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Review Article

FORTUNE JOURNAL OF HEALTH SCIENCES

ISSN: 2644-2906

Revolutionizing Pharmacy with Artificial Intelligence: A Comprehensive Review

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Abstract

Artificial Intelligence (AI) is rapidly transforming the pharmaceutical and healthcare industries, bringing groundbreaking advancements in drug development, clinical practice, and pharmacy education. This review explores AI's evolution, its various types, and its growing role in modern pharmaceutical systems. From enhancing drug discovery and dosage form design to advancing polypharmacology and clinical pharmacy, AI is reshaping the way medicines are developed and delivered. Additionally, we examine how pharmacy students perceive AI-driven tools like ChatGPT and their impact on learning. The integration of AI in pharmacy offers numerous advantages, such as improving efficiency, reducing costs, and enabling personalized treatments. However, its adoption also comes with challenges, including ethical concerns, data privacy issues, and the risk of biased decision-making. This review highlights both the potential and the limitations of AI in the pharmaceutical world. While AI continues to revolutionize healthcare, ensuring responsible implementation and regulatory oversight will be key to harnessing its full potential while minimizing risks.

Keywords: Artificial Intelligence, Pharmacy, Artificial Intelligence tools, Benefits and drawbacks.

Introduction

Artificial intelligence [AI], a branch of computer science, is the study of problem-solving through symbolic programming. AI is the process by which computers mimic human intellect. Information gathering, creating guidelines for applying the information, coming to tentative or firm conclusions, and self-correction are all steps in the process. There are two sides to the development of AI: while many people worry that it will jeopardize their jobs, every new development is welcomed since it is thought to significantly improve society. AI is utilized throughout a range of industries, from automating corporate procedures to developing innovative teaching strategies. From hype to optimism, the emerging concept of using AI in the medication development process (1). It has evolved into a discipline that focuses on addressing problems and has vast applications in business, engineering, and healthcare. One of the most significant applications of AI is the development of expert systems (2). Among the new endeavors adopting AI technology in pharmacy are drug discovery, drug delivery formulation, development, and other healthcare applications. Hope has already replaced hype in this movement. The employment of AI models also enables the prediction of *in vivo* reactions, therapeutic pharmacokinetic characteristics, optimal dosage, etc. Given the importance of pharmacokinetic prediction in drug research, using in silico models contributes to the medicine's affordability and efficacy. There are two primary categories for the developments in AI technology.

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Citation: Kiruthiga P, Kumudhaveni B, Yuvaranjani G, Monisha S, Sindhu AJ, Radha R. Revolutionizing Pharmacy with Artificial Intelligence: A Comprehensive Review. Fortune Journal of Health Sciences. 8 (2025): 835-844.

Received: August 17, 2025
Accepted: August 22, 2025
Published: September 04, 2025

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DOI:10.26502/fjhs.344

The first one consists of conventional computing techniques, such as expert systems, which may draw conclusions and replicate human experiences, starting with the basic concepts, like expert systems. The second one consists of systems that use artificial neural networks [ANNs] to simulate how the brain functions (3).

AI background: Timeline

In 1956, the term "artificial intelligence" was used for the first time. Nonetheless, the idea of artificial intelligence has been used since 1950 in both symbolic and problem-solving approaches (4). Important history of AI-timeline are presented in Figure 1.

Sort of artificial intelligence

There are two approaches to categorize AI (3,4,7) based on their capabilities and their functionality. Figure 2 (6).

Based on capability - Weak artificial intelligence, general artificial intelligence, and super artificial intelligence are the three basic stages of artificial intelligence based on their respective capabilities.

- **Weak Intelligence or Narrow AI** Another name for it is Artificial Narrow Intelligence. This system is made and educated to carry out specific tasks, like traffic signals, playing chess, driving, facial recognition, speech recognition, and image recognition. For example: Apple SIRI, IBM's Watson supercomputer, tagging in social media.
- **General AI or Strong AI** The term "Human-Level AI" is also used. It has the potential to simplify human intelligence. Because of this, it can figure out the solution when presented with a new assignment. AGI is capable of doing all that humans can. It is thought that we may soon be able to create a machine that is as intelligent as humans; however, there is currently no example of strong artificial intelligence.
- **Super AI** This kind of AI system is incredible; it allows computers to outsmart humans and outperform cognitively featured people in every task. They will be capable of independent thought, reasoning, problem-solving, judgment, planning, learning, and communication. Super

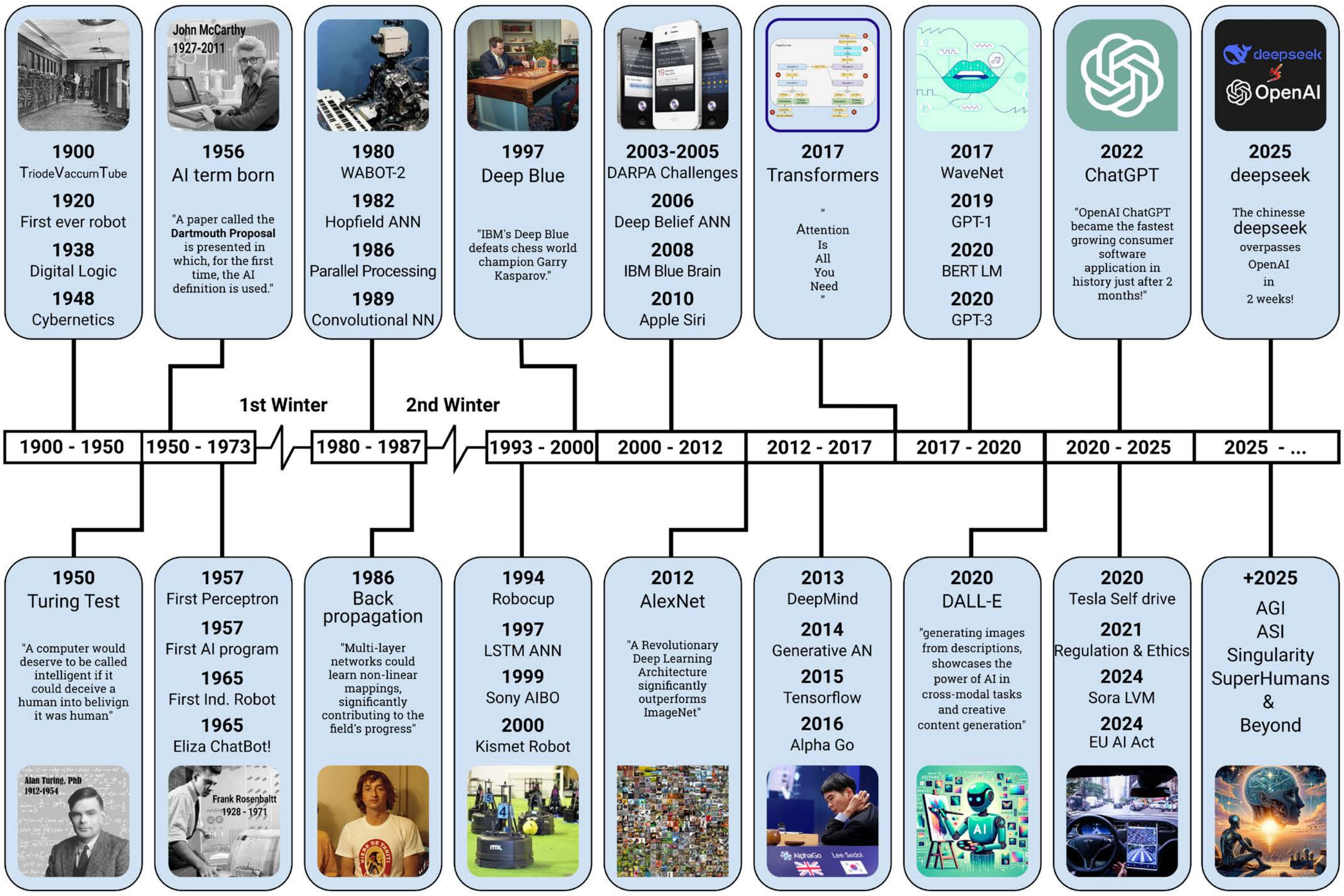

Figure 1: AI-History- Timeline (5).

[Source: https://commons.wikimedia.org/wiki/File:AI-History-Timeline-300dpi.jpg]

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DOI:10.26502/fjhs.344

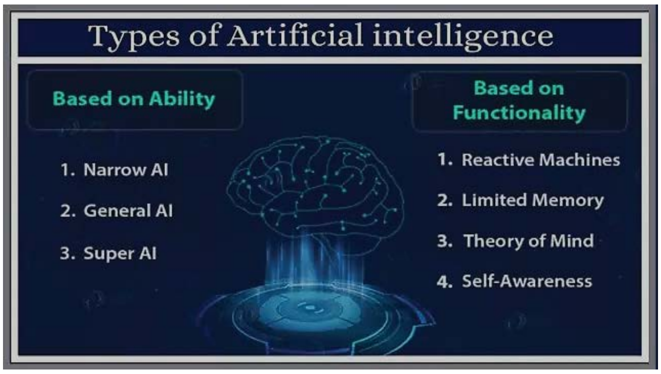

Figure 2: Types of Artificial Intelligence

Artificial Intelligence is still a theoretical idea in artificial intelligence; in fact, creating such a system is still a monumental undertaking.

Based on Functionality An AI scientist named Arend Hintze (8) categorized AI technology according to whether it was already in use or not. These are the following:

- **Reactive Machines Artificial Intelligence** Memories and prior experiences are not stored for use in future operations by this kind of AI system. They just pay attention to the current circumstance and operate in the most effective manner feasible. For example - Google's AlphaGo and IBM's Deep Blue system
- **Limited Memory Artificial Intelligence** For current and upcoming issues, this system can draw on prior experiences. Some of the decision-making processes in autonomous cars are created exclusively using this technique. The observations that are captured are utilized to document future events, such as changing lanes in a car. The observations do not remain in the memory forever.
- **Theory of Mind Artificial Intelligence** In other words, it means every human being has thoughts, intents, and desires that influence their choices. This AI doesn't exist.

Self-aware Artificial Intelligence The AI systems are sentient and have a feeling of self. If the machine is self-aware, it recognizes the situation and applies the concepts found in other people's minds. This AI doesn't exist.

AI's necessity in pharmaceutical systems

The application of AI in pharmacy systems is gaining popularity, but it's crucial to remember that its deployment needs to be well thought out and organized. Although AI has the ability to completely transform the sector by offering patients round-the-clock assistance and individualized medication management, it is crucial to make sure that its applications are morally sound and that any potential drawbacks or difficulties are taken care of. Therefore, to guarantee that AI is applied in the pharmacy system efficiently and responsibly, a careful and evidence-based strategy is required. Implementing AI in the pharmacy system will benefit the expanding population by helping to meet the rising demand for healthcare services. AI can assist patients with managing their prescriptions with 24/7 support and individualized medication management. This can enhance patient access to care and lessen the strain on the healthcare system. AI may also lessen unfavourable drug interactions and prescription errors, which would benefit patients and save healthcare expenses. AI can assist in addressing the issues brought on by the expanding population and the rising demand for healthcare services by enhancing medication management and lessening the stress on medical professionals. AI integration into the pharmacy system has the potential to improve the world in a number of ways. First off, by offering patients round-the-clock support and individualized medication management, it can increase access to healthcare services. This can lessen the need for frequent trips to the doctor and help patients better manage their drugs, which can be particularly helpful in places with limited or inaccessible healthcare facilities. Second, by decreasing prescription errors and averting negative drug interactions, AI may minimize healthcare expenditures by reducing hospital stays and associated costs. Thirdly, healthcare professionals may focus on more difficult activities and deliver higher-quality treatment by having less work to do thanks to AI. All things considered, integrating AI into the pharmacy system could enhance healthcare results, lower healthcare expenses, and expand access to healthcare services, improving everyone's quality of life (9).

The traditional pharmacy system is mostly dependent on human expertise and manual procedures, which can result in delays, mistakes, and inefficiencies. For instance, filling a prescription requires a number of manual procedures, including reading the prescription, delivering the drug, and confirming the frequency and amount. These manual procedures can take a lot of time and are prone to mistakes. Additionally, the traditional pharmacy system is unable to customize medication schedules for specific individuals, which may reduce the effectiveness of medications. Nevertheless, pharmacies can improve their operations and get beyond these restrictions by utilizing AI-powered solutions. AI can assist in automating a number of pharmacy workflow processes, such as medication dispensing and prescription interpretation, lowering the possibility of mistakes and increasing productivity. Furthermore, AI can help pharmacists create individualized drug schedules that are based on each patient's particular requirements and medical background by evaluating vast volumes of patient data. The traditional pharmacy system has been successful in giving patients the drugs they need, but it is constrained by its manual procedures and lack of customization. These restrictions can be addressed by using AI-powered solutions,

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DOI:10.26502/fjhs.344

which will improve patient outcomes by increasing the pharmacy system's accuracy, efficiency, and personalization (10).

Pharmacy students' attitudes and knowledge regarding ChatGPT and artificial intelligence (11)

The study looks at pharmacy students attitudes and knowledge about ChatGPT and artificial intelligence. 258 fourth-year pharmacy students at Kitasato University in Japan participated in a survey to gauge their literacy, perceptions of ChatGPT, and knowledge of AI concerning its proper application. 43.7% of students had previously used ChatGPT, according to the results, and 42.5% were able to explain it. More people were familiar with general AI terms like "Machine Learning" than with more specialized ones like "Natural Language Processing." 50.4% of respondents mentioned improved comprehension, and 65.5% thought ChatGPT was efficient. Only 3.5% of respondents correctly identified all improper uses, while 24.8% of respondents chose all safety measures. Compared to the other group [65 participants], the 48 participants [42.5%] who described ChatGPT and had greater AI knowledge provided more accurate responses.

Artificial Intelligence Tools

Several AI frameworks have been applied to current industry problems and are continuously being improved. Some of the AI tools that are popularly used in the pharmaceutical industry are:

- **IBM Watson for Oncology**

IBM [International Business Machines] has created a supercomputer that can answer simple queries for oncologists. Watson is a supercomputer that combines AI with contemporary diagnostic software techniques. By offering a suitable therapy based on the evidence gathered, it assists oncologists in developing better cancer treatment strategies. The best therapy alternatives are provided by this supercomputer once it has reviewed the patient's clinical data and ability. This supercomputer can readily gather patient clinical data, rephrase it in plain English, and compare it with research. Clinical research then determines the most appropriate and effective treatment plan based on patient reports (12). Watson has a vast amount of data from more than 290 medical publications, more than 200 textbooks, 12 million text pages, and literature and arguments selected by Memorial Sloan Kettering Cancer Center [MSK] (2). A 37-year-old Indian software engineer was recently diagnosed with a rare form of breast cancer that was rapidly growing to both of her breasts and threatening to remove both. Dr. Somashekhar, a Bengaluru oncologist, entered his medical records and genomic data into Watson, which within 60 seconds produced workable treatment choices (12).

- **Robot pharmacy**

Robotic technology is used by the University of California, San Francisco [UCSF] Medical Center to prepare and track medications with the goal of enhancing patient safety. They claim that the technology has accurately prepared 3,50,000 doses of medication. Both in terms of size and precision in administering medication, the robot has outperformed humans. Among the robotic technology's capabilities is the ability to prepare injectable and oral medications, including toxic chemotherapy drugs. The UCSF nurses and pharmacists now have more freedom to apply their knowledge by concentrating on providing direct patient care and collaborating with the doctors. The computers in the pharmacy's automated system initially receive electronic medication orders from UCSF's doctors and pharmacists. Following this, the robots select, package, and dispense individual pill doses. The doses are then assembled by machines onto a plastic ring with a barcode. All of the prescription drugs that a patient must take within 12 hours are contained in the thin plastic ring. The automated system's capacity to fill intravascular syringes with the appropriate drugs and make sterile preparations intended for chemotherapy is an addition to its capabilities. Together with two non-refrigerated pharmacy warehouses for the storage and retrieval of supplies and medications, the automated facility also has an inventory management system that tracks every product. Every one of these facilities is completely automated (13).

- **The MEDi Robot**

Medicine and Engineering Designing Intelligence is abbreviated as MEDi. Tanya Beran, a professor of Community Health Sciences at the University of Calgary in Alberta, oversaw the development of the pain management robot. Working in hospitals where children scream during medical procedures gave her the idea. After establishing a rapport with the kids, the robot explains to them what to anticipate during a medical procedure. It provides them with instructions on what to do, how to breathe during the procedure, and coping mechanisms. The robot can be programmed to appear to have AI even though it is incapable of thinking, planning, or reasoning. MEDi, produced by Aldebaran Robotics, is incredibly situation-adaptive, speaks 20 languages, and has built-in facial recognition technology. The robot costs $9000 at retail, but installing the applications required to assist with medical procedures drives up the price to $15000 to $30000. The robot was first created to help with pain management, but over time, its applications have grown to include physical rehabilitation, fundraising, and comfort in between procedures (14, 15).

- **TUG Robots**

Aethon TUG robots are made to move around the hospital on their own, delivering supplies, drugs, meals,

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DOI:10.26502/fjhs.344

specimens, and heavy items like trash and linen. It comes in two varieties: interchange base platform, which may be used to transport racks, bins, and carts, and fixed and secured carts. While the exchange platform is used to move products that may be put into various racks, the stationary carts are utilized to deliver laboratory specimens, sensitive materials, and pharmaceuticals. The TUG is a particularly adaptable and useful resource because it can deliver a variety of carts or racks. During operation, a user-friendly touchscreen enables users to identify the locations from which the TUG must retrieve products or supplies or make deliveries. The TUG automatically determines the optimal route when there are several destinations. Its sensors overlap to identify impediments and provide 180° coverage during navigation. Low-lying obstructions can be detected via the "Light Whisker" array of sonar and infrared sensors. Using TUG has several advantages, such as increased productivity around-the-clock, better patient care, worker safety, employee happiness, and patient safety (16).

Using AI in Pharmacy

AI in drug discovery

The accessible results from many resources, such as high-throughput screening modeling, fragment screening modeling, computational modeling, and previously published data, serve as the starting point for the drug development process. In the drug discovery process, computer-assisted design techniques can either directly or indirectly examine the structural characterisation of drug molecules. Organic synthesis of drug molecules is then carried out. The produced drug molecules or gathered drug compounds undergo high-throughput screening in primary assays, followed by successful structure-activity relationship (SAR) analysis, counter screening, and bioavailability evaluation in secondary assays (4). The methods of induction and deduction are interchanged in drug discovery. In order to obtain the optimal lead molecules, the interchangeable cycle of the inductive–deductive process serves as the final guide. The efficacy of the drug discovery process is increased when some parts of the inductive–deductive cycle are automated, since this reduces uncertainty and inaccuracy. Manufacturers of chemicals and pharmaceuticals use deep learning software, such as "NVIDIA DGX-1," to analyze and extract a large number of patents as well as scientific knowledge based on genomic data (17). The entirety of the information that is accessible to promote scientific study cannot be operated by humans.

AI supercomputers can receive and analyze data to find the relationships between substances and provide innovative medication molecules. Currently, medicinal chemistry methods rely heavily on hit-and-miss approaches and large-scale testing techniques, which can be slow, costly, and often yield results with low accuracy. Different algorithms based on AI, including supervised and unsupervised learning methods, reinforcement, and evolutionary or rule-based algorithms, can potentially contribute to solving these problems. These methods are typically based on the analysis of large amounts of data that can be exploited in different ways. For instance, the efficiency and toxicity of new drug compounds can be predicted using these approaches, with greater accuracy and efficiency than when using traditional methods. AI-based algorithms can also be employed to identify new targets for drug development, such as the specific proteins or genetic pathways involved in diseases. This can expand the scope of drug discovery beyond the limitations of more conventional approaches and may eventually lead to the development of more novel and more effective medications. In conclusion, while traditional pharmaceutical research methods have been relatively successful in the past, they are limited by their reliance on trial-and-error experimentation and their inability to accurately predict the behaviour of new potential bioactive compounds. AI-based approaches have the ability to improve the efficiency and accuracy of drug discovery processes and can lead to the development of more effective medications (18). Table (1) that lists the many AI technologies used in drug development along with their uses, salient characteristics, illustrations, and connections to related websites: (4,19).

AI in Dosage Form Design

To comprehend the effects of medication distribution, the human body system is separated into multiple compartments. Biological membranes serve as the basis for further simplification of the compartments. Biological compartments require physicochemical barriers, which can be used by the medication delivery method inside the body. The rate of penetration based on the administration route is one of the most important parameters for effective drug delivery system monitoring. After entering the stomach environment, the medication taken orally needs to pass through the intestinal or gastric epithelium. The drug's continued distribution into the blood stream depends on this phase. The medicine is delivered to the target site, which may be tissue or any particular cellular component, by the distribution step. It is also possible for drugs to enter the body through intracellular molecules. The majority of drug penetration is passively or actively aided by biological barriers. The molecular characteristics of the medication determine passive diffusion. The results of the computational analysis performed to predict drug distribution using in silico models varied slightly from those of the real drug distribution investigation. The drug's fate in the body is greatly influenced by its interactions with biological components and availability in biological settings. The drug's molecular characteristics control this process. Passive permeation is ineffective for many tiny molecules and physiologically active substances, necessitating a particular drug delivery method. The membrane drives the

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DOI:10.26502/fjhs.344

Table 1: AI technologies used in drug development

AI Tool	Application	Key Features	Examples with Website
Machine Learning [ML] Models	Drug target identification, QSAR modeling, toxicity prediction	Supervised/unsupervised learning, deep learning	DeepChem - https://deepchem.io/ Scikit-learn - https://scikit-learn.org/
Molecular Docking AI	Virtual screening, ligand-receptor binding prediction	Predicts binding affinity of molecules	AutoDock - https://autodock.scripps.edu/ Glide[Schrödinger]-https://www.schrodinger.com/products/glide AlphaFold - https://alphafold.ebi.ac.uk/
Generative AI for Drug Design	De novo drug design, optimization of chemical structures	Uses GANs, VAEs to generate novel compounds	ChemGAN - https://github.com/aspuru-guzik-group/chemical_vae AIDD [AI-driven Drug Discovery by Merck] - https://www.merckgroup.com/en/research/science-space/envisioning-tomorrow/future-of-scientific-work/aiddison.html
Natural Language Processing [NLP]	Literature mining, clinical trial analysis	Text mining, biomedical literature synthesis	IBM Watson - https://www.ibm.com/watson BioBERT - https://github.com/dmis-lab/biobert
Quantum Computing AI	Molecular simulation, energy calculations	Uses quantum mechanics for accurate predictions	Google Quantum AI - https://quantumai.google/ D-Wave Quantum Computing - https://www.dwavesys.com/
High-Throughput Screening AI	Accelerated compound screening, lead optimization	Automated screening, feature extraction	DeepScreening - https://deepscreening.com/ AtomNet [Atomwise]-https://www.atomwise.com/
Systems Biology AI	Pathway analysis, biomarker discovery	Network-based analysis, multi-omics integration	CytoReason - https://www.cytoreason.com/ DeepPath - https://deep-path.ai/
AI in Clinical Trials	Patient recruitment, trial simulation	Predicts outcomes, optimizes trial design	Unlearn.AI - https://www.unlearn.ai/Deep 6 AI - https://www.deep6.ai/

active permeation process. The process of active permeation relies on intricate biological interactions and is propelled by membrane transport. Numerous precise parameters must be investigated in this intricate process employing methodical modeling techniques and computation.

The pharmacokinetic parameters of the drug delivery system are investigated using this more recent computer model. The predictability of preclinical models is one of the main gaps in the pharmacy industry's research and development. The chosen parameters determine the predictability assumption, and complicated in silico models are no exception. The modeled environment allows for a more thorough analysis of all these cases, which are connected to medication interactions with membranes. AI makes it possible to study and evaluate this modeled world more efficiently. Advanced technology for the analysis of such multilayer data is made possible by AI. A deeper comprehension of the research units will result from the analysis's thoroughness. In order to find the best results, the methodically applied model and parameter evaluation are based on a number of elements, including simulation, scoring, and refinement at every stage of the research process. For better guessing and anticipated data refinement for continuous improvement, AI may offer an automated solution that can be used for all of these tasks. The system biology type of the databases indicates that a solid understanding of the drug–biological interaction is necessary for better AI training in the biological environment. Numerous cutting-edge AI technologies, including artificial neural networks, can be used to conduct pharmacokinetic investigations. Additionally, AI offers a variety of databases, including chemical, genomic, and phenotypic databases, to enhance comprehension of medication interactions and facilitate the efficient investigation of the intricate unit roles of molecules. In order to effectively comprehend the medication's toxicity and disposition, several techniques are also used to investigate how the drug delivery system affects the drug's pharmacokinetics. Designing quality and important qualities and assessing their effects on experimental trials before conducting actual tests are key components of many novel methods for medication delivery systems.

AI has the advantage of gathering data from various sources and indicating how the chosen drug delivery method should function to get the desired effects. The assessment of patient, pharmacokinetic, and molecular data is regarded as a component of the complicated data for analysis to potentially choose the most effective active pharmaceutical to treat patient conditions or needs. When identifying molecular entity features, the passive form of AI is used to compare them to those of known molecules. The precision of the medication delivery system selection, which AI provides, is essential to effective treatment. AI is helpful for both the drug repurposing approach and the drug discovery process. This deals with how the current treatments can be applied to the new illness. Formulation, pharmacokinetics, and medication development are significantly influenced by the patient's needs and the state of their illness. The availability of databases with comprehensive information is one of the main obstacles to the full-scale use of AI in the development of delivery systems. This is necessary in order to evaluate the models and parameters objectively. Using existing information, AI aids in future applications (20).

AI in Polypharmacology

Because of a better understanding of the pathogenic processes in diseases at the molecular level, the "one-disease–multiple-targets" paradigm currently predominates over the "one-disease–one-target" paradigm. Polypharmacology is the word for one disease, numerous targets (21). Numerous databases are available to integrate various information about molecular pathways, crystal structures, binding affinities, drug targets, disease relevance, chemical properties, and biological activities. These databases include ZINC, PubChem, Ligand Expo, KEGG, ChEMBL, DrugBank, STITCH, BindingDB, Supertarget, and PDB, among others. AI could be utilized to probe these databases to create polypharmacological agents. An achievement narrative of the use of AI in creating polypharmacological agents was recently released in the book. The writers created a computational platform, DeepDDI, for better comprehension of drug-drug interaction and connected it to the mechanisms and forecasting of an alternative medication for intended clinical utilize without adverse health impacts (1).

AI in Clinical pharmacy

AI has become a transformative force in healthcare, with its applications rapidly expanding across various sectors, including clinical pharmacy. AI systems are designed to assist pharmacists and healthcare providers in delivering effective, efficient, and personalized patient care. By leveraging machine learning, natural language processing, and predictive analytics, AI tools enhance decision-making processes, optimize workflows, and improve patient outcomes. These technologies enable pharmacists to use vast amounts of patient data to make more informed decisions, mitigate risks, and provide tailored therapeutic regimens. AI applications in clinical pharmacy can be divided into several key areas. One of the most prominent is medication safety, which is being optimized through AI-driven systems that track medication-taking behavior and provide personalized interventions to improve patient compliance. Furthermore, AI is integral to patient-centered care, enabling personalized treatment plans that align with each patient's unique characteristics and preferences. Integrating AI into these areas not only improves the safety and efficacy of medications but also helps streamline pharmacy operations, reducing the burden on healthcare professionals. The importance of drug safety, adherence, and patient-centered care cannot be overstated, especially in the context of a healthcare system that increasingly relies on complex medication regimens. Medication errors are a leading cause of harm in healthcare systems worldwide, so improving drug safety is a top priority for clinical pharmacy.

Medication adherence, or the extent to which patients follow prescribed treatment regimens, is another crucial factor in ensuring the effectiveness of medical treatments. Poor adherence can lead to treatment failure, relapse of chronic conditions, and increased healthcare costs. Improving adherence is especially important for managing chronic conditions, where long-term medication regimens are necessary for maintaining health and preventing complications. Patient-centered care focuses on treating patients individually, recognizing their preferences, values, and unique needs in decision-making. By integrating AI technologies into clinical pharmacy practices, pharmacists can better understand patient’s needs, preferences, and behaviors, allowing for the development of more personalized treatment plans. AI's potential to address these three critical areas—drug safety, adherence, and patient-centered care—forms the foundation for its transformative role in clinical pharmacy. Integrating AI into these areas can lead to more accurate, personalized, and efficient medication management, improving patient health outcomes. AI applications in medication error detection and prevention are particularly important, as they can help prevent medication errors, such as incorrect prescriptions and wrong dosages, which pose significant risks to patient safety. AI-powered systems can instantly verify prescriptions against established clinical guidelines, patient data, and other relevant information (22).

Artificial Intelligence in Rare Disease Treatment: A Breakthrough in POEMS Syndrome (23)

Joseph Coates, 37, who has POEMS syndrome, was informed that he will either pass away in the hospital or at home. He suffered from failing kidneys, an enlarged heart, and numb hands and feet. A stem cell transplant could have placed him into remission, but he was too ill to get one. But Tara Theobald, his girlfriend, wasn't prepared to give up. A Philadelphia physician named David Fajgenbaum, to whom she appealed via email for assistance, recommended an unusual course of treatment for Coates's illness that included immunotherapy, steroids, and chemotherapy. Coates responded to treatment within a week, and after four months, he was well enough to get a stem cell transplant. He is in remission as of right now. An artificial intelligence model spit out the life-saving medication regimen. AI is being used by researchers all across the world to go through current medications for rare disease remedies. Machine learning and drug repurposing are accelerating the process and may increase therapy options for those with uncommon diseases and limited options. Drugs are being swiftly repurposed for ailments such as aggressive and rare cancers, deadly inflammatory disorders, and complex neurological conditions, thanks to variations of the technology created by

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DOI:10.26502/fjhs.344

Dr. Fajgenbaum's team at the University of Pennsylvania and other locations.

AI-Powered Assistive Technologies: Enhancing Mobility for the Visually Impaired (24)

Artificial intelligence (AI) is revolutionizing assistive technology, offering new hope for individuals with disabilities. One such groundbreaking innovation is **Lumen's AI-powered smart glasses**, designed to enhance mobility and independence for the visually impaired. These glasses use advanced AI algorithms to interpret the surroundings, detect obstacles, and provide real-time guidance, mimicking the functionality of a guide dog. Recent advancements in AI-driven assistive devices have demonstrated significant improvements in accessibility, allowing visually impaired individuals to navigate complex environments with greater confidence. Technologies like computer vision, machine learning, and real-time spatial mapping are now being integrated into wearable devices, enabling a more seamless interaction with the world. A key example is Lumen's AI-powered glasses, which leverage neural networks and haptic feedback to provide users with enhanced spatial awareness. This innovation marks a major step toward fostering independence for the visually impaired, reducing their reliance on external assistance. The development of such AI-driven solutions not only enhances mobility but also aligns with the broader goal of inclusive technology in healthcare.

As AI continues to evolve, its application in assistive technology will likely expand, further transforming the lives of those with disabilities. Future research should focus on refining these technologies, making them more affordable, accessible, and integrated into daily life.

Benefits of Artificial Intelligence (25)

AI technology is a complex combination of mathematics, computer science, and other sciences that enables machines to reproduce the cognitive abilities of humans. It offers several advantages, including error reduction, difficult exploration, daily applications, digital assistants, repetitive jobs, medical applications, and technological growth rate. Error reduction is achieved by using intelligent robots for space exploration due to their metal bodies and resistance to harsh atmospheric conditions. Difficult exploration is achieved in mining and fuel exploration sectors, where AI systems can perform more hard work and laborious work without exhaustion. Daily applications include GPS systems, digital assistants, repetitive jobs, medical applications, and technological growth rate. AI systems, such as Lady SIRI and Cortana robots, can predict typing and correct spelling errors, identify and tag faces on social media, and manage data to detect swindles. Digital assistants, or avatars, are used by organizations to reduce human resources and think logically, unlike human emotions that can affect judgment and efficiency. Machines can perform multitasking and think faster than humans, and can perform dangerous tasks with adjustable parameters. Medical applications involve AI in assessing patients and analyzing health risks, and AI programs educate physicians about various medicines and their side effects. AI technology also contributes to the development of advanced technological innovations, such as QSAR and QSPR, which can help find new chemical compounds and entities.

Drawbacks of AI in the healthcare industry besides its benefits (26)

The healthcare industry is experiencing significant transformation due to the increasing cost of healthcare and the scarcity of educated experts. To address these challenges, the industry is integrating new IT-based technologies and processes. Challenges include accessibility, high costs, waste, and an aging population. Pandemics like COVID-19 have exposed flaws in healthcare systems, such as insufficient protective equipment, inaccurate diagnostic tests, overworked physicians, and a lack of information exchange. To address these issues, new systems of care and administrative support for healthcare can be implemented. However, accessing healthcare remains difficult due to complex networks. ML, an artificial intelligence application, can assist medical practitioners in patient care and clinical data management. AI has the potential to simplify healthcare systems and advance medical research. Medical care delivery systems are artificially intelligent, and AI can be used in diagnostics, treatment choices, and communication. AI has the potential to make healthcare more personalized, predictive, preventative, and interactive. It will continue its current path and become a mature and effective tool for biology. However, there are several obstacles to successfully implementing AI in healthcare, including data collection, technological development, clinical application, and ethical and societal concerns. To highlight the drawbacks of AI in the healthcare industry, besides its benefits, are as follows:

The use of machine learning (ML) and deep learning (DL) in healthcare has several challenges, including data collection, privacy, and algorithm development. The healthcare industry faces a complex issue with information accessibility, as patient records are often considered confidential. This makes it difficult for AI-based systems to constantly improve as more data is added to their training set. AI-based systems also raise concerns regarding data security and privacy. Health records are important and vulnerable, and hackers often target them during data breaches. Maintaining the confidentiality of medical records is crucial, and users may mistake AI systems for people and provide their consent for covert data collection, raising serious privacy concerns. In 2018, Google acquired DeepMind, a leader in healthcare AI, which led to criticism for uploading data on 1.6 million patients without patients consent to construct its algorithm.

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DOI:10.26502/fjhs.344

A patient data privacy investigation on Google's Project Nightingale in the USA further complicated the situation. The General Computational Regulations of Europe and the Health Research Regulations, both of which went into force in 2018, can help resolve this problem by restricting the collection, use, and sharing of personal information. However, data privacy regulations established to solve this issue may restrict the quantity of data accessible to train AI systems on a national and global scale. To avoid stifling innovation in the industry, more stringent data security regulations are needed. Analyzing the quality of data used to develop algorithms is also challenging. Patient data is estimated to have a half-life of around 4 months, and medical records are seldom organized neatly due to erroneous and inconsistent storage. Datasets used to develop AI systems will always include unforeseen gaps, despite intensive attempts to clean and analyze the data. Algorithm development concerns include potentially distorted outcomes due to biases in data collection processes used to inform model development. For instance, under-representation of minorities due to racial biases in dataset development might lead to subpar prediction results. While many methods exist to combat this bias, it is possible for AI models to deal with bias on their own, like the existing stereotype neural network. Time will tell whether these strategies are successful in eliminating bias in the real world.

Conclusion

AI is undeniably reshaping the pharmaceutical and healthcare industries, offering innovative solutions to long-standing challenges. From streamlining drug discovery and optimizing dosage form design to advancing polypharmacology and clinical pharmacy, AI is making significant strides in improving efficiency, accuracy, and decision-making. Its ability to analyze vast datasets, predict drug interactions, and enhance patient-centered care has positioned AI as a powerful tool in modern healthcare. However, as with any technological advancement, AI comes with its own set of challenges. Ethical concerns, data privacy issues, algorithmic biases, and the potential reduction of human involvement in critical decision-making remain areas of concern. While AI can process information at an unprecedented speed, it lacks the human touch—empathy, critical reasoning, and ethical judgment—that healthcare professionals bring to patient care. Therefore, AI should be seen as an **assistive technology rather than a replacement for human expertise**. The role of AI in pharmacy education is also crucial, as the next generation of healthcare professionals must be well-equipped to integrate these technologies effectively. Pharmacy student's attitudes toward AI highlight the need for comprehensive training programs that blend technological proficiency with ethical considerations. Encouraging a balanced approach will help future pharmacists leverage AI tools while maintaining patient trust and professional integrity.

Looking ahead, the continued development and responsible implementation of AI will be key to unlocking its full potential. A **collaborative effort** among researchers, healthcare providers, regulatory authorities, and AI developers is essential to address challenges while maximizing benefits. By fostering transparency, ethical responsibility, and regulatory oversight, AI can be harnessed to enhance drug development, personalize patient care, and improve overall healthcare outcomes. In conclusion, AI is not merely a technological trend but a transformative force that, when used responsibly, can **revolutionize pharmaceutical sciences and healthcare delivery**. However, success lies in striking the right balance—leveraging AI's strengths while ensuring that human expertise, compassion, and ethical considerations remain at the forefront of patient care.

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Citation: Kiruthiga P, Kumudhaveni B, Yuvaranjani G, Monisha S, Sindhu Aj, Radha R. Revolutionizing Pharmacy with Artificial Intelligence: A Comprehensive Review. Fortune Journal of Health Sciences 8 (2025): 835-844.