REVIEW ARTICLE

Artificial Intelligence in Medicine: Transforming The Future of Healthcare

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SUMMARY

The rate of development in artificial intelligence (AI) technologies has brought revolutionary transformations across the healthcare sector. The advancements especially impacted the manner in which the diagnosis, treatment, and management of diseases are undertaken with a growing emphasis laid on optimizing clinical workflow and patient care. Machine learning (ML) and deep learning (DL) technologies have proved invaluable for the analysis of complex datasets, supporting early diagnosis and optimizing treatment protocols. AI showcased tremendous promise in a plethora of applications, such as the accurate analysis of medical imagery, the personalization of therapies through the tailor-made dosing of medicines, predictive analysis in forecasting the course of the disease, and the assistance of patients and clinicians by deploying virtual health tools. Moreover, the increasing application of AI in healthcare has also boosted access to quality healthcare, particularly in underserved populations. The following review also explores the ethical, legislative, and regulatory issues related to the application of AI in medicine, reiterating the need for protection of the data, transparency, and equitable access. With careful implementation that respects these boundaries, AI holds the potential to significantly enhance global healthcare delivery. Despite these benefits, integrating AI into healthcare systems raises important ethical, legal, and regulatory concerns. Ensuring data privacy, promoting algorithm transparency, and maintaining fairness in AI-driven healthcare solutions are key concerns. Addressing these challenges is vital to building trust and ensuring that AI technologies benefit all populations fairly. With responsible and ethical implementation, AI holds immense potential to transform global healthcare delivery and improve patient outcomes on a large scale.

Keywords: *Diagnostic Imaging, Natural Language Processing, Radioomics, Telemedicine.*

How to cite this: *Jan TA, Naz S. Artificial Intelligence in Medicine: Transforming The Future of Healthcare. Life and Science. 2025; 6(2): 284-291. doi: http://doi.org/10.37185/LnS.1.1.904*

Machines can now perform actions that involve a degree of human use of language through Natural Language Processing (NLP). It has evolved as a kind of communication form that humans made voluntarily, allowing computer programs to understand and respond to people in real time.[1] The machines can also understand by open learning from their past data and processing that information analytically to apply this understanding in the execution of a large number of business-related activities.[2] Healthcare generally starts with a tremendous amount of information, which is then processed with sophisticated algorithms to find hidden insights.[3]The insights are used in an attempt to design practical solutions that will address a specific problem in the healthcare industry.[4.] The general workflow of an AI healthcare system can be outlined as follows:

- Types of information collected include medical records, their histories, diagnostic images, and other health information. The data preparation involves cleaning, organizing, and standardizing collected data to ensure quality and consistency.
- Extract relevant features or patterns from data. This stage is critical for identifying key information in the dataset.

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Received: Sep 20, 2024; Revised: Jan 18, 2025
Accepted: Jan 25, 2025

- Machine learning algorithms process preprocessed data to recognize patterns, correlations, and trends. Various methods like supervised learning, unsupervised learning, and deep learning can be utilized by such algorithms.
- Machine learning models use past data to recognize patterns and make predictions and judgments.
- Trained models can draw inferences and make predictions based on new data. This may contain diagnostic forecasts, risk evaluations, or therapy recommendations.
- AI outputs are embedded into healthcare systems so that practitioners can use it as guidance in their well-informed choices. Such choices can relate to treatment plans and diagnostic tools.
- AI systems continuously learn and adapt to new data, improving performance and accuracy over time.
- The AI solution undergoes thorough validation and clinical testing to assure accuracy, safety, and effectiveness in real-world scenarios.
- Regularly monitoring and maintaining the AI system is crucial to ensure optimal performance and compliance with medical requirements.
- Healthcare professionals and system performance are used to improve AI algorithms and applications, resulting in a continual cycle of improvement.

The primary objective of this review is to provide a comprehensive analysis of how AI is transforming the healthcare landscape. It aims to trace the historical development of AI technologies and examine their current application in both communicable and non-communicable disease management. It also highlights the utility of AI tools in diagnostics, treatment planning, surgical support, medical imaging, mental health, and public health policy. The review investigates the integration of advanced methodologies in clinical decision-making.

Methods

The review employed a systematic approach to identify, select, and synthesize relevant literature speaking about applications and challenges of Artificial Intelligence (AI) in healthcare, and a thorough literature search was executed by accessing PubMed, Scopus, Web of Science, and Google Scholar. The search was limited to articles published between 2000 and 2024 when combined with keywords: using "AI in healthcare", "machine learning in medicine", "AI diagnostics", "AI medical imaging", "predictive analytics in healthcare". Studies were included if they were peer-reviewed, published in English, and discussed the use of AI technologies in healthcare applications such as diagnostics, treatment planning, public health, and ethics. Articles focusing on theoretical or algorithmic development without a clear healthcare application were excluded.

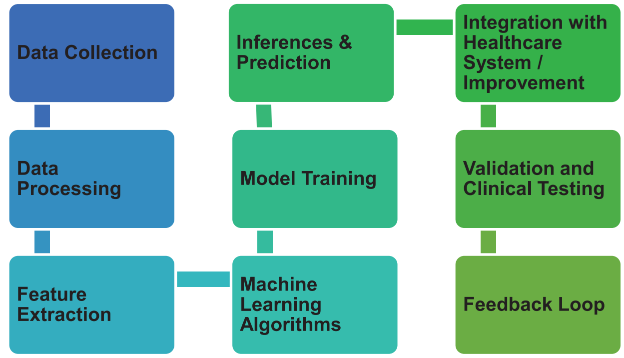

Fig.1: Flow of Pattern of Working of AI in Healthcare

Initial screening was performed based on titles and abstracts. Full texts were reviewed for relevance and quality, and the final selection included studies offering substantial insights into the practical application, effectiveness, and challenges of AI in healthcare. Priority was given to systematic reviews, meta-analyses, and high-impact original research articles. This procedure assures that the review is broad, equitable, and deliberate of the ongoing case of AI application in the healthcare sector.

Historical View of Use of AI in the Medical Field

The term 'AI' was coined for the first time in 1956 during the Dartmouth Conference, when American computer scientist John McCarthy and colleagues met for the purpose of the Dartmouth Summer Research Project on Artificial Intelligence, which initiated the direction of this research. Before then, Dietrich Prinz had developed a chess-playing program as part of his AI research. Reflecting, the timeline of AI in the medical field stretches for decades, with critical milestones and achievements illustrated as follows:

1950s–1960s: First-generation concepts for artificial intelligence in medicine

During this period, there was an increasing interest in embracing computational methodologies for the resolution of medical problems through the application of AI to healthcare. There was a major breakthrough in the 1960s with the creation of Dendral, which was one of the AI programs used for decision support and problem-solving for organic chemistry.[5]

1970s-1980s: Development of an Expert System

Stanford University's development of MYCIN in 1976 was a breakthrough. MYCIN, as it is not an abbreviation, was programmed to recognize bacterial diseases and suggest appropriate antibiotic treatments for treating human patients, proving the early capabilities of AI in the medical domain. 1982 saw the creation of INTERNIST-I, which was a groundbreaking demonstration of AI's capability for evaluating complex medical issues, marking its significance in handling intricate medical situations.[6]

1990s-2000s: Data Mining and Imaging Advances

In the 1990s and 2000s, there was a turning point with the integration of algorithms used in medical image handling, like radiology and pathology. It was a landmark achievement in the application of artificial intelligence for medical interpretation and diagnosis based on images. The internet facilitated the exchange of medical information and collaborative research in the health industry during this period. Online connectivity offers new possibilities for the exchange of medical intelligence and collaborative enterprises among experts.[7]

2010s: Deep machine learning Development in Healthcare

The decade of 2010 saw a huge shift in healthcare as machine learning advanced, producing astonishing results. Interestingly, Convolutional Neural Networks (CNNs) excelled in photograph identification tests and revolutionized the analysis of medical images. IBM Watson, a computer query system that was named after IBM's founder Thomas J. Watson, proved to be effective in handling large volumes of medical material and providing valuable inputs towards clinical decision-making. The most remarkable leap, however, was the arrival of Natural Language Processing (NLP) applications, which allowed AI to read and analyze clinical material, thereby enhancing its capability to derive meaningful information from medical records and texts.[8]

2020s: Integrating and Advancing in Personalized Medicine

During the 2020s, healthcare experienced a strong trend towards the incorporation of AI in most aspects of healthcare, ranging from diagnostics to the development of drugs and tailored treatments. AI has facilitated the detection of the conditions and the construction of therapies attuned to the specific genetic makeup of an individual. More specifically, AI-based genomics has made waves by revealing complex patterns in the genetic material, which allows clinicians to design very personalized treatment plans.[9] This is a vast leap towards precision medication and a step towards tailoring the therapeutic interventions to the specific molecular characteristics of each patient.

Future: Ongoing Progress in Healthcare AI

The future of early disease detection through AI-driven devices is bright. The technologies will become increasingly effective at detecting subtle signals and patterns in medical information, enabling faster detection of diseases and, down the line, enhanced patient outcomes. AI is more likely to assist in the advancement of precision medicine by tailoring the medicines according to the needs of individual patients. The amalgamation of genomes with patient histories and real-time streamed data are expected to bring much more focused and customized medicinal approaches. Cooperation between healthcare professionals and AI scientists will greatly increase in frequency and intensity, resulting in the development and deployment of AI solutions for healthcare. This will further improve patient care, produce new tools, and further improve medical AI technology [10]

AI in the Medical Field

Infectious/Communicable Diseases

Artificial intelligence is now an essential tool for controlling infectious diseases with unprecedented speed, accuracy, and flexibility. From detection and early-stage diagnosis, policy planning, to outbreak response, AI has been very effective.[11] Algorithms, for instance, interpret radiological scans, chest X-rays, and CT scans to identify hints for infections such as tuberculosis. With the power of AI, genomic sequencing technologies quickly identify pathogens as well as their variants, which are essential for containment and outbreak surveillance in real-time.[12] AI-enhanced digital interfaces and chatbots serve as first-line screeners, asking symptom-based questions and assessing threats based on travel history and exposure [13]

In the lab, AI-driven automation maximizes throughput by automating sample handling and result analysis, decreasing turnaround time and error. Further, machine learning algorithms can also predict antimicrobial resistance pathways by comprehending microbial genomes, supporting the creation of targeted treatments.[14] AI also supports epidemiological modeling to simulate disease spread and forecast the impact of public health interventions, providing data-driven insights for policymakers. Remote monitoring systems, often integrated with wearable devices, track patient vitals and symptoms, particularly in isolated or underserved communities. [15-16] These advancements demonstrate the breadth and depth of AI's role in responding to infectious disease threats. This aids in the identification of atypical presentations and enhances diagnostic accuracy.[17] AI algorithms can predict antimicrobial resistance patterns by analyzing the genetic makeup of pathogens. This information helps in tailoring treatment plans and prescribing effective medications [18]

AI contributes to the development of epidemiological models that simulate the spread of infectious diseases within populations. These models assist public health officials in planning and implementing effective control measures.[19] AI-enabled remote monitoring tools track individuals with infectious diseases, providing real-time data on symptoms and vital signs. Telemedicine platforms leverage AI for initial assessments and follow-up consultations, reducing the need for in-person visits.[19] AI is integrated into point-of-care diagnostic devices, allowing for rapid and accurate on-site testing for infectious diseases. These devices are particularly valuable in resource-limited settings.[17] Personalized treatment plans generated by AI, considering the patient's history and the specifics of the disease strain. Optimization of resource allocation in hospitals using AI to manage patient flow during outbreaks.[9] AI enhances contact tracing efforts by automating the identification of potential exposure and transmission chains. Integration with mobile technology to track and alert individuals about their exposure to communicable diseases.[20] AI accelerates the discovery of antiviral drugs and vaccines by simulating molecular interactions at a scale not feasible for human researchers. AI-assisted analysis of clinical trial data to identify effective treatments faster.[21]

AI models assist policymakers in evaluating the potential impact of public health interventions. Scenario analysis and simulation to inform decisions regarding lockdowns, social distancing measures, and vaccination campaigns.[22] Tailored public health campaigns were created using AI to maximize engagement and information retention. Combatting misinformation through AI-powered verification of health information spread online.[23] AI-driven chatbots provide first-line support for healthcare inquiries, reducing the burden on human healthcare workers. Enhanced training for healthcare workers using AI simulations to prepare for communicable disease scenarios [10]

Non-communicable/Non-Infectious Diseases

The role of AI in non-infectious/non-communicable diseases spans the entire spectrum of disease management. AI algorithms analyze medical images, including X-rays, CT scans, MRIs, and pathology slides, for the detection and characterization of non-infectious diseases such as cancer, cardiovascular diseases, and neurological disorders. Deep learning models can identify subtle abnormalities and aid in early diagnosis.[24] AI assists pathologists in analyzing tissue samples and identifying patterns associated with cancer and other diseases. Automated histopathological image analysis improves the efficiency and accuracy of diagnosis.[8] AI is used to analyze electrocardiograms (ECGs), echocardiograms, and other cardiac imaging data to detect signs of cardiovascular diseases. Predictive models assess the risk of heart-related conditions based on patient data.[25] AI algorithms analyze continuous glucose monitoring data, insulin dosages, and lifestyle factors to optimize diabetes management. Predictive models help forecast blood glucose levels and adjust treatment plans.[26] AI aids in the diagnosis of neurological conditions such as Alzheimer's disease, Parkinson's disease, and multiple sclerosis. Brain imaging analysis and predictive models contribute to early detection and personalized treatment plans.[27] AI applications analyze skin images to assist dermatologists in diagnosing skin conditions, including melanoma and other dermatological diseases.[28] AI algorithms analyze pulmonary function tests, lung imaging, and other respiratory data to diagnose conditions like asthma, chronic obstructive pulmonary disease (COPD), and interstitial lung diseases.[29] AI aids in the analysis of endoscopic images for the detection of gastrointestinal conditions, including colorectal cancer and inflammatory bowel diseases. Computer-aided detection enhances the accuracy of lesion identification.[30]

AI analyzes genomic data to identify genetic markers associated with non-infectious diseases. Precision medicine uses AI to tailor treatments based on individual genetic profiles. AI applications contribute to the ongoing management of chronic diseases, including hypertension, diabetes, and chronic kidney disease. Remote monitoring, predictive analytics, and personalized treatment plans improve patient outcomes.

Radiomics and Radio-genomics

Radiomics and radio-genomics are two distinct but interrelated fields in healthcare that leverage AI and data analysis to gain valuable insights from medical images and genetic data. They play a vital role in advancing personalized cancer treatment strategies.

Radiomics

Radiomics is a methodology that involves extracting a large number of quantitative features from medical images, such as CT scans, MRIs, and PET scans, using data-characterization algorithms. These qualities go beyond what the human eye can see, including subtleties such as image shape, texture, and intensity patterns. Radiomics is valuable because it can provide detailed insights into tumour biology, heterogeneity, and the microenvironment. By analysing these radiomic traits, healthcare providers can better comprehend tumour characteristics, predict therapy response, and assess prognosis.[31]

Radio-genomics: The term radio-genomics is used in two contexts:

Radiation Genomics: In this context, radio-genomics refers to the study of genetic variation associated with the response to radiation therapy.

Imaging Genomics: Here, radio-genomics relates to the correlation between cancer imaging features and gene expression data.

Both radiomics and radio-genomics offer substantial promise in cancer diagnosis, prognosis, and treatment planning. They enable healthcare providers to make more informed decisions, tailor treatments to individual patients, and monitor treatment responses over time.[32]

Mental Health Diagnosis

AI is indeed employed in the analysis of behavioral data, speech patterns, and various digital biomarkers to support the diagnosis and management of mental health conditions. AI's contribution to mental health diagnosis and management is transformative, offering the potential for early intervention, personalized care, and improved access to mental health support. It complements the efforts of mental health professionals and helps bridge gaps in mental healthcare.[33]

The recent revolutionary role of AI

The most recent application of AI in global healthcare has been the prediction of emerging COVID-19 hotspots through the use of contact tracing and flight traveler data. Contact tracing is a vital disease control measure that instructs patients to quarantine or take preventive measures to curb further transmission. BlueDot, a Canadian company, played a pioneering role in this domain by publishing the first scientific paper on COVID-19 that accurately predicted the global spread of the virus. Through advanced AI and data analytics, BlueDot analyzed vast datasets, including traveler information and epidemiological data, to forecast potential outbreak locations. Their early warning system proved invaluable in assisting public health officials and policymakers in making informed decisions to mitigate the spread of the virus (https://bluedot.global/).[34]

Future of AI in healthcare

The future of AI in healthcare is indeed exciting and holds the promise of transformative changes in the industry. The future of healthcare will be marked by improved patient outcomes, enhanced efficiency, and a more patient-centric approach to medical care. As AI-powered applications continue to advance, we can anticipate several key shifts. AI will enable a fundamental change in healthcare, moving from reactive treatment of diseases to proactive care that emphasizes preventive measures and early intervention. By analyzing patient data and risk factors, AI can help identify potential health issues before they become critical, leading to better health outcomes.[35] AI will transform healthcare by offering personalized care based on each patient's specific needs. Treatment strategies, pharmaceutical regimes, and lifestyle suggestions will be tailored to a person's genetic composition, medical history, and real-time health data.[36] AI will improve how healthcare providers connect with patients. Virtual health assistants, chatbots, and telemedicine software will make it easier for patients and healthcare practitioners to communicate in real time, continuously, and with data. This improves patient involvement and encourages people to have a more active part in their treatment.[37]

AI-powered automation and decision support systems will reduce administrative procedures, lowering paperwork and administrative loads on healthcare personnel. As a result, the healthcare system will become more efficient, perhaps cutting operational costs and improving resource allocation.[38] AI will continue to revolutionize medication discovery, speeding up the creation of novel drugs and treatment options. Machine learning algorithms can analyze large datasets to forecast possible medication candidates and assess their safety and efficacy faster.[21] AI-powered analysis of medical images will deliver more accurate and timely diagnostics, allowing for illness diagnosis earlier. This will result in better patient outcomes and may reduce the need for intrusive procedures.[24] AI will enable data-driven public health efforts, helping governments and healthcare agencies respond more effectively to outbreaks, pandemics, and rising health emergencies.[23] Remote monitoring of patients' health via AI-enabled wearable gadgets and healthcare platforms will become more common. This will enhance access to healthcare services, particularly in impoverished communities.

Limitations and Challenges

Despite the potential, the implementation of AI in healthcare is accompanied by several notable limitations and challenges. Data privacy is a foremost concern, as the integration of AI relies on large-scale patient data, raising risks of breaches and unauthorized access to sensitive health information. It is important to safeguard patient confidentiality.[39] Algorithm bias is another important issue, as the AI system trained on non-representative datasets may continue existing healthcare gaps, particularly for marginalized populations.[40] Additionally, the high cost of AI development, deployment, and maintenance poses financial barriers, especially in low- and middle-income countries. These cost-related challenges hinder equitable access to AI technologies across diverse healthcare settings. Clinical integration remains a persistent hurdle as well; incorporating AI into existing workflows requires not only technological interoperability but also acceptance and adaptation by healthcare professionals.[41] The challenges underscore the importance of a multidisciplinary, ethical, and inclusive approach of AI development and implementation in healthcare.

Conclusion

Artificial intelligence is reshaping disease detection and medical decision-making by offering enhanced accuracy, early intervention capabilities, and the ability to personalize treatment strategies. Its applications range from diagnostics and treatment optimization to broader areas like public health management and strategic policy formulation. Especially in infectious disease management, AI facilitates quicker, more accurate interventions that can stop the outbreak and optimize the delivery of health services.

Nonetheless, for all these encouraging developments, there is a continuing need to handle AI incorporation responsibly. Ethical imperatives like data privacy, algorithms transparency, and access for all must be dealt with through robust regulatory mechanisms. Simultaneously, interdisciplinary convergence is equally vital to ensure that the AI systems are designed and used to prioritize patient well-being, protection, and rights. With appropriate regulation and further development, AI can be used to dramatically raise the level of healthcare throughout the world.

Acknowledgement: None

Conflict of Interest: The authors declare no conflict of interest

Grant Support and Financial Disclosure: None

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Author Contributions

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SN: Conception and design of the work, data acquisition, curation, and statistical analysis, revising, editing, and supervising for intellectual content