IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

ROLE OF AI IN PHARMACY: A REVIEW

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ABSTRACT: Artificial Intelligence (AI) is becoming more and more common in several aspects of society, especially in the pharmaceutical industry. AI has benefits both professionally and economically. The amount of human labor required is reduced since it mimics human intellect and combines it with state-of-the-art technology to provide the greatest outcomes. The assessment looks at the pharmaceutical industry's beneficial use of AI across several departments and at every step from drug discovery to medication development. It not only reduces the need for human labor but also increases pharmaceutical output and clinical research efficacy while lowering mistake rates. The challenges facing the pharmaceutical business in deploying AI are also examined in the review. It also evaluates existing problems and makes recommendations for fixes.

KEYWORDS: artificial intelligence, clinical trials, disease diagnosis, drug discovery, personalized medicine, prediction.

INTRODUCTION

Artificial Intelligence is the modern world's greatest tool. It helps in many ways to make today's life easy and comfortable. It is a part of computer science which solve the problem with the help of symbolic programming. It of the most important use of AI is to development the problem solving system .The AI was introduced in the year 1956 which is informed by a conference organized by Dartmouth College. John McCarthy is considered as the father of AI.[1] However the appearance of AI in the human use was introduced already in the year 1955 in the form of a tool named Logic Theorist, which is developed by the scientists named Allen Newel, Herbert A. Simon. By this tool or system about 40 theorems of Principia Mathematic by Alfred N. Whitehead and Bertand Russel was resolved and proved. AI focuses on the creating modeling and intelligency to solve a problem. It is now a wide used technology. In pharmaceutical branch it is used in various processes like drug dose count, QSAR [quantitative structural activity relationship], drug development programs, drug discovery aspects and also in the production of ANN's [Artificial neural network].[2] The 1987 is known as the "AI WINTER" as in this period the funding for researches in AI is provided in very less amount by the governments. The "AI WINTER" was fell in the year from 1974-1993. The apps of pharmacy provide various guidance to the patients at home and give them advantages. With the help of AI generated apps people can now get access to various facilities like contact with doctors etc. AI also assist surgeons in the operations, and surgeries. The scientific methods used in drug development and discovery are widely varied and comprise the field of pharmaceutical sciences.[3]

TYPES OF ARTIFICIAL INTELLIGENCE

In modern world the AI also been classified into two basic conditions which are as follows:

1. **According to their ability.**

It is defined as the ability of a computer program to perform the given work. On the basis of their ability it is further classifies as following categories:

a. **Artificial Narrow Intelligence [ANI]**:- This is the most common type of AI they are build to solve one single problem at once. They are having narrow capabilities, like recommending a product on the online shopping platform or in case of weather forecast.[4]

b. **Artificial General Intelligence [AGI)**:-It is a theoretical concept having intelligence level of human being. It is used in various aspects like image processing, language processing, computational functioning and reasoning. The AGI comprises of a thousands of ANI systems which working in tandem, communicating with each other to mimic human reasoning. But still with this level of advancement it takes around 40 minutes to stimulate and recreate an single second of neuronal activity.[5]

c. **Artificial Super Intelligence [ASI]:-** It is the most advanced program based on AI which can easily surpass the human capabilities. The main function of the ASI includes decision making, making art and developing emotional relationship. The ASI is basically the upgraded version of the AGI .While the problem solving gap between ASI and AGI is very low, its about the amount of less than nanosecond.[6]

2. According to their performance

On the basis of their performance or storage capacity it is classified as follow sub types which are as under.

a. **TYPE 1:-**This AI program does not contain any memory chip. They does not possess any data recording ability in them.[7]
Example: chess playing apps.

b. **TYPE 2**:- This AI program uses previous experience to perform a new function or to solve new problem. It possess the short term memory chip.
Example: In automated vehicles.

c. **TYPE 3**:- This program is the best out of above two it is based on the theory of mind. It perform various problem solving steps. It also have the ability to make decisions and also store the previous data for a long interval.[8]
Example:-non existing AI.

d. **TYPE 4**:- It is the most advanced AI tool ever exist. It has the sense of self awareness and even the consciousness. It is basically present in the most advanced robots.
Example: Sofia robot.

(1.) **DRUG DISCOVERY:**

AI Contribution: Utilize machine learning algorithms to analyze biological data, identify potential drug candidates, and predict their efficacy and safety profiles.

(2.) **PATIENT TREATMENT**:

Objective: Tailor treatment plans to individual patient characteristics.[9]

AI Contribution: Analyze patient data, including genetic information, to predict optimal drug choices and dosages for personalized treatment regimens.

(3.) **Drug Interaction and Adverse Event Prediction**:

Objective: Enhance patient safety by predicting and preventing drug interactions and adverse events.[10]

AI Contribution: Analyze large datasets to identify potential drug interactions and predict adverse reactions based on patient profiles.

(4.) **Pharmaco-vigilance**:

Objective: Improve monitoring of drug safety after-market release.[11]

AI Contribution: Utilize natural language processing (NLP) to analyze medical literature, social media, and healthcare records for early detection of adverse drug reactions and safety concerns.

(5.) **Supply Chain Management**:- **Objective**: Optimize pharmaceutical supply chains for better efficiency.[12]

AI Contribution: Use predictive analytics to optimize inventory management, anticipate demand, and ensure the availability of medications.

(6.) Clinical Decision Support Systems:

Objective: Assist healthcare professionals in making informed decisions.

AI Contribution: Develop systems that integrate patient data with medical knowledge, providing real-time guidance to healthcare providers in diagnosis, treatment, and medication management.[13]

(7.) **Patient Adherence and Education**:

Objective: Improve patient adherence to medication regimens and enhance patient education.

AI Contribution: Develop applications and tools that use AI to provide personalized medication reminders, educational materials, and support for patients.

(8.) **Data Analysis and Research**:

Objective: Facilitate research and evidence-based practices.

AI Contribution: Analyze large datasets to identify patterns, trends, and correlations that can inform research studies and contribute to evidence-based decision-making.[14]

(9.) **Fraud Detection and Compliance**:

Objective: Prevent fraud and ensure compliance with regulatory requirements.

AI Contribution: Implement AI algorithms to detect fraudulent activities, monitor compliance with regulatory standards, and enhance overall pharmaceutical industry integrity.[15]

(10.) Cost Reduction and Efficiency:

Objective: Improve operational efficiency and reduce costs.

AI Contribution: Implement automation and AI-driven processes in various pharmacy operations, such as inventory management, prescription processing, and administrative tasks.[15]

Application or Functions:

1. AI in Disease Diagnosis

Disease analysis becomes pivotal in designing a considerate treatment and safeguarding the wellness of patients. The inaccuracy generated by humans creates a hindrance for accurate diagnosis, as well as the misinterpretation of the generated information creating a dense and demanding task. A substantial amount of evidence has revealed that though vulnerable, contradictory, non-analyzing incongruities exist, the development of new methods can define the applicability by portraying the current existing scenario that has not been covered.[16] Nowadays, identification, extraction and catering all the collated data would lead to ample technology usage based on deep learning, neural networking and algorithms.Cancer and dementia are the two major diseases where AI has gained important. Algorithms can never be biased if they are not self-generated or have never with any existing data.[17] Hepatitis can be diagnosed through unsupervised learning. In the diagnosis of liver diseases, decision trees and reasoning were integrated. Many studies were performed for the predictive modeling, which was noticeable for predicting early Parkinson's disease. Recently, algorithm and machine leaning was used by the researchers in identification and classification of cardiac arrhythmia by processing the electrocardiograms signals. In another study, tuberculosis was classified and diagnosed by using the optimization genetic algorithm (GA) and support vector machine (SVM) classifier.[18]

2. AI in Digital Therapy/Personalized Treatment

A variety of newer techniques which are used for computational understanding in this emerging field have the potential to be applied in almost every field of medical science. The development of medical AI has helped clinicians to solve complex clinical problems. The systems such as ANNs, evolutionary computational, fuzzy expert systems and hybrid intelligent systems can assist the healthcare workers to manipulate the data. The ANN is a system that is based upon the principle of the biological nervous system.[19] There is a network of interconnected computer processors called neurons that can perform parallel computations for data processing. The first artificial neuron was developed using a binary threshold function. The multilayer feed-forward perceptron was the most popular model having different layers, such as input layer, middle layer, and output layer. Each neuron is connected through links having numerical weight.[20]

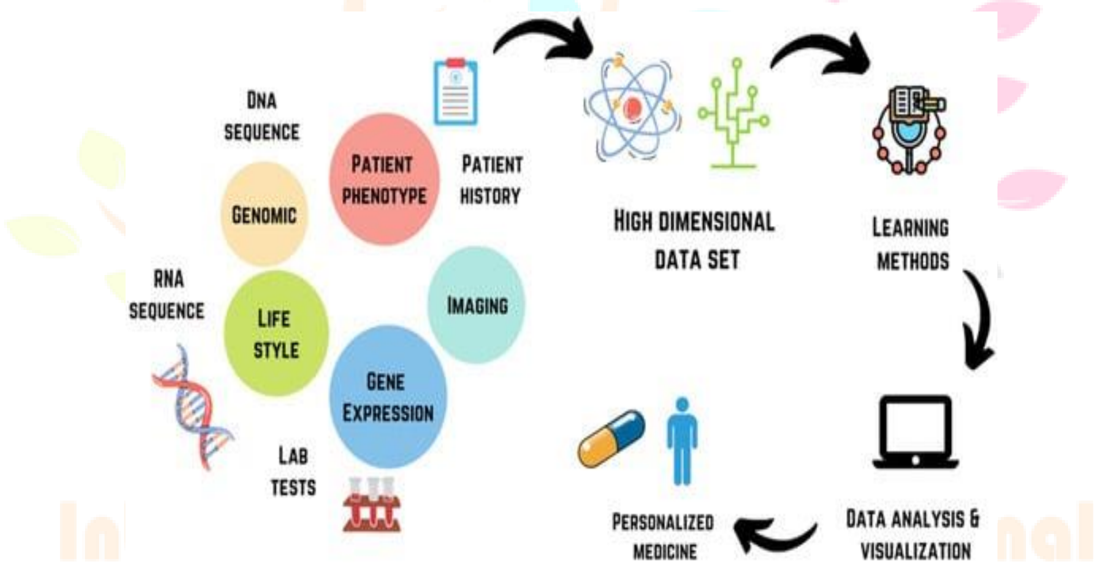

Figure 1. AI in acquiring and analyzing data of a patient in personalizing the treatment.

Paul Werbos introduced a new technique called "Back propagation learning" in 1974, which has a suitable learning algorithm. The ANN has been used in diagnosis image analysis. It mainly uses a continuous set of membership from 0 to 1, i.e., 0 for false and 1 for true. Fuzzy controller has also been used for administering vasodilators and anesthetics in the operating room. This evolutionary computation technique is based on the natural evolution process that is focused upon the natural evolution process and survival of the fittest. The most popular algorithm is the genetic algorithm. It finds out many random solutions for one problem and ultimately, one best solution is chosen, while the inferior ones are eliminated.[21]

3.2. AI in Retina

The high-resolution imaging of the retina has given the scope to assess human health remarkably. From a single photograph of the retina, one can extract highly personalized data; with high-definition medicines, the ophthalmologist/ retinologist can define a personal therapy and establish a continuously improving learning healthcare system.[22]

3.3. AI in Cancer

With the huge applicability of AI, it has gained importance in the fields of diagnosing and treating various cancers. The lymphoma subtypes of non-Hodgkin lymphoma were predicted by using gene expression data in a multilayer perceptron neural network. Lymphoma subtypes includes mantle cell lymphoma (MCL), follicular lymphoma, diffuse large B-cell lymphoma (DLBCL), marginal zone lymphoma and Burkitt . An AI neural network has predicted the lymphoma subtypes with high accuracy. The Multilayer perceptron (MLP) with multivariate analysis of gene expressions reported that four genes correlate with favorable survival and three genes with poor survival for DLBCL. MLP and radial basis function (RBF) neural networks were used for prediction of overall survival and prognosis of Follicular lymphoma (FL) patients. After analyzing 22,215 genes, it was reported that 43 genes are associated with the prediction of the overall survival, whereas 18 genes were associated with poor prognosis. AI provided reproducible, efficient, and affordable assays for classification and further clinical application. AI is used in cancer diagnosis by minimizing the time with high accuracy. AI-based PET imaging of lymphoma is used in tumor burden evaluation which was later applied in characterization of tumor, quantification of heterogeneity, as well as prediction of treatment response.[23]

3.4. AI in Other Chronic Diseases

Different computerized therapies are available based on computer programming techniques. The therapies are focused upon the behavioral and cognitive approach, which involves multiple-choice questions or joysticks. Recently, a new computer interaction has been developed, i.e., intelligent computer-assisted instruction, which has the potential to use other AI technologies such as natural language understanding and expert systems and with the use of AI, one can develop a combination therapy based upon the patient's own biopsy and can adopt *n*-of-1-medication recommendations.[24] Chronic disease requires monitoring on regular basis, and with the use of AI, this monitoring can be performed using virtual medical assistants. Many companies have installed such assistance, which generally provides virtual coaching through text messages with the use of the mobile applications, and with the use of AI, nutrition recommendations can also be given specifically based upon the gut microbiome. Arterial fibrillation can be predicted with the use of an integrated system based upon deep learning, single-lead ECG sensor and physical activity via accelerometer data along with a smart watch. Case-based reasoning, which is designed using AI technique, is being extensively used in the management of diabetes.[25]

4. AI in Drug Discovery

The possibility of the development of a large number of drug molecules from a chemical space becomes lengthy due to lack of appropriate technologies, which can be improvised by using AI in the drug development process. The quantitative structure–activity relationship affects the various parameters' forecasting activities such as log P or log D, which can foresee the predictions and generation through computations and can justify the biological safety, efficacy and adverse effects, including the pharmacokinetics of the significant molecule. It is advisable to collect all prior information regarding the selectivity and the positioning of the molecules for showing the bioactivity using numerous domains including PubChem, ChemBank, DrugBank and ChemDB. Different physicochemical properties can increase the effectiveness and biological activity. QSAR is geared for the potential application of the drug candidate through AI-based QSAR approaches. If the traditional approaches are followed for obtaining the statistical differences, the biological activity discovered and developed can take a decade to control . The solubility, partition coefficient, degree of ionization and intrinsic permeability of the drug affect target receptor binding when designing a new drug. Algorithms include molecular descriptors, such as Simplified Molecular Input Line Entry System (SMILES), to forecast the binding properties.[26] A quantitative structure–property relationship (QSPR) is generally used for the determination of the six physicochemical properties, known as the Estimation Program Interface Suite. Deep learning and neural networks based on the ADMET predictor and ALGOPS program have been utilized for the prediction of the lipophilicity and solubility of various compounds.

4.1. AI in Prediction of Bioactivity and Toxicity

The efficacy depends on the affinity for the target protein or receptor. In similarity-based interaction, the drug and target are deemed, and it is thought that they will interact with the same target. Chem Mapper and the similarity ensemble approach predict the drug–target interactions. The substructure, connectivity or a combination can also be considered. Deep learning approaches have shown improved performance as deep learning is independent of the 3D protein structure. Deep Affinity, protein, and drug molecules interaction prediction are the approaches.[27] Several Web-based technologies are accessible to lower the cost various computational technologies can solve problems encountered with QSPR. Decision-support tools use rule-based choosing systems, depending upon the nature and control of the quantity of the added ingredients for obtaining a positive feedback process. With the increasing complications of better product efficiency and quality, manufacturing systems are trying to grant human knowledge to machines.[28]

2. AI in Clinical Trials

Despite the time and capital invested in clinical trials, the success rate is only marginal for those that obtain approval from the Food Drug Administration (FDA). Those bottlenecks include the insufficient number of participants, drop-outs during the trial, side effects of the test drug, or inconsistent data. If such failure occurs in late phases of clinical trials, such as in phase-III and phase-IV, the sponsor has to absorb an extremely high economic burden. The clinical trials which are associated with high costs also have subsequent effects on therapeutic costs for patients. Due to this reason, biopharma companies tie R&D costs of failed trials into the pricing of approved drugs to hold out the profit. The process of execution and conducting of clinical trials includes clinical trial design, patient recruitment/selection, site selection, monitoring, data collection and analysis.[29] Out of these processes, patient recruitment and selection is the cumbersome process where 80% of the trials overshoot the enrolment timeline, and 30% of phase-III trials are prematurely terminated due to patient enrolment challenges. Trial monitoring in a multi-centered global trial is a very expensive and time-consuming process. Other challenges in clinical trials are the duration from the "last subject last visit" to data submission to regulatory agencies, which are huge data collection and analysis procedures. With the help of AI and digitization, these challenges in the clinical trial have been trasforming.[30]

4.2.1. Clinical Trial Design, Patient Identification, Recruitment and Enrollment

As per the FDA, AI models are useful in improving the quality of trial design, patient selection by reducing population heterogeneity, prognostic enrichment, and predictive enrichment. Bayesian nonparametric models (BNMs) have emerged as a powerful tool in clinical trial design with many other applications. This model is flexible and uses a nonparametric approach. Other designs such as modified toxicity probability interval (mTPI) designs use the Dirichlet process. This design learns from the emerging data selects the dose by prior approximation and automatically groups patients into similar clusters.[31]Collecting the patients' data/history or fresh testing would be time-consuming and costly. AI provides an opportunity to combine patient data with the electronic medical record (EMR) including omics data and other patient data, scattered among different locations, owners, and formats. Such analysis using computer vision algorithms such as optical character recognition (OCR) and Natural language processing (NLP) can provide an efficient process in patient identification and characterization.

4.2.2. Monitoring Trial, Patient Adherence and Endpoint Detection

Monitoring the trial participants is another challenge in the clinical trial and can be performed by AI-enabled wearable devices. Such monitoring is real-time, individualized and power efficient. Risk-based monitoring (RBM) has recently emerged as the AI-enabled efficient and cost-effective technique alternative to traditional monitoring.[32]An advanced version of RBM may be able to reduce the cost and increase the efficiency and quality of data monitoring in the trial site. AI-assisted "smart monitoring" can use predictive analysis and data visualization in improving the data quality check and trial site performance. Patients' compliance to adherence criteria of the trial is important to obtain the reliable data and success of the trial. Video monitoring and wearable sensors capture the patient data automatically and continuously making the trial efficient in monitoring patient adherence.

5. AI in Forecasting of an Epidemic/Pandemic

Pandemic is boundless and capable of causing morbidity and mortality. Globally, there have been several pandemic outbreaks, to name a few, Black Death, Spanish flu, Cholera, Influenzas, AIDS, COVID-19, and they are capable of causing social and economic interruption. There is intense interdependence between the early detection and successful management of the disease, which reduces the stress on individuals' health, economic, social, and political systems.[33]To achieve early detection, surveillance plays a major role. ML and deep learning are being incorporated in various healthcare segments and are found to be more effective when compared to human resources. Developing epidemiological models is still challenging due to their complexity. Recently, ML has been incorporated to develop outbreak prediction models. AI is being used in detection, prevention, response, and recovery in pandemics and epidemics.[34]

AI SOFTWARE USED IN PHARMACY

Sr. No.	SOFTWARE	USE	REFERENCE
1.	AlphaFold	Fight antibiotic resistance	Chan , H.C.S, Vogel ,Advancing Drug Discovery via Artificial Intelligence . Trend pharmacol science. 592-604,2019
2.	DeepChem	For drug discovery, material science	Thorland , Haggstorm ,Prarker, AAA key design for comparison of clinical pharmacy.1-392.2018
3.	ODDT	Material studio, discovery studio	Harrer, Shah ,Antony.Artificial intelligence and its features.577-591.2019
4.	Cyclica	Predicting both on target efficacy and poly pharmacology	Li, m, liu, bunn. Semi parameter Design for adaptive dose-finding with multiple starata.806-820.2020.
5.	AMPL	To solve linear and non –linear and integer optimization problems.	Fong,S.J,Li,Dey,Finding accurate Early Forecasting Model from small dataset.132-140.2020

Challenges For Artificial Intelligence:

While the integration of artificial intelligence (AI) in pharmacy offers numerous benefits, there are also several challenges that need to be addressed. Some of the key challenges for AI in pharmacy include:

1. Data Quality and Integration:

Challenge: Inconsistent or incomplete data from various sources can hinder the effectiveness of AI algorithms. Integrating data from disparate systems may also be challenging.

Solution: Implement robust data quality assurance measures and ensure seamless integration of data sources. Standardize data formats and structures for better interoperability.[35]

2. Privacy and Security Concerns:

Challenge: Patient privacy is a significant concern, especially when dealing with sensitive health information. Ensuring the security of patient data is crucial to maintain trust.

Solution: Adhere to strict data protection regulations, implement encryption, access controls, and anonymization techniques. Communicate clearly with patients about data security.[36]

3. Regulatory Compliance:

Challenge: The healthcare industry is subject to stringent regulations. Ensuring that AI applications comply with regulatory standards, such as HIPAA (Health Insurance Portability and Accountability Act), can be complex.

Solution: Stay informed about relevant regulations and work closely with regulatory bodies. Implement measures to ensure compliance, including regular audits and assessments.

4. Interoperability with Existing Systems:

Challenge: Integrating AI solutions with existing pharmacy information systems and electronic health records can be challenging due to differing standards and technologies.

Solution: Invest in flexible and interoperable AI solutions. Work towards standardization and collaboration within the healthcare industry to facilitate seamless integration.

5. Lack of Standardization:

Challenge: The lack of standardized protocols and terminology in healthcare data can impede the development and deployment of AI applications.

Solution: Advocate for industry-wide standards and collaborate with relevant organizations to establish common data standards. Participate in initiatives that aim to standardize healthcare data.

6. Limited Clinical Validation:

Challenge: Many AI applications lack extensive clinical validation and real-world testing, which can make healthcare professionals skeptical about their reliability.

SOLUTION: CONDUCT THOROUGH CLINICAL VALIDATION STUDIES TO DEMONSTRATE THE EFFICACY AND SAFETY OF AI APPLICATIONS. INVOLVE HEALTHCARE PROFESSIONALS IN THE VALIDATION PROCESS TO GAIN THEIR TRUST AND ACCEPTANCE.[37]

7. Resistance to Change:

Challenge: Healthcare professionals may be resistant to adopting AI technologies due to fear of job displacement, lack of understanding, or skepticism about AI capabilities.

Solution: Provide comprehensive training programs, clearly communicate the benefits of AI, and involve healthcare professionals in the decision-making and implementation processes.

8. Ethical Considerations:

Challenge: Ethical concerns, such as bias in algorithms, transparency, and accountability, need to be addressed to ensure fair and responsible use of AI in pharmacy.

Solution: Implement ethical guidelines and standards for AI development. Regularly audit and assess algorithms for bias. Promote transparency in AI decision-making processes.[38]

9. Cost and Resource Constraints:

Challenge: Implementing AI technologies can be costly, and resource constraints may limit the ability of some pharmacies to adopt these innovations.

Solution: Explore cost-effective AI solutions, consider collaborative efforts or partnerships, and assess the long-term return on investment. Governments and healthcare organizations can provide financial support or incentives.

10. Continual Technological Advancements:

Challenge: The rapid pace of technological advancements in AI may lead to the obsolescence of current systems and require continuous updates and adaptation.

Solution: Establish a robust framework for ongoing technological updates and upgrades. Stay informed about emerging technologies and trends in AI to ensure the pharmacy remains at the forefront of innovation.

Addressing these challenges requires a collaborative effort involving healthcare professionals, technology developers, regulatory bodies, and policymakers. Proactive measures and ongoing adaptation are essential to overcome these challenges and maximize the benefits of AI in pharmacy.[39]

Future Aspects of Artificial Intelligence:

The future of artificial intelligence (AI) in pharmacy holds tremendous potential for transformative advancements in various aspects of pharmaceutical practice, healthcare delivery, and drug development. Here are some key future aspects and trends for AI in pharmacy:

1. Precision Medicine and Personalized Therapeutics:

AI will play a crucial role in advancing precision medicine by analyzing large datasets, including genomic and clinical information, to tailor drug therapies to individual patients. This will lead to more effective and targeted treatments with fewer side effects.

2. Drug Discovery and Development Acceleration:

AI-driven predictive modeling and machine learning algorithms will continue to expedite the drug discovery and development process. Virtual screening, identification of potential drug candidates, and optimization of molecular structures will be enhanced, leading to faster innovation in pharmaceuticals.

3. Advanced Clinical Decision Support Systems:

Future AI applications will provide more sophisticated clinical decision support, integrating patient data, electronic health records, and real-time medical knowledge to assist healthcare professionals in making more informed and timely decisions.

4. Automated Robotic Pharmacy Systems:

AI-powered robotic systems will become more prevalent in pharmacies, automating tasks such as dispensing medications, managing inventory, and even compounding personalized drug formulations. This will improve efficiency and reduce the risk of errors.

5. Block chain for Drug Traceability and Supply Chain Management:

Block chain technology, combined with AI, will enhance traceability and transparency in the pharmaceutical supply chain. This will help prevent counterfeit drugs, ensure product authenticity, and streamline logistics.

6. AI-Enabled Medication Adherence Solutions:

AI applications will be employed to develop more sophisticated medication adherence solutions. These may include smart pill dispensers, personalized reminders, and interventions based on patient behavior analysis, contributing to improved patient outcomes.**7. Natural Language Processing in Drug Information Retrieval:**

AI, especially natural language processing (NLP), will evolve to better extract and interpret drug-related information from diverse sources. This will assist healthcare professionals in staying updated on the latest research, guidelines, and drug interactions.

8. Remote Patient Monitoring and Tele pharmacy:

AI will enable advanced remote patient monitoring, allowing healthcare providers to track patient health in real-time. Tele pharmacy services will expand, providing patients with virtual consultations, medication management, and remote access to healthcare expertise.

9. Drug Repurposing and Combination Therapies:

AI algorithms will continue to identify opportunities for drug repurposing and predict synergistic effects of combination therapies. This can lead to the discovery of new uses for existing drugs and more effective treatment options.

10. AI in Regulatory Compliance and Pharmacovigilance:

AI tools will be increasingly used to monitor and ensure regulatory compliance, detect adverse events, and enhance pharmacovigilance efforts. Automated surveillance systems will contribute to a safer and more reliable pharmaceutical landscape.

11. AI-Driven Clinical Trials:

AI will optimize the design and execution of clinical trials by identifying suitable patient populations, predicting trial outcomes, and streamlining data analysis. This can lead to more efficient and cost-effective drug development processes.

12. Human-AI Collaboration and Explainable AI:

As AI systems become more complex, there will be a growing emphasis on creating models that can explain their decision-making processes. Human-AI collaboration will be crucial to ensure trust, transparency, and effective utilization of AI in pharmacy settings.

The future of AI in pharmacy is dynamic and holds the promise of revolutionizing how medications are developed, prescribed, and managed. As technologies advance and stakeholders collaborate, the integration of

AI is expected to significantly improve patient outcomes, reduce healthcare costs, and contribute to the overall advancement of pharmaceutics.[65]

Conclusion

Researchers are fascinated by the recent developments in AI, especially its application in healthcare and pharmaceutical research and service. Smart hospitals and healthcare facilities enabled with AI, ML and Big Data will be shaping the future healthcare sector. Pharmaceutical industries are in constant advancement with their technologies and AI will be an opportunity for minimizing the cost and time for drug development. Various applications of AI in healthcare and pharmaceutical research as well as the limitations/challenges of these technologies have been presented in the role of AI in disease diagnosis is well demonstrated by using deep learning, neural networking and unsupervised learning. These technologies are useful in developing a personalized treatment, which is always a challenge. Drug discovery and bringing a new drug to the market is the prime objective of Pharmaceutical R&D, which is a very lengthy and costly affair. s., logistical difficulties in implementation, expense, and dependence on the hardware or computational facilities. Sometimes, AI technologies such as QSPR and chem Mapper are unreliable due to epistemic uncertainty, errors and lack of flexibility. The progressions in AI technologies are constantly.[40]

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