# Digital Health and Artificial Intelligence

*Robin George[1], Vijay Gachinamani[2]*

*[2] Department of Pharmacology, Faculty of Medicine, Kyrgyz National University, Bishkek, Kyrgyzstan.*
*[2] Department of Pharmacy Practice, Sri Adichunchanagiri College of Pharmacy, Adichunvhangiri Univeristy, BG Nagara, India.*

*CHAPTER INFO*

Received 18/11/2025
Accepted 16/02/2026
Published 02/06/2026

**Keywords:**
Artificial Intelligence
Health Sector
Digital Health

**Corresponding author:**
Dr. Robin George
robin.george793@gmail.com

*ABSTRACT*

Artificial intelligence (AI) and Digitalization stand at the forefront of transforming the healthcare landscape, offering immense potential in various domains, including diagnosis, treatment, record maintenance and even pharmacy in health care practice. However, despite its significance, clear guidance on the specific applications of AI within pharmacy remains limited. AI and Digitalization has undergone considerable development within healthcare, assuming pivotal roles in the storage and management of data and information. This encompasses a broad spectrum, ranging from patient medical histories and medicine inventories to sales records. Moreover, AI has facilitated the automation of machinery and the creation of sophisticated software and computer applications, including diagnostic tools like MRI and CT scans, all aimed at enhancing healthcare processes and simplifying complex procedures. In pharmacy settings, AI, powered by algorithms and machine learning capabilities, enables the health care professional to analyze extensive volumes of patient data. This data includes diverse sources such as medical records, laboratory results, and medication profiles. Through such analysis, pharmacists can effectively identify potential drug interactions, evaluate the safety and efficacy of medications, and predict adverse drug events, and helps in designing better effective therapeutic interventions. Furthermore, a multitude of AI models have been developed specifically to support pharmacists in their decision-making processes. These models serve various purposes, from assisting in clinical decision support systems to automating dispensing tasks in practicing physicians. They also contribute to optimizing medication dosages, detecting drug interactions, and leveraging smart technologies to enhance medication adherence. Additionally, AI plays a crucial role in detecting and preventing medication errors, providing medication therapy management services, and clinical pharmacy practice in the inpatient setup. By integrating AI and Digitalization-driven solutions, health care sector can achieve greater efficiency, accuracy, and ultimately, improved patient care outcomes.

## Introduction

In 2004, John McCarthy offered a definition of AI, characterizing it as "the science and engineering dedicated to crafting intelligent machines, notably advanced computer programs." Since then, AI has emerged as a groundbreaking technology, reshaping industries across the globe with its transformative capabilities.[1]

AI represents a branch of scientific inquiry focused on imbuing machines with intelligence, particularly through sophisticated computer programs that mimic human cognitive processes. Its integration has become indispensable across various industries, offering valuable solutions in technical and research domains alike.

Artificial Intelligence (AI) has emerged as a transformative branch of science aimed at enabling machines to mimic human intelligence, including learning, reasoning, problem-solving, and decision-making. Over the past quarter-century, the healthcare sector has demonstrated remarkable progress in addressing the growing demand for services, prescriptions, and patient care. Despite persistent challenges such as shortages of healthcare professionals, increasing operational costs, and reduced reimbursements, healthcare systems have effectively leveraged AI technologies to streamline workflows, improve efficiency, and enhance the quality of care delivery [2].

The role of AI in diagnostics has grown significantly with advancements in computational power and the development of practical, real-world applications. AI-driven diagnostic tools assist healthcare professionals in interpreting complex medical data, including imaging, laboratory results, and patient histories, thereby improving accuracy and reducing diagnostic errors. The continued enthusiasm for AI among researchers and clinicians highlights its potential to revolutionize healthcare practices and patient outcomes [3].

AI encompasses a wide range of methodological domains, including reasoning, knowledge representation, and problem-solving, and notably, the pivotal paradigm with machine learning (ML) serving as a core component. ML utilizes algorithms to identify patterns in structured and unstructured datasets, enabling predictive analytics and data-driven decision-making. A prominent subset of ML is deep learning (DL), which employs artificial neural networks (ANNs) to process large volumes of complex data, such as medical images and genomic information. These technologies have become integral across healthcare settings, supporting early disease detection, risk stratification, and personalized treatment planning. Successful implementation of AI in healthcare depends on three key principles: robust data security, meaningful analytics and insights, and collaborative expertise among healthcare professionals and technologists.

AI applications in healthcare are extensive and continue to expand across various domains. In clinical practice, AI supports medication management processes such as medication reconciliation and medication order review, ensuring safe and effective use of therapies. It also aids in clinical decision support by providing evidence-based recommendations tailored to individual patient profiles. In addition, AI is widely utilized in medical imaging, robotic-assisted surgeries, remote patient monitoring, and telemedicine, thereby improving accessibility and precision of care.

Furthermore, AI plays a crucial role in pharmaceutical and biomedical research. It accelerates drug discovery and development by identifying potential drug candidates, predicting drug interactions, and optimizing clinical trial design. AI is also instrumental in drug repurposing, where existing medications are evaluated for new therapeutic indications, thereby reducing time and cost associated with traditional drug development processes. These advancements contribute significantly to improving healthcare productivity and innovation [4].

AI represents a powerful tool that continues to reshape healthcare by enhancing efficiency, accuracy, and patient-centered care. Its ability to process vast amounts of data and generate actionable insights supports healthcare professionals in making informed decisions. As AI technologies continue to evolve, their integration into healthcare systems will further strengthen clinical outcomes, optimize resource utilization, and advance the overall quality of healthcare services [5].

Incorporating artificial intelligence (AI) into healthcare systems not only reshapes the roles of healthcare providers but also unlocks fresh opportunities to enhance patient safety and care quality. AI holds promise in aiding clinicians to achieve more accurate diagnoses and has significantly impacted drug development, personalized medicine, and patient monitoring practices. Moreover, AI's integration into electronic health record (EHR) systems enables the identification, evaluation, and mitigation of potential threats to patient safety. [6]

The FDA acknowledges that AI holds the potential to revolutionize healthcare by extracting valuable insights from extensive service delivery data. To regulate AI as software for medical devices (SaDM), the FDA is in the process of crafting policies, a move that will extend its implications to remote patient monitoring (RPM) as well. [7]

Clinical pharmacists are tasked with promoting the judicious utilization of medications while also addressing, resolving, and preempting potential and existing issues linked to pharmacotherapy and other healthcare technologies. Their professional scope is evolving to encompass activities tailored to fulfill the requirements of individuals, families, caregivers, and the broader community.[8]

AI technologies in medicine manifest in various iterations, ranging from entirely virtual systems such as deep-learning-based health information management platforms guiding physicians in treatment decisions, to cyber-physical implementations like robots aiding surgeons and targeted Nano robots facilitating drug delivery. [9]

## Role of AI in Clinical Pharmacy

AI serves as a pivotal catalyst for enhancing quality in healthcare. Its advanced technologies promise to reshape clinical pharmacy practice by seamlessly integrating duties in a synergistic manner. Leveraging its capacity to interpret vast patient data and clinical guidelines, AI can recommend suitable drug therapies, dosages, and combinations. For instance, IBM Watson for Oncology exemplifies AI's role in aiding oncologists by identifying tailored cancer drug treatments based on individual patient profiles. By analyzing patient history alongside extensive medical literature and clinical trial data, Watson proposes therapies tailored to specific cancer types. Additionally, AI algorithms are indispensable in therapeutic drug monitoring, continuously assessing the efficacy and safety of medication therapies by analyzing patient data, including biomarkers. [10]

## Personalized Medicine

Personalized medicine revolves around the notion that health interventions should be customized to accommodate the intricate and distinctive genetic, biochemical, physiological, exposure, and behavioral characteristics unique to individuals. The process of tailoring medicine or interventions to a specific patient demands a profound comprehension of their condition and circumstances. Achieving this understanding often involves deploying sophisticated assays that generate extensive datasets, such as DNA sequencing or specialized imaging protocols.

In essence, the data derived from these assays must be meticulously organized to facilitate analyses aimed at pinpointing specific features exhibited by the patient. Identifying these unique characteristics is crucial in determining the most optimal and personalized intervention for the individual's health needs. The underlying principle is to move away from a one-size-fits-all approach in healthcare and, instead, embrace a tailored strategy that considers the intricacies of each patient's biology and circumstances.[14]

The intersection of AI and precision medicine represents a powerful convergence aimed at addressing the most intricate challenges in personalized healthcare. While AI plays a significant role, it's important to recognize that it's not the sole data-driven field influencing health and healthcare. Precision medicine, which has been shaping the healthcare landscape for over a decade, exerts an equally profound if not greater influence than AI.

Precision medicine endeavors to tailor healthcare to the individual, aiming for personalized care at every level. AI-enabled clinical decision-support systems offer promising avenues to mitigate diagnostic errors, enhance decision-making intelligence, and aid clinicians in tasks such as extracting and documenting electronic health record (EHR) data. [9]

The applications of AI in medicine have expanded significantly, offering opportunities to advance personalized medicine beyond solely algorithm-driven approaches. Through the synergy of AI and precision medicine, healthcare stands to be transformed, ushering in an era of more personalized, effective, and patient-centric care.[15]

## Clinical Evaluation of Medical Record

Healthcare stands out as one of the most promising arenas for the application of AI, fueled by the abundance of data stored in electronic health records (EHRs) and bolstered by advancements in computational capabilities.

The electronic medical record (EMR) serves as a comprehensive repository capturing various medical processes, including patient reception, examinations, laboratory tests, medications, surgeries, and associated expenses.[16] Regarded as the cornerstone of medical data within the healthcare system, the EMR systematically organizes and manages each patient's health information, encompassing personal details, medical/family histories, drug reactions, health statuses, medical examinations, and admission/discharge records in a structured database format.

In recent years, AI research leveraging EMR data has gained momentum, spearheading innovative approaches to healthcare management. For instance, deep-learning-based artificial intelligence algorithms have been developed to predict cardiac arrest, with validation using electrocardiogram (ECG) data. Moreover, AI-driven solutions utilizing EMR data have emerged to facilitate more effective management of hypertension, highlighting the potential of AI to revolutionize disease management and improve patient outcomes.[15]

The health informatics community boasts a long-standing tradition of exploring and assessing the integration of AI to address challenges in care delivery. Initially, efforts centered on diagnosing medical conditions and offering therapy recommendations within clinical settings. Early iterations of AI primarily relied on symbolic approaches grounded in rules and knowledge. However, contemporary AI blends statistical methods with symbolic approaches for representing diseases more effectively.

A medical record serves as a methodical documentation of a patient's personal and social details, alongside their ailment history, clinical observations, diagnostic investigations, treatment administered, and a record of subsequent follow-up and outcomes. It encapsulates a comprehensive overview of a patient's healthcare journey, aiding healthcare professionals in delivering informed and personalized care.[17]

Medical records are essential legal documents used by insurance companies to process claims, ensure accurate billing, and prevent malpractice or fraudulent activities. They provide a reliable source of documented evidence regarding patient care, treatments, and clinical decisions. Beyond administrative and legal purposes, their primary function is to systematically record relevant patient information, including medical history, diagnoses, investigations, and therapeutic interventions. This comprehensive documentation supports continuity of care, improves communication among healthcare professionals, and serves as a valuable resource for clinical evaluation, research, and quality improvement in healthcare systems [18].

The prevailing perception is that data holds the key to empowering a broad spectrum of industries, spanning finance, marketing, entertainment, and medicine, to gain deeper insights into customer behavior. This understanding enables enterprises to tailor future services directly aligned with the economic and well-being interests of their clientele.

In recent times, a confluence of factors has fueled the resurgence of AI. These include the availability of vast Big data resources, the proliferation of open-source machine learning (ML) tools, and the affordability of computational units. Notably, the development of parallel computing technologies such as graphical processing units (GPUs) and tensor processing units (TPUs) by leading high-tech commercial information technology (IT) vendors has played a pivotal role in driving this resurgence.[19]

As AI implementations in clinical practice became more widespread, research shifted its focus towards assessing the clinical impacts of AI and addressing methodological challenges in identifying appropriate clinical endpoints.

It's crucial to recognize that algorithms can influence resource allocation and prioritization, potentially exacerbating biases in care delivery. Therefore, careful consideration must be given to the risk of reinforcing bias when deploying AI in healthcare settings. Furthermore, the impact of AI on patient outcomes, patient experience, clinical workflows, and broader organizational and societal aspects necessitates continuous monitoring.

Evaluation criteria for AI applications in healthcare are multifaceted. These include the validity of the system, ensuring correctness in reasoning, as well as assessing its usefulness in clinical practice and its effects on care processes and patient outcomes. Particularly in AI applications utilizing large datasets such as genomic, biomarker, and phenotype data, it is imperative to ensure sufficient coverage, specificity, and validity of the data used.[20]

The analysis of diseases plays a crucial role in crafting thoughtful treatments and ensuring the well-being of patients. However, human error often leads to inaccuracies in diagnosis and misinterpretation of vital information, posing significant challenges. AI offers diverse applications that promise enhanced accuracy and efficiency, alleviating the burden of these demanding tasks[9].

## Machine Learning in Diagnostics

Recent years have witnessed the emergence of various methods aimed at automating processes, notably through machine learning (ML) and deep learning (DL) approaches[21].

AI holds the potential to uncover meaningful relationships within raw datasheets, paving the way for enhanced diagnosis, treatment, and mitigation of diseases. Through sophisticated algorithms, AI can glean insights from complex datasets, empowering healthcare professionals to make informed decisions and improve patient outcomes[22].

Machine learning and computer vision have significantly advanced human visual perception, particularly in identifying clinically significant patterns within imaging data. Neural networks are increasingly deployed across various tasks in medical image analysis, including segmentation, generation, classification, and prediction of clinical datasets. Academic research labs, biotechnology corporations, and technology firms are actively exploring the integration of AI and ML in three key domains.

Firstly, machine-based learning is utilized to predict pharmaceutical properties of molecular compounds and identify potential targets for drug discovery. By leveraging algorithms to analyze molecular structures, predictive models expedite the drug discovery process by narrowing down candidate compounds for further investigation. Secondly, pattern recognition and segmentation techniques are applied to medical images obtained from diverse modalities such as retinal scans, pathology slides, and imaging of internal organs. These techniques facilitate faster diagnoses and enable more efficient tracking of disease progression. Thirdly, generative algorithms augment existing clinical and imaging datasets, enhancing the depth and diversity of available data for analysis and training. Furthermore, deep-learning techniques are evolving to analyze multimodal data sources, including the integration of genomic and clinical data. By combining disparate data types, new predictive models can elucidate disease mechanisms and inform personalized treatment approaches.

These advancements underscore the transformative potential of machine learning in healthcare and pharmaceutical research. However, rigorous validation and ethical considerations remain paramount amidst these developments[23].

AI is revolutionizing manufacturing by enabling automated and personalized processes, ensuring products meet predefined quality standards by identifying and addressing manufacturing errors within set limits. Technologies like meta classifiers and tablet classifiers are employed to achieve the desired quality in the final product, enhancing efficiency and precision in manufacturing operations.

In clinical trials, the integration of AI plays a pivotal role in subject selection and trial monitoring, leading to a reduction in dropouts due to close monitoring and intervention. Machine learning (ML) techniques are increasingly utilized in clinical trials, offering insights, and optimizing trial procedures for improved outcomes and efficiency [22].

## Monitoring Adverse Effects

Clinical pharmacists play a vital role in monitoring the impact of prescribed drug therapy on patients. Their responsibilities extend to following up with patients to identify any adverse reactions, instances of incorrect administration, or the development of drug dependence. This proactive approach allows pharmacists to not only calibrate dosages and treatment plans but also to gain insights into the efficacy and safety of drugs through evidence-based information gathered from practical use.

When AI-based algorithms offer clinically actionable predictions, clinicians may opt to adjust treatment plans based on these predictions. However, concerns regarding potential side effects and patient safety remain paramount. Clinicians must carefully evaluate AI-generated predictions in conjunction with clinical judgment and patient-specific factors to ensure optimal treatment outcomes while minimizing risks. This collaborative approach, integrating AI-driven insights with clinical expertise, holds promise for enhancing patient care and medication management[24].

## Medical History and Drug Safety

Artificial Intelligence (AI) plays an increasingly significant role in the management of medical history, transforming how healthcare providers access, interpret, and utilize patient data. AI algorithms are adept at sifting through vast amounts of medical records, including patient histories, diagnostic tests, treatments, and outcomes, to extract relevant information Getting a patient's medical history can help identify any relevant chronic conditions as well as any past disease states that may not be being treated but may have had a long-term impact on the patient's health. Differential diagnosis may also be guided by the medical history efficiently[25].

By leveraging natural language processing (NLP) and machine learning techniques, AI systems can identify patterns, trends, and correlations within medical histories, enabling healthcare professionals to make more informed decisions regarding patient care. AI-powered platforms also streamline medical documentation processes, reducing administrative burdens and improving the accuracy and completeness of medical records.

A patient's medical history may also give information to the provider about specific conditions that may guide therapy, particularly in preventing allergies or past medical procedures that could compromise the patient's care during the visit. Patients with genetically linked illnesses may benefit from a risk assessment based on their family history.

Furthermore, AI-driven predictive analytics can anticipate potential health risks or complications based on historical data, aiding in proactive intervention and preventive care strategies. However, while AI offers tremendous promise in enhancing medical history management, concerns regarding data privacy, security, and algorithm bias necessitate careful consideration and ongoing refinement of these technologies to ensure their ethical and effective integration into healthcare practices.

It has been demonstrated that AI approaches are crucial to premarketing medication safety, particularly when it comes to toxicity assessment. Finding the adverse effects of chemicals on people, plants, animals, and the environment is known as drug toxicity determination, and it is a crucial phase in the medication design process[26].

By detecting adverse drug events, forecasting drug-drug interactions, and identifying patient populations at risk for adverse events, artificial intelligence (AI) and machine learning can be utilized to enhance drug safety. AI and machine learning have the potential to improve medication safety by increasing the speed, accuracy, and efficiency of adverse event detection.

## Genomic

Genome-informed prescribing stands out as one of the initial domains highlighting the potential of precision medicine on a large scale. Considering genomics in therapy planning is crucial, especially for patients with pharmacogenomically actionable variants, as they may necessitate adjusted prescribing or dosing strategies.

Although the application of artificial intelligence and machine learning (AI/ML) in pharmacogenomics (PGx) is still at an early stage, significant progress is being made in areas such as drug development, safety, and efficacy. Predictive models using ML algorithms—including random forests, support vector machines, and neural networks—have shown strong potential in forecasting individual drug responses based on genetic profiles, enabling more precise treatment selection and dose optimization. For example, ML-based models have been successfully used to predict appropriate warfarin dosing by integrating genetic and clinical variables.

The availability of larger datasets, along with advanced ML and deep learning (DL) techniques, has improved the ability to distinguish between responders and non-responders, particularly in complex diseases like cancer, where DL models can integrate multi-omics data to predict drug–gene interactions. Similarly, ML approaches have been explored in mental health to predict treatment responses using clinical data, prior treatment history, pharmacogenomic variants, and even metabolomic profiles. However, some studies suggest that algorithms relying solely on variant databases and pathogenicity rules may perform sub optimally for PGx-specific variants.

Beyond prediction, AI is also playing a growing role in optimizing drug selection, especially in oncology, where multiple AI-driven tools are under development. Additionally, AI contributes to post-market surveillance by analyzing data from diverse sources such as social media, patient forums, electronic medical records, and adverse event reporting systems. This enables early detection of previously unrecognized adverse drug reactions and provides valuable insights into the long-term safety and effectiveness of therapies, ultimately supporting more informed and personalized clinical decision-making [39].

However, the realization of real-time recommendations relies heavily on the development of machine-learning algorithms. These algorithms play a pivotal role in predicting which patients are likely to benefit from specific medications based on their genomic information. This integration of genomics and machine learning holds promise for advancing precision medicine and optimizing treatment outcomes for individual patients[9].

## Clinical Data Analysis

Big data analytics enables the aggregation of large datasets, facilitates human capital decisions, and measures the cost-effectiveness of healthcare organizations.

The acronym CRF stands for case report form, which can be filled out on paper or electronically. The sponsor uses it extensively as a tool to gather data from patients taking part in clinical trials. The case report forms provide information on a patient's involvement in a clinical study, including details about any adverse occurrences [27].

The introduction of AI poses new communication challenges within dynamic hospital environments. This is particularly pertinent in situations where machines are assuming diagnostic roles and providing care to individuals undergoing medication treatments.

## Decision Making for Patients

In pharmacy practice, clinical decision-making (CDM) is defined as a collection of cognitive processes and skills that allow pharmacists to make therapeutic, patient-centered decisions in any practice situation[28]. In today's interconnected world, decision-making has become increasingly dynamic and uncertain, relying on dependable knowledge. The growing volume of data within the healthcare system necessitates large-scale data strategies to enhance the quality of healthcare delivery. Despite the integration of extensive data analysis techniques and platforms into current healthcare data management architectures, challenges persist in addressing emergencies effectively. Big data analytics enables the aggregation of large datasets, facilitates human capital decisions, and measures the cost-effectiveness of healthcare organizations.

AI holds the potential to augment or even replace certain processes in healthcare, such as diagnosis, treatment planning, and delivery. Patients should be informed about the use or potential integration of AI into their clinical care. Engaging in shared decision-making discussions with patients regarding the utilization of AI necessitates clinicians to understand patients' comfort levels with AI in their care. During these conversations, clinicians can elucidate the benefits of AI, including its ability to offer additional options or evidence for diagnosis, treatment planning, and delivery. Shared decision-making empowers patients to make informed choices aligned with their unique values and preferences. Conducting shared decision-making conversations is essential not only to adhere to informed consent procedures but also to assist patients in selecting the most suitable treatment based on their individual needs and circumstances[29].

AI-driven analysis of vast amounts of big data holds immense potential in providing real-time clinically relevant information to healthcare professionals, administrators, and policymakers. Clinical Decision Support Systems (CDSS) are equipped with various technologies, including rule-based systems, fuzzy logic, artificial neural networks, Bayesian networks, and general machine-learning techniques, enabling them to process and analyze data efficiently. Big data technologies are being widely implemented in healthcare systems for evidence-based clinical decision-making, despite methodological, social, and ethical challenges[30]. However, the benefits of AI-assisted CDSS may vary for patients, with those whose data was collected many years ago potentially experiencing fewer advantages compared to those currently requiring clinical care. Therefore, the ethical evaluation of AI-assisted CDSS must carefully consider and balance differing interests and values.

In this context, three examples illustrate how ethical issues can arise:

Clinicians using AI-assisted CDSS for diagnosing patients and predicting treatment outcomes based on comprehensive clinical data, including medical history, diagnostic tests, and genomic sequences stored in electronic health records (EHRs) and utilized for incremental machine learning.

AI-assisted CDSS conducting research on patient populations to assess the risks of non-compliance with prescribed management plans for individual patients.

AI-assisted CDSS generating knowledge bases to enhance system-wide efficiencies and patient outcomes within learning healthcare systems.

As AI algorithms evolve and become more widespread, concerns emerge regarding healthcare professionals potentially becoming overly reliant on AI assistance, leading to complacency in decision-making processes. It is imperative for stakeholders to navigate these concerns and ensure that AI technologies are integrated responsibly, complementing rather than replacing clinical expertise and patient-centered care[31].

Clinical decision-making (CDM) in pharmacy practice encompasses a series of cognitive processes and skills that empower healthcare proffesionals across various settings to make patient-centered therapeutic decisions. Often, pharmacists engage with patients and healthcare professionals at the point where a diagnostic label has been assigned, yet drug treatment initiation may not have occurred or may be yielding limited efficacy. Through informed decisions regarding drug treatment, pharmacists play a pivotal role in optimizing medication use and enhancing patient outcomes.

In contrast to pharmacy, CDM in medical research and education receives more extensive investigation and primarily centers on diagnostics rather than therapeutics. This distinction highlights the unique focus and scope of decision-making processes within these respective domains[28].

The adoption of electronic health record (EHR) systems has become widespread and swift across healthcare systems globally [14].

Clinical decision-making (CDM) is defined as a collection of cognitive processes and capabilities that empower pharmacists across diverse settings to make patient-centered therapeutic decisions[28].

## AI in Evidence Based Medicine Approach

AI algorithms tailored for diagnostics have highlighted performance levels comparable to, or even surpassing, those of human clinical experts. Furthermore, AI risk calculators are refining patient stratification and triage processes, while surveillance models are adept at detecting and monitoring disease outbreaks through diverse data sources.

As clinicians advance in their careers, they are increasingly likely to engage with a diverse array of AI tools. It is crucial to perceive AI as a supplementary resource to clinical practice, education, and research, rather than a substitute for traditional methods.

In particular, initiatives focused on educating clinicians about AI harmonize well with endeavors to promote evidence-based medicine (EBM). Both endeavors entail critically assessing and integrating new technologies or interventions into medical practice based on established principles[32].

The AI curriculum aims to equip future users, especially the vast majority of healthcare professionals, with fundamental knowledge about AI. This empowers them to effectively utilize AI systems and communicate to patients how AI impacts decision-making processes.

With healthcare becoming increasingly interdisciplinary, nurturing effective collaboration among various healthcare professionals is essential to ensure optimal patient care [33]

As demands mount from patients, policymakers, medical professionals, and hospitals to incorporate AI into routine medical practice, the transition from development to implementation needs to be accelerated[34].

Evidence-based medicine categorizes various types of clinical evidence and assesses their reliability levels, considering the extent to which they are free from common biases in medical research:

***Meta-analysis of multiple randomized controlled trials (RCTs).***

1b. Evidence derived from a single RCT.

2a. Evidence from well-designed controlled RCTs.

2b. Evidence from a single quasi-experimental study.

Evidence from non-experimental studies (e.g., comparative research, case studies), including information from textbooks.

Evidence derived from expert opinions and clinical practice.

Several online databases support evidence-based medicine. The Cochrane Library, available through CD-ROM, internet access, or Ovid's service, stands out as a premier source of reliable evidence on healthcare effects. It comprises:

The Cochrane Database of Systematic Reviews (Cochrane Reviews)

The Database of Abstracts of Reviews of Effects (DARE)

The Cochrane Central Register of Controlled Trials (CENTRAL)

The Cochrane Database of Methodology Reviews (Methodology Reviews)

The Cochrane Methodology Register (Methodology Register)

Health Technology Assessment Database (HTA)

NHS Economic Evaluation Database (NHS EED) [35]

## AI in Dose Optimisation

Dose optimization holds significant importance in pediatric patients due to their extended lifespan and accelerated cell growth, rendering them two to three times more vulnerable to the potential harmful effects of ionizing radiation compared to adults. While radiology plays an essential role in modern healthcare, many medical imaging modalities, including computed tomography (CT), positron emission tomography (PET), and general radiography, utilize ionizing radiation for image generation [36].

CT dose optimization emerges as a crucial consideration to mitigate patients' radiation risks. The primary objective of dose optimization is to minimize radiation exposure in diagnostic imaging while upholding image quality at an acceptable level, ensuring diagnostic accuracy. AI-based solutions have shown promise in reducing noise in low-dose CT images. Radiographers now have the capability, with the assistance of AI, to conduct CT examinations at reduced doses, potentially surpassing current dose reduction methods[37].

A genetic algorithm is a search approach that takes cues from the biological process of evolution via natural selection. Genetic algorithms are commonly employed for radiation therapy dose optimization. These algorithms typically exhibit the following characteristics:

(i) Representation of potential solutions to the problem.

(ii) Specific initialization method for the entire population of solutions.

(iii) Evaluation function to assess the quality of each solution (individual).

(iv) Genetic operators, such as crossover and mutation, which dictate the exchange of information among individuals in the population.

Genetic algorithms conduct the search for a solution in parallel fashion. Unlike calculus-based methods that utilize a single searcher, genetic algorithms employ a population of solutions to explore the solution space[38].

## Medical Diagnosis and Treatment

Medical diagnostics involves assessing medical conditions or diseases through the examination of symptoms, medical history, and test outcomes. Its aim is to pinpoint the cause of a medical issue and deliver precise diagnoses for effective treatment. Diagnostic procedures encompass a range of tests, including imaging techniques such as X-rays, MRIs, and CT scans, alongside blood tests and biopsies.

With the advent of the AI revolution, the landscape of medical diagnostics stands to be transformed profoundly. AI technologies hold the potential to enhance prediction accuracy, speed, and efficiency in diagnosing medical conditions. By analyzing medical images like X-rays, MRIs, ultrasounds, and CT scans, AI algorithms can assist healthcare providers in identifying and diagnosing diseases with heightened precision. Moreover, AI can process extensive patient data, spanning medical imaging, bio-signals (e.g., ECG, EEG, EMG, and EHR), vital signs (e.g., body temperature, pulse rate, respiration rate, and blood pressure), demographic information, medical history, and laboratory test results, further enriching diagnostic capabilities.[11]

Algorithms harness medical data to generate predictions and evolve continuously by analyzing new and updated information. They accumulate insights from various sources of knowledge and input, incorporating years of experience into their learning processes. Consequently, AI-enabled systems possess the capability to process a vast amount of knowledge, potentially surpassing human capacity in specific medical tasks.

In a separate study, researchers delved into the realm of AI within clinical epigenetics. Here, they explored personalized treatment approaches for patients based on their genetic and epigenetic profiles. This investigation highlights the potential of AI to tailor medical interventions to individual characteristics, thereby paving the way for more precise and effective healthcare strategies.[3]

### AI In Clinical Research

The emergence of AI technologies has ushered in a new era across basic biology, pharmacology, and medicine, marked by significant performance breakthroughs. In certain domains of clinical research, AI has achieved levels of performance comparable to that of human experts, representing a notable advancement. Over the past two decades, the integration of AI into clinical research has rapidly expanded, leveraging available data, techniques, and applications.

Despite the rapid adoption of AI in oncologic research, the development of AI solutions remains relatively nascent. While a handful of AI-based applications have received approval for use in various settings such as hospitals and pharmaceutical companies, the landscape still grapples with questions regarding the potential of AI to replace medical professionals.

The debate surrounding the capacity of AI to supplant medical experts continues to unfold. Much of the discourse surrounding AI centers on its progress in clinical research, particularly within the biomedical field. AI applications have accelerated in their ability to attain levels of performance on par with human experts, underscoring the transformative potential of AI in advancing healthcare and biomedical research.[12]

Analytical clinical research studies are built upon fundamental elements such as exposure and outcome, cause and effect relationships, and the identification of risk factors associated with diseases. These studies aim to delineate independent and dependent variables, crucial for understanding the underlying mechanisms driving health outcomes.

In the realm of clinical research, two primary study designs predominate: observational and experimental studies. Observational studies encompass a variety of approaches including case studies, cross-sectional studies, and cohort studies. These methodologies offer valuable insights into disease patterns, risk factors, and the natural progression of illnesses without intervening variables deliberately introduced by researchers.

Case studies provide in-depth examinations of individual patients or specific instances, offering detailed insights into unique medical phenomena. Cross-sectional studies offer a snapshot of a population at a single point in time, enabling the exploration of associations between variables without delving into causality.

Cohort studies, on the other hand, track groups of individuals over time, assessing exposures and outcomes to establish causal relationships. They offer valuable longitudinal data, facilitating the identification of risk factors and the evaluation of disease progression.

Experimental studies, such as randomized controlled trials (RCTs), introduce interventions or treatments to assess their efficacy and safety, employing rigorous methodologies to establish cause-and-effect relationships.

In essence, analytical clinical research studies employ diverse methodologies tailored to investigate exposure-outcome relationships, causal pathways, and risk factors, advancing our understanding of disease mechanisms and informing evidence-based medical practice.[13]

## Conclusion

AI stands as a transformative force poised to redefine the role of healthcare professionals, steering their focus beyond mere medication dispensation towards comprehensive patient-care services. By harnessing AI capabilities, healthcare professionals can usher patients into a realm where they glean maximum benefits from their medications, thereby fostering healthier outcomes. The integration of AI presents a myriad of opportunities for pharmacists to guide individuals in accessing cost-effective healthcare avenues, optimizing communication with healthcare professionals, and maximizing the utility of wearable data. AI serves as a catalyst in providing invaluable everyday lifestyle guidance, seamlessly integrating facets like diet and exercise into patients' healthcare regimens. Its capacity to bolster treatment compliance and adherence further underscores its pivotal role in enhancing patient wellness. However, the realization of AI's potential in clinical pharmacy services necessitates concerted efforts, fostering collaboration between pharmacists and data scientists to meticulously evaluate the efficacy and value of AI-powered apps and tools in practical healthcare settings.

Finally, AI's impact extends beyond the realms of developed nations, transcending borders to bridge healthcare disparities and enhance access to quality care in developing nations. As AI assumes a pivotal role in the data storage and its interpretation, it lays the groundwork for pioneering digital health initiatives that promise to evaluate medical, medication histories and thereby prevents interactions and adverse effects promises advanced patient safety. The evolution of personalized medicine mirrors the iterative development process inherent in drug and health device innovation, signifying a paradigm shift towards tailored healthcare solutions.

In the dynamic landscape where humans and AI systems converge, cultivating trust in the outputs of these systems emerges as paramount. As stakeholders navigate this symbiotic relationship, fostering transparency and accountability in AI-driven healthcare interventions becomes indispensable, ensuring that patients and practitioners alike can wholeheartedly embrace the transformative potential of AI in reshaping the future of healthcare delivery.

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