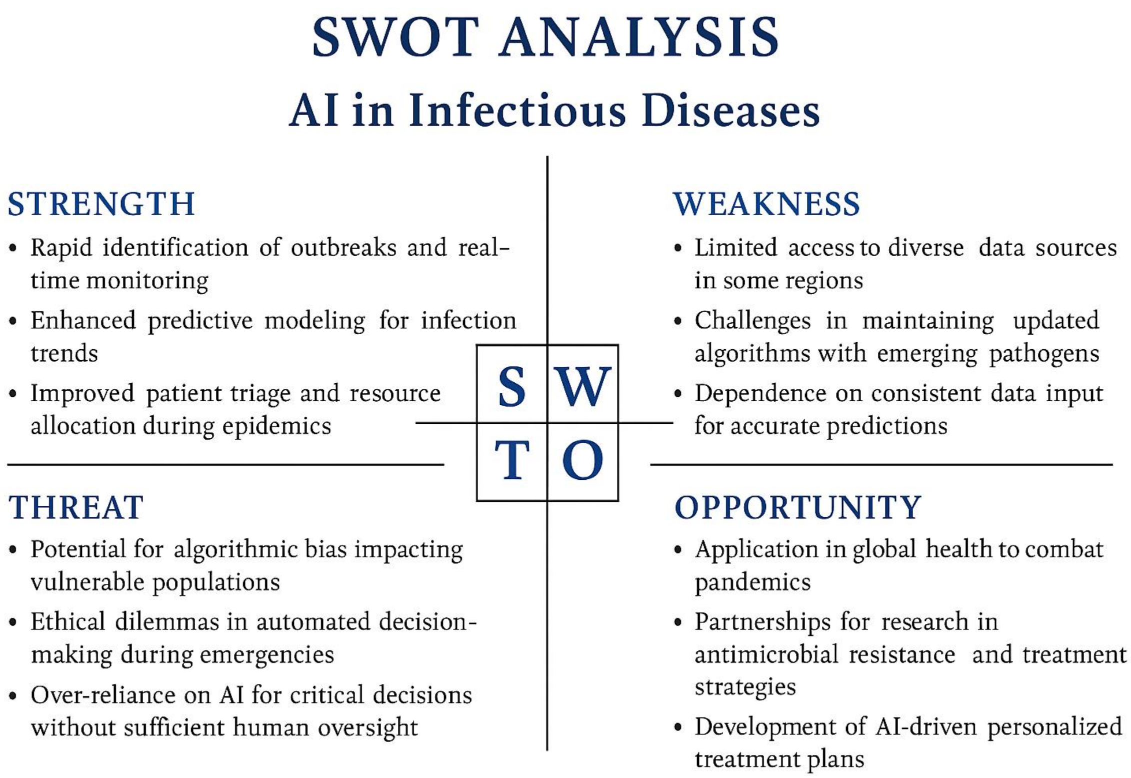

Figure 4. SWOT Analysis of AI in Infectious Diseases

5. AI in Pharmacovigilance

Pharmacovigilance represents a key component of pharmacy practice, encompassing the continuous monitoring and assessment of drug safety through systematic activities such as adverse drug reactions (ADRs) surveillance, risk assessment, post-market monitoring, and interdisciplinary collaboration with healthcare professionals to optimize patient care and prevent medication-related harm (Budha et al., 2024; Chalasani et al., 2023). Over the past sixty years, it has evolved from a voluntary, informal reporting system into a highly regulated and comprehensive framework for detecting, evaluating, and managing medication-related adverse effects (Lavertu et al., 2021). In recent years, implementing automated signal detection methods has accelerated the integration of artificial intelligence into pharmacovigilance processes (Chavhan & Uplenchwar, 2024). AI-driven systems now leverage real-world and big data from heterogeneous sources such as electronic health records and insurance claims databases to detect safety signals using diverse analytical approaches (Chen et al., 2021; Han, 2022).

These tools support associations between ADRs and medications, enable real-time surveillance of ADR trends, and contribute to the early identification of underreported drug-drug interactions (DDIs) (Hauben, 2023; Salas et al., 2022). Advanced mechanistic and data-driven techniques, including machine learning, support the detection of complex safety issues and improve pharmacovigilance workflows (Ahire et al., 2024; Alexander, 2023; Shamim et al., 2024). Several studies have demonstrated increased signal detection efficiency and accuracy with AI integration, although the broader adoption of advanced methods such as deep learning remains infrequent (Ahire et al., 2024; Kompa et al., 2022; Mockute et al., 2019).

To address current methodological limitations, integrated or federated data-sharing strategies have been proposed, enhancing AI-driven pharmacovigilance capabilities (Prasanth et al., 2024). A shared emphasis on structured and standardized quality assurance frameworks has emerged among patient safety experts, industry stakeholders, and regulators (Ahmad & Wasim, 2023; Mockute et al., 2019). Baurasien et al. (2023) further illustrated how AI may reduce medical errors and enhance patient safety by improving diagnostic accuracy, medication management, and real-time monitoring while navigating challenges related to data privacy, algorithm transparency, and system integration. While early implementations are promising, AI remains a developing field that may help address capacity constraints in pharmacovigilance systems across healthcare settings (Amponsah & Pathak, 2022). Kompa et al. (2022) concluded that despite its potential, widespread adoption of sophisticated AI tools in pharmacovigilance still requires further validation and infrastructure development.

Figure 5 provides a SWOT analysis summarizing the strengths, weaknesses, opportunities, and threats associated with implementing AI in pharmacovigilance.

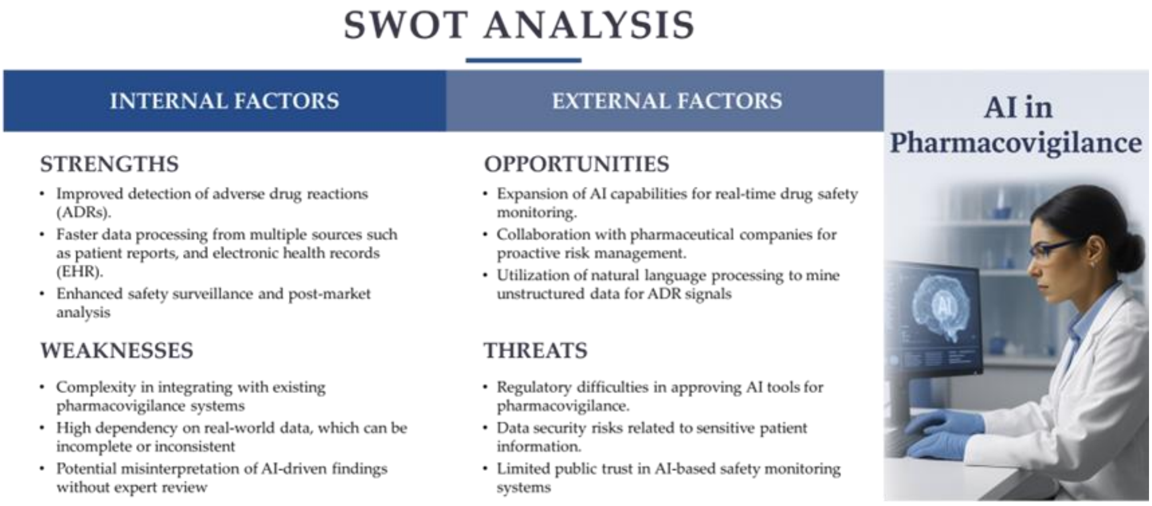

Figure 5. SWOT Analysis of AI in Pharmacovigilance

6. Discussion

6.1 Implications for Practice

The practical implications of artificial intelligence in clinical medicine are increasingly recognized as relevant (Krishnan et al., 2023). Globally, AI may support deeper insights into addressing key challenges, such as advancing disease management through improved diagnosis, treatment, and patient monitoring (Nordlinger et al., 2020). Systematic reviews and current discussions indicate that AI tools like ChatGPT in healthcare are expected to expand in use, with more targeted research appearing across various medical specialties (Bazzari & Bazzari, 2024; Egger et al., 2024). AI has the potential to assist healthcare providers in multiple ways, encompassing patient care and administrative duties (Salomon & Sibomana, 2024; Saxena et al., 2024). Socio-economic and cultural dynamics play a critical role in shaping the integration and acceptance of AI in healthcare, featuring the need for tailored adaptation strategies to ensure successful implementation and patient-centered care (Abubakr et al., 2024). Busnatu et al. (2022) reviewed the growing integration of artificial intelligence in clinical applications, highlighting advancements across various medical specialties while addressing challenges like data limitations and the need for robust methodologies in clinical practice. Aljerian et al. (2022) examined the growing role of artificial intelligence in Saudi Arabia’s healthcare system, highlighting its applications in diagnostics, personalized health planning, and pandemic response, while addressing challenges such as resource limitations and the need for adequate training. Wang (2020) reviewed the application and future potential of artificial intelligence in clinical medicine, highlighting advancements in medical diagnostics, drug development, and medical robotics while emphasizing AI's ability to improve diagnostic accuracy, enhance efficiency, and address healthcare resource shortages. Elhaddad and Hamam (2024) reviewed the integration of artificial intelligence into Clinical Decision Support Systems (CDSS), highlighting its transformative impact on healthcare decision-making, personalized treatment, and efficiency while addressing challenges like usability, bias, and ethical considerations to fully realize AI-CDSS potential.

6.2 SWOT Analysis

The comprehensive SWOT analysis of AI in clinical laboratory medicine, infectious diseases, and pharmacovigilance revealed detailed insights into its application in these areas. Across these domains, strengths included enhanced diagnostic precision, faster data processing, improved predictive modeling, real-time monitoring, and advanced safety surveillance. AI supported more efficient test standardization, rapid outbreak detection, patient triage during epidemics, and better detection of adverse drug reactions (ADRs). Despite these advantages, notable weaknesses existed, such as the need for accurate, labeled data, high initial costs for implementation and training, integration challenges with electronic health records (EHR), and dependence on consistent, high-quality data input. AI algorithms also faced difficulties adapting to emerging pathogens and maintaining up-to-date models, which complicated integration with existing systems. Opportunities included global health applications for pandemic responses, partnerships for antimicrobial resistance research (Giske et al., 2024; Shelke et al., 2023), personalized treatment plan development (El_Jerjawi et al., 2024), and expanding real-time drug safety monitoring (Desai, 2024).

Natural language processing (NLP) also showed substantial promise for analyzing unstructured data. However, threats such as algorithmic bias affecting vulnerable groups, ethical concerns in automated decision-making, reliance on AI without adequate human oversight, regulatory hurdles, data security risks, and limited public trust present significant barriers to safe and effective implementation. Continued research, refinement, and mindful implementation were essential to addressing these issues and maximizing AI's benefits in clinical practice (Egger et al., 2024).

6.3 Challenges and Future Directions

While AI in clinical medicine shows considerable promise, clinical impact, utilization, and the development of policies and regulatory frameworks to support the integration of AI in clinical practice are still in the early stages (Srivastava, 2023). The barriers to their translation into practice remain considerable. Several technical and operational issues require attention before these tools can reliably inform the care of individual patients, especially when applied to complex patients (Schwartz et al., 2023; Stevenson et al., 2023). The AI tools are only as accurate as the data used to train them (Choudhury et al., 2024). Natural language processing tools may require the expertise of a large community of researchers in computer science, linguistic science, and subject-matter experts to develop tools capable of dealing with the breadth and depth of the language used to report studies. New machine-learning tools need to be developed to generate data to help assess the variability in medical devices. Other limitations to AI tools may be difficulty integrating them across electronic health record platforms. Training and education about AI across all levels of healthcare workers are needed to create a workforce for the future for quality improvement and healthcare transformation (Sorte et al., 2024). Resistance to change and hesitancy remain notable barriers in adopting new health system technologies and must be addressed (Goldman & Patel, 2024). Incorporating clinical practice guidelines (CPGs) into large language models (LLMs) to enhance clinical decision support (CDS) through the use of collective knowledge is important to identify safety signals at an early stage (Oniani et al., 2024). Another relevant consideration is a potential algorithmic bias possibly leading to a chain reaction amplifying the effect when the algorithms are used to inform decisions, in this case, care, and a multitude of research, clinical practice, and policy questions. The development of AI that can learn continuously is an exciting scenario that challenges policy, regulators, and businesses to adapt, align interests, and engage in robust cooperation. Some studies in many clinical health domains provide a rationale for use in symptom tracking, response predictions, and treatment planning (Khalifa & Albadawy, 2024). The application of AI in clinical medicine holds great promise, but the translation into clinical practice and research poses a panoply of challenges (Sharma et al., 2022). Continuous research, ethical policy development, collaboration, sponsorship, and engagement across diverse disciplines are encouraged (Huo et al., 2023; Mashabab et al., 2024). Also, it is crucial to adopt standardized practices in the reporting, implementation, and testing of the quality of health information generated by AI-based models in clinical medicine (Sallam, Barakat, et al., 2023), reinforcing the importance of reliable methodologies and consistent reporting (Sallam et al., 2024b).

6.4 Ethical Considerations in AI Implementation

Protecting patient privacy is a primary consideration when implementing AI in clinical medicine (World Health Organization, 2021), especially in laboratory medicine, where large data sets are increasingly used for diagnostic and prognostic purposes. Such information can provide substantial insight into community health, but often without the oversight of the clinician. In implementing AI for patient data sharing, care must be taken to secure the shared data. A second consideration is perpetuating bias, in that if an AI system predicts a healthcare outcome in a biased manner, this behavior is technically accurate but unethical. Azimi and Zaydman (2023) emphasized the importance of fairness in machine learning (ML) algorithms in laboratory medicine, addressing how biases can arise during model development and emphasizing strategies to promote equity in healthcare outcomes. Habib and Gross (2023) highlighted significant gaps in the regulatory framework for AI and ML-based clinical decision support devices, noting insufficient evidence for safety, performance bias, and effectiveness, as most FDA-authorized devices rely on older, non-AI-specific predicates. An AI system should demonstrate accuracy and transparency; however, conveying the inner workings of machine learning algorithms to human experts, particularly those trained on clinical data, remains a significant challenge. Continuing, the implementation of AI in a healthcare setting must also be a transparent system to help facilitate trust in the AI system between both the practitioner team and the patient. Additionally, with healthcare professionals increasingly treating patients from various cultural backgrounds, the rise of AI in clinical medicine highlights the importance of culturally sensitive and compassionate care (Alberto et al., 2024).

Computational technologies present a broad spectrum of opportunities in the health sector, with the potential to support more equitable and efficient resource allocation. However, to achieve these benefits, it is essential to critically evaluate the potential and limitations of technological solutions and the ethical and normative considerations currently understudied (Fatima et al., 2024; Marshall Raj et al., 2024). With harmonized and coordinated global governance, we can observe policies and regulations that focus specifically on the data, technological formulation, research techniques, and ethics for responsible application and use in a real-world setting (Marques et al., 2024). Health leaders globally are encouraged to prioritize strategies such as enhancing data quality, infrastructure, and privacy safeguards to facilitate the responsible integration of AI in healthcare (Silcox et al., 2024).

7. Conclusion

Introducing artificial intelligence into clinical medicine has the potential to improve the accuracy of diagnoses, treatment planning, and patient safety across various medical disciplines. This study examined AI's reported applications and implications in three key domains of clinical medicine, including clinical laboratory medicine, infectious disease management, and pharmacovigilance. According to the literature reviewed, the SWOT analysis suggested that AI tools in these domains may contribute to faster and more precise diagnostic workflows, support more efficient clinical processes, and enable improved utilization of resources, with possible implications for enhancing patient care. Nevertheless, concerns remain regarding data privacy, algorithmic bias, transparency, and the ongoing need for human oversight.

Realizing AI's full potential in clinical practice depends on ethical implementation, sustained research, and robust regulatory frameworks. Addressing these challenges is essential to support responsible adoption and preserve patient trust and safety. Future efforts should emphasize multidisciplinary collaboration among policymakers, clinicians, technologists, and patients to enable balanced and evidence-informed integration of AI in healthcare.

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Authors Contribution

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Conflicts of Interest

The authors declare no conflicts of interest.

Institutional Review Board

Not required.

Declaration of Artificial Intelligence Use

This study utilized AI tools to enhance manuscript writing, grammar, graphics, and readability. AI-assisted in summarizing findings and technical writing, offering structures for complex descriptions.

All ideas, interpretations, and ultimate conclusions presented in this article are solely those of the authors.

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Abbreviations

AI: Artificial Intelligence

ML: Machine Learning

NLP: Natural Language Processing

LLMs: Large Language Models

ChatGPT: A Chatbot Based on Generative Pre-Trained Transformer Large Language Model

ANN: Artificial Neural Networks

DL: Deep Learning

EHR: Electronic Health Record

US FDA: United States Food and Drug Administration

ADRs: Adverse Drug Reactions

DDIs: Drug-Drug Interactions

SWOT: Strengths, Weaknesses, Opportunities, And Threats

CDS: Clinical Decision Support

CDSS: Clinical Decision Support Systems

CPGs: Clinical Practice Guidelines

AMR: Antimicrobial Resistance

PCR: Polymerase Chain Reaction

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