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The Promise and Perils of Artificial Intelligence in Pharmaceutical Industries and Healthcare System

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Abstract

Artificial intelligence is quickly changing the pharmaceutical and healthcare businesses. AI improves medicine research, development, and delivery and personalizes patient care. AI screens vast libraries of chemicals for drug candidates in drug development. AI can automate this laborious operation. AI can also forecast drug candidate toxicity and effectiveness, reducing the number of clinical trials. Clinical trials employ AI to choose the best patients. Clinical studies are costly and time-consuming, so selecting people most likely to benefit from the therapy is crucial. AI can design more efficient and successful clinical trials. AI is used in personalized medicine to discover disease-related genetic alterations. This data may be utilized to create patient-specific therapies. A patient's medication response may also be predicted by AI. AI in pharmaceutical and healthcare research is still developing, but it might transform these sectors. AI can automate jobs, enhance decision-making, and provide new insights to produce more effective disease therapies, speed up clinical trials, and give personalized medicine**.** The present article explores the use of artificial intelligence (AI) in drug research and development, drug repurposing, pharmaceutical productivity, and clinical trials, among other areas, to minimize human effort and fulfill deadlines. We also look at how AI tools and processes interact, present difficulties and solutions, and the future of AI in the pharmaceutical industry.

Keywords: Artificial intelligence, AI, Drug discovery, Pharmaceutical quality management, Clinical trials**.**

1. Introduction

A specialized area of computer science titled artificial intelligence (AI) focuses on building intelligent agent systems that can think, learn, and act independently and is concerned with developing such agents. AI research has had great success in creating efficient methods for dealing with a variety of issues, from gameplay to medical diagnosis [1]. Even though artificial intelligence is still in its infancy, it has the potential to completely transform a wide range of sectors. We may anticipate seeing even more ground-breaking applications of artificial intelligence (AI) to enhance our lives as technology advances. Depending on the work, AI could be able to replace manpower in different ways. A few operations that are now carried out by people, including customer service or data input, may in certain circumstances be automated using artificial intelligence (AI). In some situations, artificial intelligence (AI) may be utilized to improve human talents, such as when giving physicians insights into X-rays or when assisting attorneys in finding pertinent case law. AI is a wide area with several methodologies, following are some of the most popular AI strategies: Machine learning, which enables computers to learn from data without explicit programming. Large datasets of labelled data are used to train machine learning algorithms so they can find patterns in the data. This may be used to a variety of issues, including anticipating client behavior or uncovering fraud. Deep learning, is a sort of machine learning that learns from data using artificial neural networks. Artificial neural networks, which are modelled after the human brain, are capable of resolving issues that conventional machine learning approaches find challenging or impossible. Deep learning has been utilized to provide cutting-edge outcomes in a number of industries, including voice identification, picture recognition, and natural language processing. Rule-based systems, This kind of AI bases choices on rules. Rule-based systems are often used in situations where the rules are well specified, such as in fraud detection or medical diagnostics. Case-based reasoning, is a kind of AI that keeps track of examples and applies them to brand-new issues. In applications like customer assistance or legal reasoning where there is a limited quantity of data, case-based reasoning is often employed [2].

The evolution of artificial intelligence (AI) may be split into five major stages including (a)The pre-history of AI (1940s-1950s) was marked by the creation of early AI ideas and procedures, such as Alan Turing's Turing test and John McCarthy's suggestion of the phrase "artificial intelligence." (b) The first wave of AI (1950s-1970s) was defined by the creation of early AI systems such as ELIZA and MYCIN. These systems were based on rule-based reasoning and had limited capabilities. (c) The AI winter (1970s-1980s) was marked by a drop-in interest in AI owing to a variety of issues, including the difficulty of constructing effective AI systems and a lack of financing for AI research. (d) The second wave of AI (1980s-1990s) witnessed a revival of interest in AI owing to the development of new methods such as machine learning and neural networks. These strategies enabled AI systems to learn from data and improve their performance over time. (e) The third wave of AI (2000s-present) is distinguished by the fast growth of AI technologies such as deep learning and natural language processing. These methods have allowed AI systems to attain human-level performance in a range of tasks, including image identification and voice recognition (Figure 1).

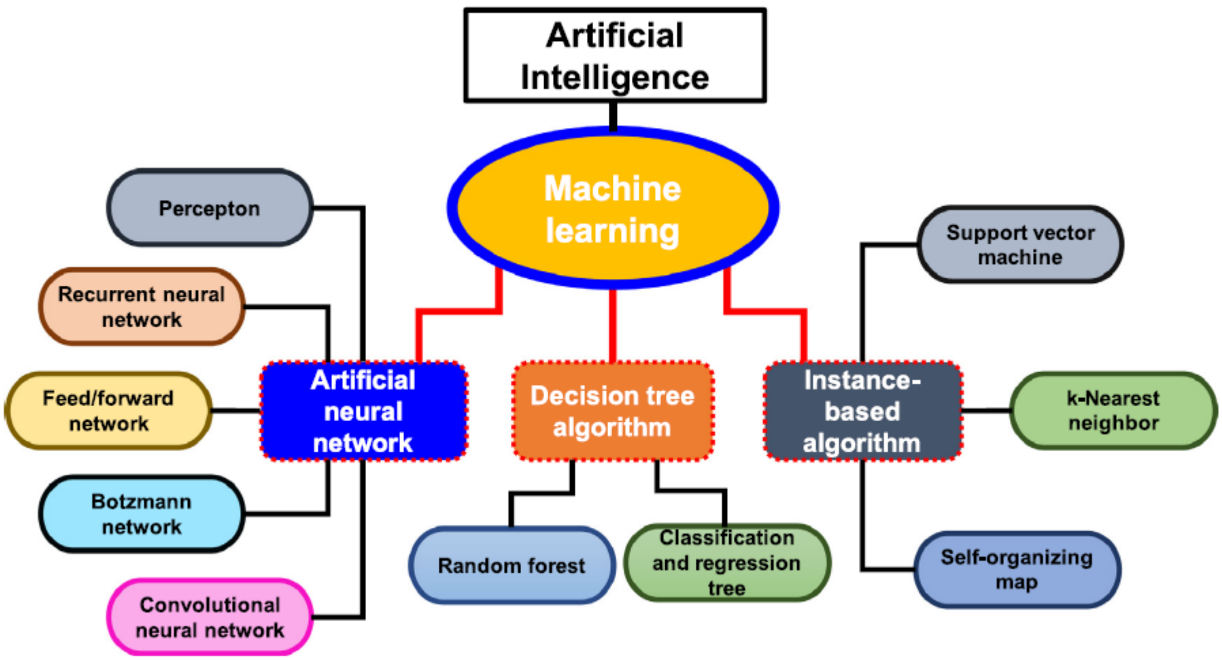

Figure 1: Artificial intelligence-based model

The history of AI is lengthy and convoluted, yet it is apparent that the discipline is fast evolving. As AI technologies advance, we should expect to see even more inventive and profound uses of AI in the future (Figure 2) [3]. Here we are enlisting some of the most significant AI milestones:

1950: Alan Turing publishes his article "Computing Machinery and Intelligence", proposing the Turing test as a method of measuring a machine's intelligence [4].

1956: John McCarthy organises the Dartmouth Summer study Project on Artificial Intelligence, which is often regarded as the beginning of the area of AI study.

1957: Arthur Samuel creates the first machine learning algorithm capable of learning to play checkers.

1966: Joseph Weizenbaum creates ELIZA, a chatbot capable of simulating human communication.

1972: Edward Feigenbaum creates MYCIN, a medical expert system that can identify illnesses.

1982: Yann LeCun creates the LeNet-5 neural network design, which is used for image identification.

2012: Geoffrey Hinton, Ilya Sutskever, and others create the ImageNet Large Scale Visual Recognition Challenge (ILSVRC) as a benchmark for image recognition systems.

2015: Google DeepMind's AlphaGo overcomes a professional Go player, which is seen as a big advance for AI [5].

2022: ChatGPT, a GPT-3.5 chatbot, was trained using a massive corpus of text by Open AI, which had no Internet connectivity at the time. This natural language processing system, published on 30 November 2022, generates human-like text from inputs [6].

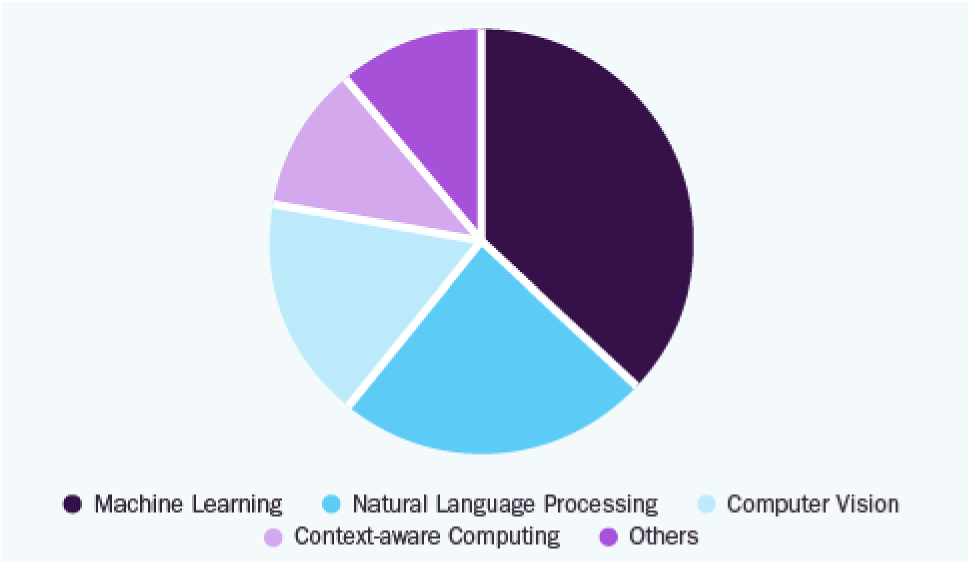

Figure 2: Global automotive artificial intelligence market in 2022 (%)

2. Current Scenario of Artificial Intelligence in Global Market

The worldwide artificial intelligence in drug discovery market was worth USD 1.1 billion in 2022 and is anticipated to rise 29.6% from 2023 to 2030 (Figure 3). The life science industry's increased production capacity and desire for innovative medical treatments are driving the demand for AI-enabled drug discovery solutions. Since most top sellers fall off patent, life science manufacturers regularly replace their product pipelines [7]. Market growth is also driven by public-private collaborations promoting AI-powered medication research and development. The U.K. prioritises research and development, whereas France, the U.S., Spain, and Japan dominate clinical trials. According to industry journals, creating innovative medication treatments costs USD 2.6 billion and takes over 10 years. The tight development testing funnel eliminates most potential therapeutics in preclinical and phase-1 trials, which increases costs and timeframes. AI technologies minimise barriers, shorten clinical trial cycle time, and boost clinical trial productivity and accuracy. In the life science field, these powerful AI technologies are becoming more prevalent in drug development [8]. Strategic agreements between key AI-based drug discovery startups and pharmaceutical corporations expanded from 4 in 2015 to 27 in 2020, according to Clinical Trials Arena statistics in 2021 [9]. In the current scenario, there is a vast Digitalization in biology, and clinical research provides AI solutions. Because compound screening and preclinical trials generate vast datasets, AI techniques are employed. AI can speed up screening and reduce turnaround time for researchers analyzing huge datasets. COVID-19 has also changed clinical trial perspectives and increased AI usage [10]. Pfizer, Novartis, Bayer, Sanofi, and Johnson & Johnson use AI-based drug discovery. Customization, data mining, and other AI drug development techniques are driving the market. Deep learning and machine learning increase drug molecule binding feature detection in AI systems. Advanced technologies like EDC help manufacturers manage patient data and reduce monitoring costs. Using AI with e-COA decreases errors. Advanced analytics in these AI systems aid stakeholders with data mining, patient recruitment, and medical and clinical records administration. The highest revenue loss and lowest returns in clinical trials are in preclinical testing. AI reduces preclinical testing costs. Without experiments, AI models study human physiological responses. AI solutions for medication development are predicted to rise due to global clinical trial research regulations. Governments in developed and developing nations are encouraging AI adoption and clinical trials [11].

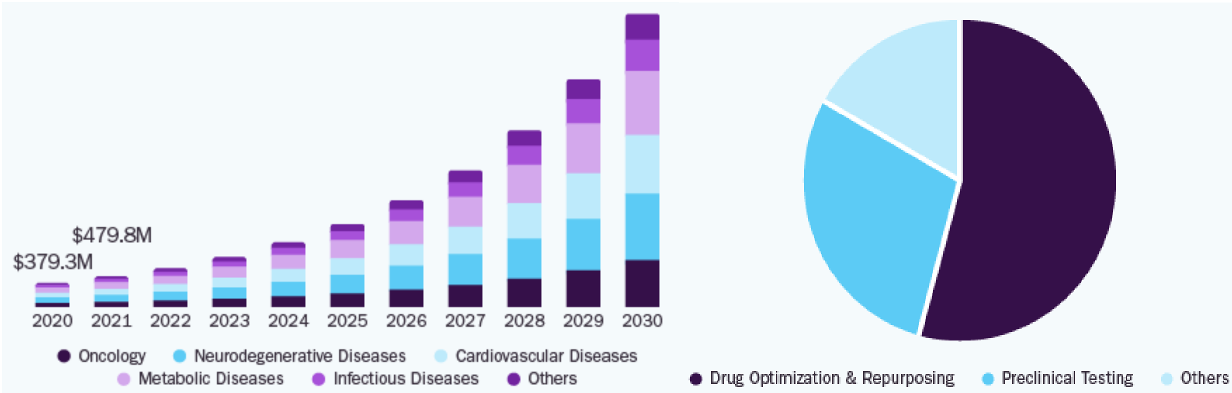

Figure 3: Artificial intelligence market in drug discovery; by various therapeutic area covering 2020-2030 in USD million

Pharmaceutical and healthcare sectors are fast changing due to AI. Personalized patient care and medicine research, development, and delivery are being improved by AI [12]. Recently, there has been a surge in interest in employing AI in medicinal chemistry to transform the pharmaceutical industry. The process of identifying and developing new pharmaceuticals, known as drug discovery, is time-consuming and involves trial-and-error testing and high-throughput screening. AI techniques such as machine learning (ML) and natural language processing may help to accelerate and improve this process by evaluating massive amounts of data more rapidly and precisely [13]. The scientists recently reported on using deep learning (DL) to precisely predict the efficacy of pharmaceutical compounds. AI may also predict the toxicity of medication candidates. These and other research suggest that AI can improve the efficiency and effectiveness of drug development. AI can find new bioactive compounds, but it has limitations. Ethics must be addressed, and more research is needed to understand AI's benefits and drawbacks in this area. Despite these challenges, AI will significantly enhance medicine and treatment research in the forthcoming years [14].

3. Role of Artificial Intelligence in Various Field of Health Care System

AI is being used more in society, especially in the pharmaceutical business. This review discusses the use of AI in drug discovery and development, drug repurposing, pharmaceutical productivity, and clinical trials, among others, to reduce human workload and meet targets quickly. We also explore crosstalk between AI tools and methodologies, current issues and solutions, and the future of AI in the pharmaceutical business [15]. AI has revolutionized patient diagnosis, treatment, and monitoring. More precise diagnosis and personalized therapies are greatly boosting healthcare research and results using this technology (Figure 4). AI in healthcare can swiftly analyses massive clinical paperwork to find illness signs and patterns that would otherwise be missed [16]. From analyzing radiological images for early detection to predicting outcomes from electronic health information, AI has many healthcare uses. Artificial intelligence can make hospitals and clinics smarter, quicker, and more efficient in treating millions of patients. Healthcare AI is changing how patients get excellent treatment, lowering provider costs, and increasing health outcomes [17]. AI has incredible healthcare potential, in healthcare, it will transform data processing, diagnosis, treatment, and prevention. Medical workers may make better judgments with more accurate data utilizing artificial intelligence, saving time, and money, and enhancing medical records management [18]. AI in healthcare will revolutionize medical care by discovering novel cancer therapies and enhancing patient experiences. Artificial intelligence is being used to enhance several aspects of the healthcare system, including drug research, clinical trials, personalized medicine, medical imaging, healthcare decision-making, healthcare management, and diagnostics [7].

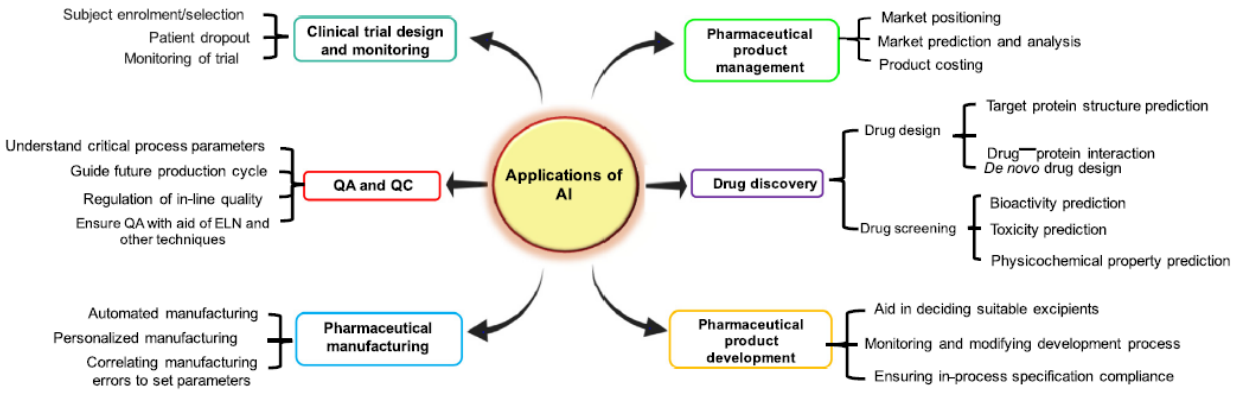

Figure 4: Application of artificial intelligence in various subfield of pharmaceutical industry.

3.1. Artificial intelligence in drug discovery: Conventional drug discovery takes around 20 years to commercialize a single medicine. Currently, AI can identify hit and lead compounds and validate the drug target and optimize the drug structure design faster. AI struggles with data volume, growth, variety, and unpredictability despite its benefits. Pharmaceutical company drug research data sets may include millions of molecules, which typical ML methods may not be able to handle [19]. Table 1 delineate the list of various artificial intelligence enabled tools employed in drug discovery. The quantitative structure-activity relationship (QSAR)-based computer model may rapidly predict several chemicals or basic physicochemical parameters like log P or log D. These models can not anticipate complicated biological features like chemical effectiveness and side effects. QSAR-based models also have issues with short training sets, experimental data inaccuracy, and lack of experimental validations. To solve these issues, freshly emerging AI tools like DL and relevant modelling studies may be used to evaluate drug molecule safety and effectiveness using big data modelling and analysis. Merck funded a 2012 QSAR ML competition to demonstrate DL's drug discovery benefits. AI helps drug development by designing new molecules with specified features and activities [20].

Table 1: List of AI based software advancing drug discovery and development process [21].

Application	AI Method	Description	Software and Tools
Drug discovery	Virtual screening	Screening of large libraries of compounds for potential drug candidates using AI algorithms.	AutoDock Vina, Schrödinger Suite, Cheminformatics Suite
Target identification	Machine learning	Identifying potential drug targets by analyzing large datasets of biological data.	DeepChem, Dragonfly, BenevolentAI
Drug design	Generative adversarial networks	Designing new drug molecules that are likely to be effective against a particular target.	AlphaFold, generative adversarial networks
Toxicity prediction	Machine learning	Predicting the toxicity of drug candidates.	ToxCast, Tox21, REACH
Personalized medicine	Machine learning	Developing treatments that are specifically tailored to the individual patient.	IBM Watson Health, GRAIL
Clinical trials	Machine learning	Improving the design and analysis of clinical trials.	Enlitic, Insilico Medicine
Healthcare data analysis	Machine learning	Identifying patterns in healthcare data to improve diagnosis, treatment, and prevention of diseases.	Google Health, IBM Watson Health
Medical image analysis	Computer vision	Identifying and classifying medical images, such as X-rays, CT scans, and MRIs.	IBM Watson Health, Google Cloud Healthcare API

Natural language processing	Natural language processing	Understanding and analyzing medical text, such as patient records and clinical trial data.	Google Cloud Healthcare API, Amazon Comprehend Medical
Robotics	Robotics	Developing robots that can perform medical tasks, such as surgery and drug delivery.	Intuitive Surgical, Boston Dynamics
Virtual reality	Virtual reality	Creating virtual environments that can be used for training, simulation, and therapy.	Oculus Rift, HTC Vive
Augmented reality	Augmented reality	Superimposing digital information onto the real world, such as for surgical guidance and medical education.	Microsoft HoloLens, Magic Leap
Blockchain	Blockchain	Storing and managing medical records and other healthcare data in a secure and decentralized way.	Hyperledger Fabric, Corda

Traditional approaches include lengthy, laborious chemical identification and modification. However, AI-based techniques can quickly and efficiently develop new molecules with desired characteristics and activities. A deep learning (DL) algorithm was trained on a dataset of known drug compounds and their properties to propose new therapeutic molecules with desirable properties like solubility and activity, demonstrating the potential for rapid and efficient drug candidate design [22]. Since developing AlphaFold, a groundbreaking biology software platform, DeepMind has made important contributions to AI research. This strong method predicts protein three-dimensional architectures using protein sequence data and AI. These structural biology advances should revolutionise personalised medicine and drug discovery. AlphaFold advances AI in structural biology and life sciences. ML and MD simulations are improving de novo drug design efficiency and accuracy [23]. Combining these methods to maximise synergy is being investigated. Interpretable machine learning (IML) and DL approaches are also helping. Researchers may create medications more efficiently and effectively using AI and MD. Several in silico techniques for virtual screen compounds from virtual chemical spaces, combined with the structure and ligand-based methodologies, improve profile analysis, eliminate nonlead compounds, and pick therapeutic molecules at a lower cost [24]. Molecular fingerprint recognition and coulomb matrices use physical, chemical, and toxicological features to choose a lead component. Solubility, partition coefficient (logP), degree of ionisation, and intrinsic permeability indirectly affect pharmacokinetics and target receptor family, therefore innovative medicines must address these [22]. Different AI approaches predicts physicochemical properties. ML trains on massive compound optimisation data. Drug design methods employ DNN to build viable compounds and predict their features using chemical descriptors including SMILES strings, potential energy measurements, electron density around the molecule, and 3D atom coordinates [25]. Target protein or receptor affinity influences drug efficacy; however, Non-targeted protein-binding drug molecules cannot cure. Developed drugs may interact with unwanted proteins or receptors, producing toxicity [26]. Drug-target binding affinity predicts drug-target interactions. Drug binding affinity may be measured by AI by comparing its properties to its target. Feature-based interactions determine drug-target chemical moieties' feature vectors. Whereas similarity-based interaction suggests similar drugs interact with the same targets [27].

3.2. Artificial intelligence in clinical trials: Clinical studies take 6–7 years and need a lot of money to prove a drug's safety and effectiveness in people. The industry loses a lot since just one in ten molecules cleared these trials. These failures might stem from inadequate patient selection, technological needs, and infrastructure. These problems may be decreased using AI and the huge digital medical data accessible [28]. One-third of the clinical trial timeframe is patient enrollment. To assure clinical trial success, recruit eligible participants, since otherwise 86% of trials fail. Patient-specific genome–exposome profile analysis may help AI pick a particular sick population for Phase II and III clinical trials by forecasting therapeutic targets in the chosen patients. Clinical trial candidates are selected using AI. Clinical studies are costly and time-consuming, so choosing participants most likely to benefit from the therapy is crucial. AI can improve clinical trial design. AI helps identify new molecular targets quicker and better, meeting medicinal needs. To design and train algorithms that yield new stable drugs with treatment potential, preclinical and clinical PK and PD data (including failed trials) is needed. Not having public PK/PD data for competitive or private motives hinders AI in innovative medication development [29]. Many AI safety prediction algorithms are described. Medication toxicity is predicted using target software. Toxicity estimates may replace pre-clinical in vitro and animal studies. Trial design and precision medicine need clinical outcome prediction to remove general population statistical variability [30]. AI can mimic data to improve statistical measures. This article suggests that using an AI system to predict participant outcomes and identify those most likely to move swiftly and reach objectives sooner might reduce trials. AI predicts CT dropout using EMRs. In cardiovascular TA, potential dropouts are targeted and taught to encourage participation. These methods decrease trial samples and participants. ML models may predict regulatory approval and phase transition success using CT design and patient characteristic information [31]. Knowing phase success and failure features (protocol complexity, clinical endpoint selection, interventional arm selection, and eligibility criteria) impacts present and future trial design. AI accelerates hypothesis formation and analysis to enhance illness development, pharmaceutical discovery, cohort composition, monitoring, adherence, and endpoint selection [32]. With enough data, AI systems may predict illness progression in a virtual control arm. A fully virtual placebo arm with produced data might be used. Lower costs, site and patient load, and faster CT exams are possible. Various artificial intelligence enabled software used in clinical trial studies are summarized in **Table 2**.

Table 2: List of AI enabled software used in clinical trials [33].

Software	Application	Description
Enlitic	Drug discovery	Uses AI to identify and prioritize drug targets, design new drug molecules, and predict the efficacy and toxicity of drug candidates.
In silico Medicine	Drug discovery	Uses AI to screen large libraries of molecules for potential drug candidates, identify new drug targets, and predict the efficacy and toxicity of drug candidates.
Atomwise	Drug discovery	Uses AI to design new drug molecules that are likely to be effective against a particular target.
Exscientia	Drug discovery	Uses AI to design new drug molecules and predict their efficacy and toxicity.
Berg Health	Clinical trials	Uses AI to identify patients who are likely to benefit from a particular treatment.
Sherlock AI	Clinical trials	Uses AI to predict the risk of adverse events in clinical trials.
Deep Genomics	Clinical trials	Uses AI to identify patients who are likely to respond to a particular treatment.
Evidation Health	Clinical trials	Uses AI to collect and analyze data from clinical trials.
IBM Watson Health	Clinical trials	Uses AI to automate tasks in clinical trials, such as data collection and analysis.

3.3. Artificial intelligence in pharmaceutical quality management: Production of the desired product from basic resources requires balancing several aspects. Manual intervention is needed for product quality control and batch-to-batch uniformity. This may not always work, highlighting the necessity for AI at this level. The FDA included ‘Quality by Design’ into Current Good Manufacturing Practises (cGMP) to comprehend the key operation and specific criteria that regulate pharmaceutical product quality [34]. AI might revolutionise pharmaceutical quality management (PQM) by automating processes, enhancing efficiency, and minimising mistakes. Disruptive technology typically faces financial, operational, training, and acceptance obstacles. Even in recessions, artificial intelligence (AI) is considered as a commercial driver rather than a financial liability. Between 2016 and 2021, pharmaceutical company filings mentioned AI 105% more. The remarkable pace of safe and effective vaccinations generated during the COVID-19 pandemic proved AI's efficacy. AI can analyse vast volumes of clinical trial, manufacturing, and other data. Data may reveal patterns and trends that humans cannot. AI can analyse PQM risk, this helps identify, prioritise, and mitigate risks [35]. It can monitor compliance with rules and norms. This may improve product safety and PQM efficiency. AI can perform automatic inspection to automate product and process inspection. This improves efficiency and reduces human mistake. AI can forecast equipment and system failure. This reduces downtime and ensures product quality. AI-based recommendation systems may enhance PQM. This helps prioritise resources and find areas for improvement [15] .

3.4. Artificial intelligence in diagnosis of disease: The most essential component in treating any disease is accurate diagnosis [36]. AI is being utilised in medicine to improve diagnosis and understanding of serious illnesses. Since AI can interact constructively with medical picture data, it is increasingly employed in illness detection and prognosis (**Table 3**). AI can diagnose image-based diseases and predict treatment outcomes like survival and responsiveness [37]. Digital images of illnesses are used to diagnose numerous diseases. AI-automated medical image assessments have lowered physician effort, diagnostic mistakes and delays, and illness prediction and detection [38]. AI approaches based on medical image processing use robust algorithms for prediction, diagnosis, and treatment planning, altering decision-making [39]. Healthcare uses advanced AI methods like ML and DL to diagnose diseases, develop medications, and identify risk factors. ML and DL algorithms have benefited from electronic medical records and big data. ML automates prediction and diagnosis via neural networks and fuzzy logic. Professional feature extraction is not needed for DL algorithm, unlike neural network approaches [40]. High-performance DL algorithms enhance medical image fusion, segmentation, recording, and classification. SVM and CNN algorithms are used in most sickness analysis and diagnosis.

Table 3: List of AI based techniques used to diagnose human disease and illness [38].

Software or Technique	**Description**
Medical imaging	This includes techniques such as X-rays, CT scans, MRIs, and ultrasounds. These techniques can be used to visualize internal organs and tissues, and to identify abnormalities.
Laboratory tests	This includes tests such as blood tests, urine tests, and stool tests. These tests can be used to measure the levels of different substances in the body, and to identify infections or other diseases.
Genetic testing	This is used to test for changes in genes that can cause diseases.
Biomarkers	These are molecules that can be measured in the blood or other tissues, and that can be used to diagnose or monitor diseases.
Machine learning	This is a type of artificial intelligence that can be used to analyze data and identify patterns that may be associated with diseases.
Natural language processing	This is a type of artificial intelligence that can be used to analyze text data, such as medical records, to extract information about diseases and treatments.

4. **Future Perspective on Contribution of Artificial Intelligence in Healthcare System** Future drug research and development may leverage AI in several ways. AI can automate data mining, screening, and molecular modelling in drug discovery and development. This might allow scientists to operate more creatively and strategically. AI may help drug research and development teams analyse challenging data [41]. AI might find patient data trends that lead to new pharmacological targets. It can explore massive volumes of data and find patterns that humans cannot notice to produce new drug research and development ideas [42]. AI might create more effective medication candidates. In personalized medicine sector it can customize patient therapies. AI might discover genetic mutations linked to a disease and design medicines targeting them. AI can enhance clinical trials by increasing efficiency and effectiveness. AI might be used to choose the best patients for trials and construct more statistically meaningful studies. AI may design innovative medication delivery methods that target particular tissues or organs to improve drug delivery [43]. AI might create nanocarriers that transport medications to cancer cells. These are some possible drug research and development uses for AI. As technology advances, AI may help these businesses find new and more effective illness treatments. Before AI may be used in drug research and development, multiple challenges must be overcome [44]. The challenges include data availability, quality, interpretability, biases, and ethics. AI in drug research and development may offset these limitations. AI can generate better illness therapies to benefit millions of lives. AI will undoubtedly become more essential in several businesses as technology advances [45,46].

5. **Conclusion**

The pharmaceutical sector is undergoing rapid transformation because to Artificial intelligence. Pharmaceutical quality management, drug research, clinical trials, health care management, and illness detection are improved by AI. AI is being used to find novel pharmacological targets, create new compounds, and forecast medication effectiveness and toxicity. AI is automating drug discovery, which speeds up drug development. AI analyses data identifies challenges, and predicts patient outcomes in clinical trials. AI is also personalizing cli nical studies, which may boost efficiency and efficacy. AI is improving patient care, cost, and healthcare administration efficiency. Data analysis, risk assessment, and result prediction are done using AI. AI automates appointment scheduling and drug management. Artificial intelligence is analysing medical pictures, including X-rays, CT scans, and MRIs, to diagnose illnesses. AI is also analyzing patient records and clinical trial data to derive illness and therapy information. AI is used in pharmaceutical quality management to monitor compliance, detect hazards, and enhance quality control. AI helps design new quality control approaches. AI in the pharmaceutical sector is relatively new but might change medication development, testing, and delivery. We may anticipate new methods to utilize AI to enhance global health as AI technology advances.

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Conflict of interest

None

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