Review Article

Transforming Healthcare with Artificial Intelligence (AI)

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International Archives of Integrated Medicine, Vol. 10, Issue 11, November, 2023.
Available online at http://iaimjournal.com/
ISSN: 2394-0026 (P) **ISSN: 2394-0034 (O)**
Received on: 05-10-2023 **Accepted on:** 16-10-2023
Source of support: Nil **Conflict of interest:** None declared.

How to cite this article: Tahreem Riaz, Muhammad Akram, Umme Laila, Muhammad Talha Khalil, Rida Zainab, Momina Iftikhar, Fethi Ahmet Ozdemir, Gaweł Sołowski, Ebrahim Alinia-Ahandani, Marcos Altable, Chukwuebuka Egbuna, Adonis Sfera, Muhammad Adnan, Pragnesh Parmar. Transforming Healthcare with Artificial Intelligence (AI). IAIM, 2023; 10(11): 41-50.

Abstract

Healthcare delivery, management, and optimization have undergone a radical change as a result of the introduction of artificial intelligence (AI) into the sector. This review article examines the diverse effects of AI in healthcare, encompassing a wide range of applications from administrative and

operational improvements to support for diagnostic and therapeutic procedures. The analysis goes into the most recent developments in AI technologies, including computer vision, natural language processing, and machine learning, and how they might change the face of healthcare. We also discuss the ethical and legal issues raised by the expansion of AI in healthcare and provide predictions for the future. The enormous potential for AI to revolutionize healthcare is highlighted in this review, but it also stresses the need for responsible and ethical deployment to guarantee the greatest results for patients and healthcare systems.

Key words

Artificial intelligence, Healthcare transformation, Digital health, Precision diagnosis, Precision therapeutics, Challenges.

Introduction

The 'quadruple objective' for healthcare - improving population health, patient experience of treatment, carer experience, and lowering the steadily rising cost of care - presents considerable problems for healthcare systems worldwide [1-3]. Governments, payers, regulators, and providers are being pushed to innovate and transform healthcare delivery models as a result of ageing populations, an increase in the burden of chronic diseases, and rising healthcare expenditures worldwide. Additionally, in the wake of the worldwide pandemic, healthcare systems are faced with the issue of "performing" (providing efficient, high-quality care) and "transforming" care at scale by integrating data-driven insights from real-world scenarios into patient care. Inequities in access to care and shortages of healthcare workers, previously identified by The King's Fund and the World Health Organization, have also been brought to light by the pandemic [4-5].

With its complicated web of data, patient records, and complex decision-making, the healthcare sector is poised for a revolutionary change driven by artificial intelligence (AI). Various applications of artificial intelligence (AI) have crept into the healthcare industry over the past few years, promising to transform how treatment is provided, overseen, and optimized. This review article looks into the complex topic of "Transforming Healthcare with Artificial Intelligence (AI)," providing a thorough investigation of the multifarious impact and possibilities of AI in this vital industry.

AI has become a versatile tool that supports early and accurate disease diagnosis, improves treatment planning, and streamlines administrative chores for healthcare practitioners and organizations. Its data analysis, predictive modeling, and automation skills have the potential to not only enhance patient care but also increase the general effectiveness of healthcare systems. The most recent developments in AI technologies, including machine learning, natural language processing, and computer vision, as well as their applications in healthcare, will be covered in this overview. We will also address the moral questions and legal difficulties raised by this revolutionary journey, ensuring that the quick development of AI is in line with the interests of patients and healthcare professionals.

A new era of precise, personalized, and easily accessible healthcare may be brought about by the integration of AI in healthcare. The complicated landscape of healthcare must be negotiated with caution, understanding, and a persistent commitment to ethics and laws if AI is to realize its full promise. In order to offer a comprehensive understanding of how AI is influencing the future of healthcare, this essay tries to offer insights into the benefits and drawbacks of this revolutionary endeavor.

Artificial intelligence

The science and engineering of building intelligent computers that replicate human cognitive processes, like learning and problem-solving, is referred to as AI in the context of the review article [6]. AI systems are dynamic, autonomous, and capable of learning from experience and adjusting as additional data become available because they function intentionally, intelligently, and adaptively [7]. The strength of artificial intelligence lies in its capacity to recognize patterns and relationships in vast multidimensional and multimodal datasets. For instance, AI systems might synthesize the entirety of a patient's medical history into a single number that would likely reflect a diagnosis [8, 9]. Additionally, AI systems are flexible and autonomous, learning from experience and modifying when new facts become available [10].

The review article emphasizes the importance of AI systems in the healthcare industry since they can foresee issues, provide solutions, and improve the standard of care in general. Machine learning (ML) and deep learning (DL), two subfields of AI, are used to give applications intelligence. With the help of these subfields, AI systems can handle and analyze massive, multidimensional datasets, allowing them to spot patterns, links, and even produce insights like converting a patient's medical history into a likely diagnosis.

Unsupervised learning, reinforcement learning (RL), and supervised learning are highlighted within the subfields. Unsupervised learning seeks to extract information from unlabelled data, enabling the categorization of patients with similar symptoms in order to discover common causes [11]. Supervised learning employs labeled data for applications like medical picture analysis. AI agents can learn by trial and error or expert demonstration with the help of RL, which is becoming more and more significant. Ultimately, they can create ways to maximize rewards [12]. Deep learning, a branch of AI, has accelerated development in fields like speech and image recognition. It has become a popular approach in current AI research and applications because of its capacity to process and learn from huge collections of samples through layered neural networks [13, 14]. This background information prepares the reader for the review article's exploration of AI's potential to revolutionize healthcare, as well as its applications and related ethical and legal issues.

Role of Artificial Intelligence (AI) in healthcare

Artificial intelligence (AI) has a wide range of applications in the healthcare industry and is revolutionizing a number of fields of medical practice and study. The following list highlights important fields where AI is having a significant impact.

Medical imaging, disease detection, and diagnosis

The use of artificial intelligence (AI) in the diagnostic process is proven to be extremely beneficial for the medical community and patients' general wellbeing [15]. The main goal of illness diagnosis is to determine a person's status with respect to a certain condition [16]. Traditionally, this procedure starts with the gathering of a thorough medical history and a physical examination.

AI has recently improved healthcare by providing creative methods for identifying and diagnosing diseases. For instance, AI can identify illnesses like COVID-19 by analyzing various respiratory sounds, such as coughing, breathing, and voice patterns [17]. AI algorithms are also useful for deciphering a variety of medical scans and pathology images. AI makes it possible to determine vital characteristics in the field of medical imaging, such as the ejection fraction from echocardiograms [18], the detection and volumetric quantification of lung nodules from radiographs [19], and the quantification of breast densities via mammography [20]. Furthermore, FDA-cleared systems for whole-slide imaging (WSI) have

been developed as a result of AI-driven imaging applications in pathology. There are many benefits to using these technologies in laboratories as opposed to conventional light microscopy.

These developments not only improve the precision and speed of diagnosis but also hold the promise of revolutionizing patient care by giving medical practitioners the tools they need to make wise choices. AI has the potential to become increasingly important in disease diagnosis and management as it develops, which will eventually enhance patient wellbeing and healthcare results.

Treatment Planning and Personalized Medicine

AI is able to predict and create individualized treatment plans thanks to its ability to process massive amounts of data and recognize complex patterns. As a branch of medical science, personalized medicine uses artificial intelligence (AI) and data-driven insights to provide patients with specialized therapy. The CURATE.AI platform is one exemplary illustration of AI's potential in personalized medicine. Based entirely on personal information, this platform with AI-derived capabilities builds a distinctive profile for each individual. The platform plots the association between phenotypic outcomes (output) and intervention intensity (input-drug) for that particular person. By allowing for the prediction of outcomes for specific inputs and advising the most suitable intervention intensity to produce the greatest result, these mapping acts as a personalized guidance.AI-driven personalized medicine essentially seeks to optimize treatment regimens by customizing them to the distinctive traits and reactions of each patient. This could improve patient outcomes overall, reduce negative side effects, and increase therapeutic effectiveness. AI tools are projected to play a bigger part in personalizing medical interventions as they develop, which will ultimately lead to more effective and patient-centered healthcare [21-22].

Drug Discovery and Development

The integration of AI into the pharmaceutical sector has resulted in a paradigm shift in drug discovery and development, providing important advantages including decreased human workload and quicker goal completion [23].

The effects of AI on drug discovery are noteworthy in a number of ways. The early stages of drug development are considerably accelerated by its capacity to find potential hit and lead compounds. The quick validation of drug targets is also made possible by AI, guaranteeing that promising candidates are thoroughly examined. Additionally, it is essential for optimizing drug structure designs, which increases the effectiveness and efficiency of the drug development process [24, 25]. Insilico Medicine serves as a prime example of AI's accomplishment in this field. The phase 1 safety and pharmacokinetics trial of the AI-assisted molecule INS018_055, which had positive results, was reported by the company in January 2023. Idiopathic pulmonary fibrosis is a debilitating disease that progresses over time and is characterized by lung scarring. This chemical is intended to cure this condition [26].

AI's use in drug research and development speeds up the process and has the potential to discover new medication candidates that might not have been discovered otherwise. AI-driven approaches are poised to revolutionize pharmaceutical research as they grow further, possibly accelerating the creation of strong medicines for a variety of illnesses.

Predictive Analytics and Risk Assessment

In predictive analytics and risk assessment, AI plays a crucial role in assessing a person's propensity to develop particular diseases, which is crucial for early intervention and individualized healthcare. In this approach, risk factors such genetic predispositions, environmental exposures, and lifestyle selections are evaluated. Clinical genomic analysis has used AI approaches at several phases, including

variant calling, genome annotation, variant categorization, and phenotype-genotype association. These AI-driven methods could be expanded to include genotype-to-phenotype predictions, allowing for a more thorough understanding of a person's health profile [27].

In one famous case, Ramazzotti and colleagues used AI to accurately forecast the prognosis for 27 out of 36 different cancer types. To do this, they examined a variety of biological data, including RNA expression, point mutations, DNA methylation, and omics data on copy number variation. The Cancer Genome Atlas (TCGA), a comprehensive database of genetic data pertaining to cancer, served as the source of the information used in this investigation [28].

Predictive analytics and risk assessment powered by artificial intelligence present a viable path to early disease identification, risk reduction, and individualized therapy. The potential of AI in this field holds the possibility of more individualized and precise healthcare interventions, ultimately enhancing patient outcomes and wellbeing.

Precision diagnostics

Imaging Diagnostics

Artificial intelligence (AI) integration in diagnostic imaging is a key advancement for contemporary healthcare. The automated classification of medical images is now the principal use of AI in this field, making it one of the most well-known AI applications in healthcare. Recent analyses of medical devices using AI and machine learning (ML), covering the years 2015 to 2020, showed a high approval rate for radiological usage. For radiological applications, 58% of devices in the USA and 53% in Europe gained approval [29].

Numerous studies have shown that AI is capable of making image-based diagnoses in a variety of medical disciplines that are on par with or better than human experts. These include pathology (using AI algorithms trained on whole-slide pathology images to detect lymph node metastases of breast cancer, demonstrating comparable performance to pathologists), dermatology (with a convolutional neural network accurately classifying skin lesions from clinical images), and radiology (where a convolutional neural network outperformed radiologists in detecting pneumonia based on labeled frontal chest X-ray images) [30-34].

The National Pathology Imaging Co-operative in the NHS and notable projects like the University of Leeds Virtual Pathology Project serve as examples of the advancements being made in this area. In the long term, we expect AI-based diagnostic imaging will be widely adopted and scaled up, with significant positive effects on patient outcomes and healthcare delivery [35]. We give two illustrative use cases of these revolutionary technologies in the section that follows.

Screening for diabetic retinopathy

The early detection and timely treatment of diabetic retinopathy are essential components of managing diabetes and lowering preventable diabetes-related visual loss globally. A consequence of diabetes called diabetic retinopathy damages the eyes and can cause blindness and visual loss. Given the high prevalence of diabetes patients and the scarcity of eye care specialists globally, screening for diabetic retinopathy can be an expensive endeavor [36]. The potential of automated AI algorithms for screening for diabetic retinopathy has been emphasized in research studies from a variety of countries, including the USA, Singapore, Thailand, and India. These AI systems have proven to be reliable in their diagnostic performance and economical, providing a viable answer to the problems associated with mass screening for this ailment.

Significant regulatory and reimbursement developments have also occurred in this field. Medicare reimbursement for the usage of the Food and Drug Administration (FDA) approved

AI algorithm known as "IDx-DR" was approved by the Centres for Medicare & Medicaid Services in the USA. With 87% sensitivity and 90% specificity in identifying diabetic retinopathy that was more severe than mild, our AI system demonstrated outstanding diagnostic performance. These regulatory and reimbursement milestones represent a significant step towards increasing accessibility and use of AI-based diabetic retinopathy screening, which will ultimately benefit people with diabetes and aid in preventing diabetes-related vision loss [37].

Planning Radiotherapy with Greater Accuracy and Less Waiting

While concurrently reducing the waiting times for patients in need of life-saving radiotherapy treatment, AI is making great progress in improving the precision of radiotherapy planning. This programme assists clinicians in planning and image preparation for cancer radiation. Image segmentation, which entails defining the regions of interest within medical pictures, is currently one of the crucial steps in this procedure. Traditionally, oncologists have had to spend a lot of time and effort physically contouring these areas using specialized software.AI-based technology, like the open-source InnerEye system, has emerged as a game-changing answer to this problem. For particular cancer kinds including head and neck and prostate cancer, InnerEye's AI capabilities can greatly speed up the picture production process. The planning procedure for radiation could be greatly streamlined by this breakthrough, which has the potential to cut preparation times by up to 90%. Such efficiency gains have significant consequences since they can significantly shorten the wait times for patients seeking radiation treatment that could save their lives. Healthcare providers can improve treatment precision and guarantee that patients receive prompt and efficient care by integrating AI into radiotherapy planning. This application is a powerful illustration of how AI is transforming healthcare delivery by streamlining processes and enhancing patient outcomes [38, 39].

Precision Therapeutics

It is essential to have a thorough understanding of diseases at the cellular and molecular level in order to advance towards precision therapies. A wide variety of multimodal datasets are being produced as a result of extensive investigations into the cellular and molecular causes of diseases being conducted by researchers all over the world. These databases form the basis for the creation of digital and biological biomarkers, which are essential for disease diagnosis, severity evaluation, and prognosis. In this sense, immunomics/ synthetic biology and drug discovery are two key AI applications with a promising future.

Synthetic biology and immunology

Future research will heavily rely on AI to better understand the biological mechanisms underlying disease by utilizing multimodal datasets. Through the clustering of diseases and patient populations made possible by this knowledge, more specific preventive measures will be developed. For instance, AI-enabled immunomics can be used for diagnosis and better care and treatment option prediction. With special relevance for the treatment of cancer, neurological disorders, and uncommon diseases, this research has the potential to completely alter current standards of care. Because of this, each person's healthcare experience can be unique; ensuring that the care they receive is suited to their particular needs and situation.

Drug Discovery Powered by AI

AI is expected to significantly boost clinical trial design and process optimization in the pharmaceutical industry. Any combinatorial optimization procedure in healthcare could be transformed by it. Recent innovations by DeepMind and AlphaFold, among others, have cleared the path for a better comprehension of disease processes, the prediction of protein structures, and the creation of more specialized

therapies. This development is relevant to a wide range of illnesses, including both uncommon and more prevalent ailments.

Challenges

The application of artificial intelligence (AI) in healthcare is extremely promising, with the potential to revolutionize patient care and medical procedures. The successful integration of AI into healthcare systems, however, is hampered by a number of obstacles, each of which is essential. These problems are complex and wide-ranging, including a variety of elements and aspects, some of which have been covered in this article while others are outside its purview. The following are the main difficulties that must be overcome for AI in healthcare to be successfully implemented:

Data Access and Quality

The availability of high-quality, standardized data is essential for the efficiency of AI systems in the healthcare industry. AI algorithms need access to complete, accurate, and well-structured data in order to make smart conclusions. But difficulties exist in this area. Healthcare data's variability and consistency, which come from various sources and formats, provide a substantial challenge. Due to the sensitive nature of patient data, data privacy issues are of utmost importance in the healthcare industry. The smooth integration of many systems and data sources, or interoperability, is still a difficulty. The success of AI in healthcare depends on the harmonisation of data from electronic health records, medical devices, and other sources.

Infrastructure Technology

A strong technical foundation that can manage big and complex datasets, guarantee data security and privacy, and efficiently enable AI algorithms is required for the use of AI in healthcare. Many healthcare organizations must upgrade their current technical infrastructure to support AI, which is a difficult process. This calls for the implementation of secure data transmission and storage technologies in addition to hardware and software changes. Given that AI in healthcare deals with sensitive patient data and crucial decision-making processes, the integrity and reliability of this infrastructure are of the utmost significance.

Capacity for Organization

The technological, operational, and human resource capability must be developed before healthcare organizations can begin their AI journey. This calls for a complex strategy that includes educating current employees, hiring AI specialists, and developing workflows that can easily include AI tools. The development of a workforce with the knowledge and abilities to collaborate with AI systems is crucial for their effective deployment. Additionally, healthcare organizations need to create plans for managing AI initiatives successfully and ensuring that they fit with administrative and clinical workflows.

Ethical and responsible practices

A key issue is how AI should be used ethically in healthcare. To foster confidence among medical personnel and patients, AI algorithms must be transparent, equitable, and accountable. Another important concern is addressing difficulties with bias and discrimination in AI algorithms. If biases are not recognized and reduced, discrepancies in healthcare outcomes may result. Additionally, crucial ethical considerations for AI-driven systems include preserving patient privacy and guaranteeing informed consent. In order to maintain patient safety, healthcare organisations must negotiate the complicated ethical environment of AI while abiding by moral precepts and industry standards.

Regulation and safety

The security of AI-based medical solutions is crucial. To protect patients' health, these solutions must adhere to strict safety standards and legal restrictions. Regulatory organizations, like the Food and Drug Administration (FDA) in the US, must adjust to the healthcare AI landscape's rapid evolution. The delicate yet crucial duty of striking a balance between

promoting innovation and upholding safety. AI in healthcare regulations must adapt to new developments in technology while protecting patients from any hazards. To guarantee the safety and effectiveness of AI-driven medical devices and therapies, they must undergo thorough review and approval.

Conclusion

Artificial intelligence's ability to revolutionize the healthcare industry has the power to raise the standard, effectiveness, and accessibility of healthcare services. It is clear from the analysis of a range of AI applications - including disease diagnosis, treatment optimization, patient management, and administrative procedures - that AI can be a valuable tool for healthcare professionals, assisting them in making more informed decisions and streamlining processes. The use of AI in healthcare is not without its difficulties, though. To ensure that AI serves everyone without violating patient rights or escalating healthcare disparities, ethical concerns about patient privacy, data security, and algorithmic bias must be addressed. The creation and enforcement of regulations that strike a balance between patient safety and innovation fall under the purview of regulatory authorities. Future initiatives should prioritize appropriate implementation and strong cooperation between healthcare practitioners, data scientists, and regulatory agencies as AI in healthcare continues to develop. The promise for better patient outcomes and more effective healthcare systems remains not only promising but within reach by utilizing AI for healthcare while retaining a strong ethical and regulatory framework. The application of AI in healthcare represents a transition in how we provide for the health and wellbeing of people and populations around the world, not just a technological advancement.

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