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Revolutionizing Pharmacy: The Transformative Power of Artificial Intelligence and Machine Learning in Drug Discovery and Patient Care

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Abstract: Pharmaceutical sciences are currently experiencing a truly transformational change from historical empirical concepts to data-driven Artificial Intelligence (AI)/ Machine Learning (ML) innovation applications. The author is one of the key transformational drivers. Their application in drug discovery, clinical trials, pharmacovigilance and personalised medicine has promoted research efficiency and quality. Meanwhile, shortening the time of the drug development cycle is helpful to control costs and increase therapeutic precision. AI algorithms accurately predict new drug targets, molecular interactions, formulations, and repurposed therapies. AI in clinical applications is capable of patient-tailored dose optimization, real-time adverse drug reaction (ADR) diagnosis, and intelligent prescription control for preventing medication errors. Deep learning and natural language processing (NLP) can also assist researchers in drawing upon the deep wells of biomedical literature and unstructured data, plus computer vision adds to quality control and imaging-based diagnostics. Additionally, AI-based big data analytics helps in predictive modelling for treatment results and disease prognosis. With its large potential, however, challenges remain in data privacy, algorithmic bias, explainability and regulatory adoption. This perspective article takes a look at mechanistic approaches of AI and ML in pharmaceutical sciences, including their connection to big data and biopharmaceutical research, and the developing ethical and regulatory landscape. The research demonstrates how mindful AI adoption can transform care delivery, optimise drug operations and usher in a new dawn of intelligent, patient-focused therapeutics.

Keywords: Artificial intelligence (AI), Adverse drug reaction (ADR), Natural language processing (NLP), Deep learning, Machine learning (ML).

1. Introduction

Artificial Intelligence is transforming the pharmacy profession with improved drug discovery, efficient drug management, and improved patient care. AI-powered ML and NLP technologies are transforming pharmaceutical research to enable rapid drug development and tailored treatment regimens. AI drug discovery can be the most unexpected use of artificial intelligence in pharmacy. Traditional drug discovery takes too much time and effort, but the AI tool will filter through giga-data to pick potential drug candidates, validate them as effective, and even choose the best combination [1]. AI speeds up clinical trials by eliminating good prospects and forecasting the impact of the drug, cutting costs and creating more effective results. AI improves the practice of pharmacy through computerised verification of prescriptions, drug error detection, and drug compliance monitoring. Intelligent dispensing machines that are powered by artificial intelligence make accurate dispensation of drugs and minimise drug errors. Virtual assistants and chatbots that are AI-powered provide immediate drug counselling and improve patient activation and treatment plan adherence. AI-driven automated stock management systems in pharmacy retail and hospital pharmacies provide maximum inventory levels and minimise wastage and stockouts of essential drugs [2]. AI also supports pharmacovigilance by monitoring ADR with the help of real-time data analysis to improve drug safety. Though welcome, there are some inherent ethical issues like data privacy, algorithmic bias, and a need for regulatory intervention. Addressing these is the essence of the management of responsible integration of AI. With the advancement of technology in AI, it has a vast potential to fuel drug research, workflow automation, and aid patient care outcomes, and hence keeps on surfacing as a valuable gem in pharmacy for the next few days [3].

2. AI Roles in Pharmacy

Artificial Intelligence is transforming the pharmaceutical sector with enhanced drug discovery, patient treatment, drug delivery, and process optimization. AI technologies like machine learning, natural language processing, and robotics are streamlining pharmaceutical processes at a larger, more efficient, and more economical scale. A step-by-step explanation of AI in pharmacy applications is as follows [4].

2.1 Drug Discovery and Development

Pharmaceutical development is a long, costly, and complex process. AI hastens it by searching large pools of data, making educated guesses at drug candidates, and enhancing scientific research with precision.

2.1.1 Identification of Targets

AI allows scientists to identify the biological targets of disease aetiology, such as proteins, genes, or enzymes. AI determines which drug targets should be worked upon from genetic and molecular information. AI reduces trial and error and optimises drug development.

2.1.2 Repurposing

AI finds new leads in licensed drug databases. This avoids decades of R&D on pre-computed safety data. Example: AI guided researchers to the fact that Remdesivir, which was initially found to cure Ebola, can be repurposed to cure COVID-19.

2.1.3 Molecular Modelling

AI predicts how different molecules behave at the atomic level. It simulates chemical reactions and builds drug structures to enhance their effectiveness with fewer side effects. AI software helps in designing new drug molecules quickly.

2.1.4 Clinical Trial Optimisation

AI selects the right patients for clinical trials as per their genetic makeup, medical history, and health status. AI predicts trial success rates, reducing the failure rate and increasing success. AI optimises data gathering and processing, increasing efficiency and precision in monitoring trials [5].

2.2 Personalized Medicine

AI is transforming health care by tailoring treatments according to an individual's own genetic makeup and medical history.

2.2.1 Precision Drug Therapy

Genetic information is analysed by AI for optimal drug selection for a patient. AI simplifies treatment regimens with maximum efficacy and minimum toxicity. Example: AI systems allow selection of the correct cancer drugs from tumour genomics.

2.2.2 Dose Optimization

AI considers weight, age, metabolism, and disease severity to decide on the best dose for a patient. It does not over- or underdose, causing treatment failure or side effects.

2.2.3 Drug Reaction Prediction

AI forecasts how the body of a patient would react to a drug according to his/her medical history and genetic makeup. This reduces side effects and increases the rate of successful treatment [6].

2.3 Computerized Prescription Management

Accuracy and safety in prescribing medication are guaranteed by AI by preventing human errors.

2.3.1 Error Identification

AI identifies potential medication errors, e.g., inappropriate dosages, duplicate prescriptions, and drug interactions. AI reduces drug-related complications.

2.3.2 e-Prescriptions

AI systems mechanically produce accurate electronic prescriptions. AI-based systems provide substitute medicines when medicines are not available or too expensive.

2.3.3 Adherence Monitoring

AI applications and wearables remind the patient to take medication at the right time. They track medication intake, reminding the patient about his or her drug schedule. AI also reminds doctors if the patient is not following the regular treatment [7].

2.4 Intelligent Drug Dispensing

AI improves the precision and efficiency of drug dispensing.

2.4.1 AI-Enabled Robots

Robots used in hospitals and by pharmacists dispense medications with precision, minimising room for error. High volumes of prescriptions are dealt with by robotic equipment to enhance efficiency.

2.4.2 Pharmacy Kiosks

Kiosks equipped with automated dispensing of medicines and infused with AI allow patients to access prescribed medicine with less queue time. The kiosks give crucial information about the usage, side effects, and storage of drugs.

2.4.3 Automated Refill Systems

AI monitors the use of medications and refills medications automatically whenever they are in demand. Patients thereby never have inadequate medication at the time required [8].

2.5 Pharmacy Stock Control and Supply Chain Management

AI optimises the pharmaceutical supply chain for appropriate medicine is in place at the time it is required.

2.5.1 Demand Forecasting

AI analyses the history of sales, seasonality, and pandemics to forecast demand for a drug. This avoids stockouts or overstock of medicines.

2.5.2 Supply Chain Optimization

AI monitors medicine delivery in real time for on-time delivery. AI optimizes the delivery route dynamically to avoid delays and costs.

2.5.3 Fraud Detection

AI identifies fake drugs by authenticating proof of the supply chain. Blockchain and AI-powered track-and-trace software make medicines genuine and safe to use [9].

2.6 Pharmacovigilance (Drug Safety Monitoring)

AI assists in monitoring and controlling drug safety by identifying adverse effects.

2.6.1 Adverse Drug Reaction (ADR) Detection

AI reads through medical reports, electronic health records, and social media posts to detect possible adverse reactions. It assists drug companies in acting before problems arise.

2.6.2 Real-Time Drug Safety Updates

AI continuously tracks patient reports and informs healthcare professionals of newly found side effects.

2.6.3 Predictive Risk Analysis

AI forecasts the probability of side effects caused by a drug based on patient demographics, genetic information, and medical history. This helps doctors make informed and intelligent prescribing choices [10].

2.7 AI-aided Patient Care and Counselling

AI enhances patient interaction with assistance and medical counselling.

2.7.1 Chatbots & Virtual Assistants

AI chatbots provide 24/7 drug guidance, respond to patients' questions, and notify patients about drug interactions.

2.7.2 Remote Patient Monitoring

Mobile wearables and AI-based health apps monitor the patient's readings of the patient and alert if readings are abnormal. Doctors can use the data to modify the treatment regimen accordingly.

2.7.3 Personalised Health Apps

AI-based health apps direct patients to monitor chronic conditions by monitoring their drug regimen and disease progress [11].

2.8 Medical Research and AI in Drug Regulation

AI simplifies medical research and drug law compliance.

2.8.1 Analysis of Research Data

AI works on enormous volumes of medical research data to supply trends for disease treatment and drug effectiveness.

2.8.2 Compliance with Drug Law

AI supports compliance by drug corporations with legislation and safety controls.

2.8.3 Automated Preparation

AI aids in the automation of preparing regulatory and clinical documentation to eliminate mistakes and speed up approvals [12].

2.9 AI in Biopharmaceuticals

AI pushes the limits of biologic drug development, vaccines, and gene therapy.

2.9.1 Manufacturing of Biologics

AI enhances the production process of biologic medicines like monoclonal antibodies and vaccines.

2.9.2 Gene Therapy Discovery

AI supports gene-editing research to enhance the cure for genetic diseases.

2.9.3 Cell-Based Drug Testing

AI modeling of human cell drug response decreases the need for animal testing [13].

2.10 AI in Mental Health Pharmacy

AI assists in the management of mental illness by considering patient behavior and drug efficacy.

2.10.1 AI-Based Mental Health Care

AI tracks behavioural patterns and recommends medication for anxiety, depression, and bipolar disorder.

2.10.2 Voice and Emotional Analysis

AI detects signs of mental illness through voice and facial behavior to facilitate early diagnosis.

2.10.3 Medication Adjustment

AI constantly tracks improvement in the patient and suggests dosage changes of psychiatric medication [14].

3. Machine Learning (ML)

Machine learning is an artificial intelligence (AI) in which computers learn automatically and decide without explicit programming for every application. Rather than adhering to hard-and-fast rules, the system learns from experience, recognizes patterns, and predicts the outcome. Show the difference between traditional and AI-based machine learning methods. Machine learning assists pharmacies as follows:

- Prediction of drug effectiveness on an individual.
- Identification of possible side effects before human subject testing.
- New drug discovery through investigation of chemical structure and bioactivity [15].

3.1 Pharmacy Machine Learning Types

3.1.1 Supervised Learning

Supervised learning is where a computer is trained using a pre-tagged set of correct responses. The program is instructed by being shown examples and speculating based on patterns discovered. Pharmacy Example: A model can be trained from historical patient records to be able to predict if a new drug will cure a specific disease.

3.1.2 Unsupervised Learning

In this case, the computer is provided with unlabelled data (no predefined answers). The algorithm detects the natural groupings or patterns within the data on its own. Example in Pharmacy: It can be used to identify various subforms of a disease or unseen drug interactions by grouping similar cases of patients.

3.1.3 Reinforcement Learning

Learns from trial and error and is rewarded for correctness and penalized for each error. Used where there is a need to make decisions sequentially based on learning from the outcome of each. Pharmacy Example: Drug dosage adjustment by modifying amounts based on response or enhanced robot surgical skill.

4. Artificial Intelligence in Pharmacy

Artificial Intelligence (AI) is revolutionising the pharma sector by propelling drug development to its peak, streamlining treatment procedures, diagnostics, and healthcare operations. Deep Learning (DL), Natural Language Processing (NLP), and Computer Vision (CV) are the most pervasive of all AI technologies present in the pharmacy of our time, bringing improved efficiency and precision into research and development, production, and patient care [16].

4.1 Deep Learning

Deep Learning (DL) is a Machine Learning (ML) field based on Artificial Neural Networks (ANNs) applied to processing complicated data and learning patterns. The networks are made up of a series of layers of nodes (neurons) that are connected, replicating the behaviour of the brain. Data layers are processed sequentially, one after the other, to establish useful features and enhance prediction performance.

4.1.1 Deep Learning Applications in Pharmacy

DL models are trained on huge pharmacological databases such as patient records, clinical trial outcomes, and molecular structures. DL models are trained by passing raw data to a neural network, modifying connections on failure, and improving prediction over time. DL models can identify very weak patterns in huge databases and select very weak correlations between variables, and that is where high precision is needed, i.e., personalised medicine and drug discovery [17].

4.1.2 Most Significant Deep Learning Challenges in Pharmacy

4.1.2.1 Artificial Neural Networks (ANNs)

Mimic the brain's decision-making process to process pharmaceutical data.

4.1.2.2 Convolutional Neural Networks (CNNs)

Image processing skills, assisting in medical imaging and molecular examination.

4.1.2.3 Recurrent Neural Networks (RNNs)

Sequential data processing, assisting in time-dependent data analysis such as tracking the progression of a disease.

4.1.2.4 Generative Adversarial Networks (GANs)

Produce fake drug molecules for new pharmaceutical medications [18].

4.2 Natural Language Processing (NLP) in Pharmacy

Natural Language Processing (NLP) is among the Artificial Intelligence (AI) technologies that allow computers to process, understand, and generate human language. NLP fills the gap between unstructured text (such as medical literature and patient history) and action-oriented, structured conclusions [19].

4.2.1 NLP in Pharmacy

NLP employs language rules together with machine learning algorithms in processing large volumes of text-based data. NLP breaks down sentences into words, flags key terms, and derives meaning from context. Technology is most relevant in drug-related details extraction from clinical narratives, research articles, and patient interactions.

4.2.2 Fundamental Elements of NLP in Pharmacy

4.2.2.1 Text Mining

Extracts relevant information from unstructured text, *i.e.*, clinical documents and patient case histories.

4.2.2.2 Named Entity Recognition (NER)

Pulls out relevant entities such as drug names, diseases, and patient symptoms from clinical data.

4.2.2.3 Sentiment Analysis

Contrasts the perceptions of patients about drugs in an attempt to measure their performance and side effects.

4.2.2.4 Speech Recognition

Interprets written words into speech and makes the process of developing voice-based applications in pharmacies possible.

4.2.2.5 Machine Translation

Translates drug texts in other languages, providing medical information [20].

4.3 Computer Vision in Pharmacy

Computer Vision (CV) is among the subsets of Artificial Intelligence (AI) that gives machines the power to process, analyse, and scan visual information, such as drug packaging, medical images, and microscopic morphologies. Computer Vision renders computers capable of reading patterns from images and videos and is hence highly valuable in drug production, disease diagnosis, and quality control.

4.3.1 Computer Vision Applications in Pharmacy

Computer Vision is based on deep learning algorithms, i.e., Convolutional Neural Networks (CNNs), to interpret images. These algorithms utilise pixel-level information to recognise patterns, detect anomalies, and classify visual information with high accuracy [21].

4.3.2 Key Features of Computer Vision in Pharmacy

4.3.2.1 Image Recognition

Recognizes chemical compounds, pill shapes, and disease conditions from images.

4.3.2.2 Object Detection

Detects defects in drug packaging, e.g., quality checks during production.

4.3.2.3 Segmentation

Identifies definite regions in medical images, like tumors or inflamed tissue.

4.3.2.4 Optical Character Recognition (OCR)

Reads prescriptions, medication package inserts, and doctors' scripts.

4.3.2.5 Microscopy Analysis

Refines drug formulation by microscopic biological morphology testing [22].

5. Regulatory Aspects and Ethical Considerations in AI-Based Drug Development

Since Artificial Intelligence (AI) is now being utilised as an inherent tool in pharmaceutical research and drug development, regulatory agencies such as the United States Food and Drug Administration (FDA) and the European Medicines Agency (EMA) of Europe are required to devise policies that make AI-driven processes efficient, safe, and ethical. The potential to speed up drug development, speed up clinical trials, and tailor drugs to the individual needs of patients is revolutionary, but with regulatory and ethical issues to be addressed [23].

5.1 Challenges to AI-Driven Drug Development on a Regulatory Level

AI is much different from traditional drug development approaches, and it also presents new challenges for regulators. AI processes are defined by sophisticated machine learning models that are continually updated throughout a lifetime. Regulatory agencies have to reorganise their systems to accommodate these advances without affecting patient safety and data integrity.

5.1.1. Regulatory Barriers

5.1.1.1 Explainability and Transparency

Transparency throughout the AI-drug development process is the greatest challenge. Some AI models, such as DL and Neural Networks, are "black boxes", and hence it is difficult to understand the reasoning behind the decisions. Regulators insist that AI models need to be explainable, particularly where they make decisions affecting patient treatment, e.g., the effectiveness of a drug or estimating potential side effects [24].

Regulators can insist:

- **Explainable AI (XAI):** Transparent models as to how they arrive at their predictions.
- **Model Auditing:** AI algorithms to be audited and accredited by independent experts before authorization.
- **Clear Documentation:** Pharmaceutical companies should make complete records of the development of the AI model, training data, and decision-making available.

5.1.1.2 Validation and Standardization

AI models employed in drug discovery need to be thoroughly tested for reproducibility, accuracy, and reliability. AI-aided drug discovery is distinct from conventional clinical trials because protocol standards are strictly defined there.

Regulatory bodies can mandate:

- **Preclinical and Clinical Validation:** AI models need to be validated on actual patient data before they can be used in clinical trials.
- **Benchmarking and Performance Measures:** AI forecasts need to be verified in comparison with predefined medical benchmarks.
- **Continuous Monitoring:** AI algorithms need to be regularly put through tests so that defects or bias, in the long term, can be identified [25].

5.1.1.3 Data Security and Privacy

AI drug development is dependent on enormous amounts of data, which are typically full of sensitive patient information from electronic health records (EHRs), genomic information, and clinical trial databases. All of this poses concerns regarding data security, privacy, and ethical utilization.

Regulatory considerations are:

- **Compliance with Data Protection Laws:** AI technologies should comply with legislation such as the General Data Protection Regulation (GDPR) of the EU and the Health Insurance Portability and Accountability Act (HIPAA) of the US.
- **Anonymization and De-identification:** Data anonymization is essential for protecting individuals' privacy.

- **Policy on Sharing Data:** Pharmaceutical companies should maintain ethical data sharing procedures and proper patient consent [26].

5.2 Ethical Implications of AI-based Drug Development

In addition to the regulatory issues, there are ethical issues in drug development with AI too. Besides following legal limitations, the AI models should also be free from bias, clear, and maintain the rights of the patients [27].

5.2.1 Bias of AI Models

AI systems are only as good as the training data that trains them. If the training data are biased, i.e., biased against a certain group of people in favour of another group of people, then AI systems can perpetuate healthcare inequities. Examples of AI-based drug development bias:

5.2.1.1 Lack of Clinical Trial Diversity

When narrow population-based data (say, Western countries alone) is used to train AI models, the drugs designed with the help of these AI models might be less effective in underprivileged sections.

5.2.1.2 Algorithmic Bias in Drug Recommendations

AI can anticipate unequal treatment outcomes for different ethnic or socioeconomic populations based on biased past data [28].

5.2.2 Patient Consent and Privacy

Pharmaceutical innovation using AI would, in most situations, entail analysis of vast patient health data, including treatment records and genomic data. Obtaining patients' consent for the use of their data is a fundamental ethical dilemma.

The greatest challenges are:

a) Lack of Awareness: Patients cannot be assumed to know how their data is used by AI systems.

b) Involuntary Data Capture: AI systems capture data from media like social media or wearables without the active engagement of patients.

c) Threat of Misuse of Data: Patient data has to be protected from misuse by pharma companies and AI system developers for gain without patients' consent [29].

5.2.3 Responsibility and Accountability

When AI models fail, i.e., a failed medicine or a failure to find a key safety flaw, the question is: Who is responsible? AI models are usually created jointly by pharma, technology companies, and researchers, so responsibility is nuanced. The gravest issues of responsibility are:

a) Whose fault would it be if there were an AI error? Would the fault of an AI drug development process lie with the injury of patients being with the AI developers, the drug company, or regulatory bodies?

b) Who verifies AI decisions? There should be strict regulations for auditing AI in order to prevent negligence or malpractice.

c) If AI replaces human judgment? AI is designed to aid and augment, rather than replace, human judgment in critical areas like clinical decision-making [30].

6. Pharmacovigilance and Regulatory Compliance with AI

Pharmacovigilance is a holistic area of medicine and pharmaceuticals with the aim of observing drug safety for detection, evaluation, explanation, and prevention of adverse drug reactions. Drug safety is not a static process but continuous and encompasses post-market surveillance and clinical trials. Conventional pharmacovigilance activity is greatly dependent on labour-intensive manual reporting and analysis, which is time-consuming and prone to errors. The application of Artificial Intelligence (AI) has transformed the practice of pharmacovigilance by incorporating data collection into an automated system so that identification of adverse drug reactions (ADRs) is made easier and overall monitoring for drug safety more efficient. Machine learning (ML), deep learning, and natural language processing (NLP) artificial intelligence technologies support the quick processing of big data for real-time detection of indications of safety [31].

6.1 Use of AI in Pharmacovigilance

6.1.1 Detection of Adverse Drug Reaction

Detection of adverse drug reactions is perhaps the most significant use of AI in pharmacovigilance. ADRs are unwanted, drug-induced adverse reactions, and they may have serious health implications if they remain undetected at the earliest possible stage. AI has the potential to scan vast quantities of data from diverse sources such as electronic health records (EHRs), clinical trials, patient forums, and social media, and detect potential ADRs in real-time [32]. Traditional ADR discovery systems rely on voluntary reporting systems, and these systems are normally underreported [33]. AI can turn this disadvantage upside down since it has the capability of scanning patient records round-the-clock and gaining meaningful insights from unstructured sources of data with the help of NLP strategies. For example, artificial intelligence has the capacity to recognise sentences in tweets through which patients share unexpected side effects of medications and can help regulatory agencies identify impending safety issues at a quicker rate [34].

6.1.2 Signal Detection

Any new or unanticipated pattern of adverse events with a drug is a safety signal in pharmacovigilance. Signal detection can be aided by AI through the identification of slight patterns in large amounts of structured and unstructured data. Machine learning algorithms can be trained to monitor ADR reports submitted to regulatory bodies, peer-reviewed articles, and social media for the identification of slight differences between side effects reported. AI systems can also rank safety signals by frequency and severity so that regulators and pharmaceutical firms can target high-risk cases. Identifying safety signals at an early stage prevents major public health problems by permitting instantaneous investigation and, if necessary, regulatory action in the form of safety notices or formula changes to drugs [35-36].

6.1.3 Predictive Drug Safety Analytics

Predictive analytics by AI is able to forecast the likelihood of ADRs before they occur and is therefore capable of being useful in preventing them. Based on gene profile, patient population, drug-drug interaction, and medical history, AI has the ability to predict which group of patients will be susceptible to side effects [37]. Precision medicine can be facilitated with personalized pharmacovigilance, wherein treatment regimens are adapted in accordance with each patient's personal clinical and biological attributes. Aside from that, AI enables drug-drug interaction prediction, where two or more drugs are consumed concurrently and produce unanticipated side effects [38]. AI can run through enormous databases of information via deep learning algorithms to test potentially toxic combinations of drugs to decrease the likelihood of negative results among polypharmacy patients (patients who are under treatment by two or more drugs at a time) [39].

6.2 AI in Regulatory Compliance

Pharmaceutical companies are subject to stringent regulatory requirements to achieve drug quality, efficacy, and safety. Regulatory compliance with organizations such as the U.S. Food and Drug Administration (FDA), European Medicines Agency (EMA), and International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use (ICH) is mandatory at drug development, approval, and post-marketing phases. Non-compliance may result in harsh punishment, litigation, and compromising public health. AI is a vital solution for increasing compliance efficiency by way of computerised regulatory processes, surveillance of safety information, and compliance with global standards [40].

6.2.1 Computerised Reporting

Regulatory agencies compel pharmaceutical companies to provide drug safety, clinical trial findings, and manufacturing process reports of gigantic magnitude. AI can make such reporting more computerised and automated by extracting information from databases and rearranging it based on regulations [41]. Such computerization not only enhances efficiency but also minimises the incidence of human error in reporting. AI-powered software can process large volumes of clinical trial data and generate automatic summaries according to FDA and EMA guidelines. Moreover, AI can monitor geographically regulatory news across geographies and adjust report templates to report accordingly and therefore stay compliant with changing regulations [42].

6.2.2 Real-Time Monitoring of Drug Safety

AI can enable real-time tracking of drug safety by monitoring patient data and clinical trial reports. Conventional pharmacovigilance systems rely on random manual checks that are likely to be behind schedule in identifying safety issues of the highest priority [43]. AI-monitored systems can analyze incoming patient data in real-time, triggering potential ADRs and compliance breaches ahead of time when they would otherwise have been more serious offences. For example, AI can analyse patient biometrics, lab results, and prescription histories to detect early warning signs of side effects. Such pre-emptive intervention allows regulatory agencies and drug companies to react promptly, averting mass health crises [44].

6.2.3 Regulator Decision-Making Based on Real-Time Analysis

Regulators require real-time information so that they can make well-informed decisions regarding drug safety, approval, and post-launch monitoring. AI systems can integrate and analyse information from different sources like clinical trials, hospitalisation history, pharmacovigilance databases, and wearable health devices to provide regulators with real-time safety information [45]. With the help of AI-based data analysis, regulatory agencies can monitor the effectiveness of drugs, adherence of patients, and new safety issues in real time. This enables them to make faster decisions and implement improved risk management strategies. In addition, AI is able to identify potential fraud or misconduct in clinical trials by identifying inconsistencies in reporting data to secure the integrity of research results [46].

7. Conclusion

Pharmaceutical research and healthcare have been redrawn in fundamental ways by Artificial Intelligence. Pharmaceuticals and machine learning. With machine learning, deep learning, and big data analytics underpinning innovation, the pharmaceutical industry is embarking upon an age of predictive precision and automation. AI accelerates innovation not only in drug discovery, clinical optimization, pharmacovigilance and supply chain management but also enhances the safety, efficacy and accessibility of medicines. AI-powered tools for monitoring, faster compliance with regulatory initiatives and a deeper understanding of pharmacology in real time translate to better-informed clinical decisions that benefit patients. Ultimately, AI in pharmacy can work to its full potential only if ethical and transparent use occurs -- the standard application of AI becomes widespread. To promote fair and responsible usage, challenges like data security, debiasing, interpretability of algorithms and achieving global agreement on regulatory policies need to be considered. Cross-stakeholder collaboration of pharmaceutical scientists, data engineers, clinicians and regulators is required to make this transformation. After all, AI is not a substitute but rather an addition to human intelligence that improves the decision-making process, advances innovation and shortens the time between science and therapeutic practice. And that is only the beginning: as AI continues to develop, it will usher in a smarter, safer and personalized pharmacy—an era of digital precision medicine and patient-focused Pharmaceutical care.

8. References

1. Buchanan BG, Smith RG. Fundamentals of expert systems. Annu Rev Comput Sci. 1988;3:23-58.
2. Chapelle O, Scholkopf B, Zien A. Semi-supervised learning. Cambridge: MIT Press; 2006.
3. DiMasi JA, Grabowski HG, Hansen RW. Innovation in the pharmaceutical industry: New estimates of R&D costs. J Health Econ. 2016;47:20-33.
4. Ding Y, Tang J, Guo F. An introduction to deep learning for the novice. Neural Netw. 2020;121:1-16.
5. Esteva A, Kuprel B, Novoa RA, Ko J, Swetter SM, Blau HM, Thrun S. Dermatologist-level classification of skin cancer with deep neural networks. Nature. 2017;542(7639):115-118.

6. Hosny A, Parmar C, Quackenbush J, Schwartz LH, Aerts HJWL. Artificial intelligence in radiology. Nat Rev Cancer. 2018;18:500-510.
7. Kandeel M, Yamamoto M, Tani H, Kobayashi A, Gohda J, Kawaguchi Y, Park BK, Kwon HJ, Inoue JI, Alkattan A. Discovery of New Fusion Inhibitor Peptides against SARS-CoV-2 by Targeting the Spike S2 Subunit. Biomol Ther (Seoul). 2021;29(3):282-289.
8. Kandeel M, Al-Nazawi M. Virtual screening and repurposing of FDA approved drugs against COVID-19 main protease. Life Sci. 2020;251:117627.
9. Kandeel M, Abdelrahman AHM, Oh-Hashi K, Ibrahim A, Venugopala KN, Morsy MA, Ibrahim MAA. Repurposing of FDA-approved antivirals, antibiotics, anthelmintics, antioxidants, and cell protectives against SARS-CoV-2 papain-like protease. J Biomol Struct Dyn. 2021;39:5129-5136.
10. Karger E, Kureljusic M. Using artificial intelligence for drug discovery: A bibliometric study and future research agenda. Pharmaceuticals. 2022;15:1492.
11. Krittanawong C, Zhang H, Wang Z, Aydar M, Kitai T. Artificial intelligence in precision cardiovascular medicine. J Am Coll Cardiol. 2017;69(21):2657-64.
12. Kui B, Pintér J, Molontay R, Nagy M, Farkas N, Gede N, Vincze Á, Bajor J, Gódi S, Czimmer J, Szabó I, Illés A, Sarlós P, Hágendorn R, Pár G, Papp M, Vitális Z, Kovács G, Fehér E, Földi I, Izbéki F, Gajdán L, Fejes R, Németh BC, Török I, Farkas H, Mickevicius A, Sallinen V, Galeev S, Ramírez-Maldonado E, Párniczky A, Erőss B, Hegyi PJ, Márta K, Váncsa S, Sutton R, Szatmary P, Latawiec D, Halloran C, de-Madaria E, Pando E, Alberti P, Gómez-Jurado MJ, Tantau A, Szentesi A, Hegyi P; Hungarian Pancreatic Study Group. EASY-APP: An artificial intelligence model and application for early and easy prediction of severity in acute pancreatitis. Clin Transl Med. 2022;12(6):e842.
13. Liao KP, Cai T, Savova GK, Murphy SN, Karlson EW, Ananthakrishnan AN, Gainer VS, Shaw SY, Xia Z, Szolovits P, Churchill S, Kohane I. Development of phenotype algorithms using electronic medical records and incorporating natural language processing. BMJ. 2015;350:h1885.
14. Malgwi YM, Goni I, Ahmad BM. A survey on recent advances in medical diagnosis and telemedicine using machine learning techniques. Orient J Comput Sci Technol. 2023;16(2):1-10.
15. Miyazawa T, Hiratsuka Y, Toda M, Hatakeyama N, Ozawa H, Abe C, Cheng TY, Matsushima Y, Miyawaki Y, Ashida K, Iimura J, Tsuda T, Bushita H, Tomonobu K, Ohta S, Chung H, Omae Y, Yamamoto T, Morinaga M, Ochi H, Nakada H, Otsuka K, Miyazawa T. Artificial intelligence in food science and nutrition: a narrative review. Nutr Rev. 2022;80(12):2288-2300.
16. O'Connor AB, Lang VJ, Bordelon KJ, Leuthner SR. Use of a novel artificial intelligence platform on mobile devices to assess dosing compliance in a phase 2 clinical trial in subjects with schizophrenia. JMIR Mhealth Uhealth. 2019;7(1):e10868.
17. Panigrahi N, Ayus I, Jena OP. An expert system-based clinical decision support system for hepatitis-B prediction & diagnosis. In: Mohanty SN, Nalinipriya G, Jena OP, Sarkar A, editors. Machine learning for healthcare applications. Beverly, MA: Scrivener Publishing LLC; 2021. pp. 57-75.
18. Parikh RB, Obermeyer Z, Navathe AS. Regulatory oversight of machine learning-based software as a medical device in the European Union and the United States. NPJ Digit Med. 2019;2:53.
19. Patel V, Shah M. Artificial intelligence and machine learning in drug discovery and development. Intell Med. 2022;2:134-40.
20. Rajkomar A, Dean J, Kohane I. Machine learning in medicine. N Engl J Med. 2019;380(14):1347-1359.
21. Rodriguez-Gonzalez CG, Herranz-Alonso A, Escudero-Vilaplana V, Ais-Larisgoitia MA, Iglesias-Peinado I, Sanjurjo-Saez M. Robotic dispensing improves patient safety, inventory management, and staff satisfaction in an outpatient hospital pharmacy. J Eval Clin Pract. 2019;25:28-35.
22. Roosan D, Chok J, Baskys A, Roosan MR. PGxKnow: A pharmacogenomics educational HoloLens application of augmented reality and artificial intelligence. Pharmacogenomics. 2022;23:235-245.
23. Roosan D, Wu Y, Tatla V, Li Y, Kugler A, Chok J, Roosan MR. Framework to enable pharmacist access to health care data using blockchain technology and artificial intelligence. J Am Pharm Assoc. 2022;62:1124-32.
24. Ross J, Stevenson F, Lau R, Murray E. Factors that influence the implementation of e-health: a systematic review of systematic reviews (an update). Implement Sci. 2016;11(1):146.
25. Sak J, Suchodolska M. Artificial intelligence in nutrients science research: a review. Nutrients. 2021;13(2):322.
26. Shortliffe EH, Sepúlveda MJ. Clinical decision support in the era of artificial intelligence. JAMA. 2018;320(21):2199-200.
27. Siddiq M. ML-based medical image analysis for anomaly detection in CT scans, X-rays, and MRIs. Devotion J Res Community Serv. 2020;2:53-64.

28. Smith A, Jones B. Application of machine learning in drug discovery: a review. Drug Discov Today. 2020;25(7):1249-61.
29. Stasevych M, Zvarych V. Innovative robotic technologies and artificial intelligence in pharmacy and medicine: paving the way for the future of health care—a review. Big Data Cogn Comput. 2023;7:147.
30. Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. Nat Med. 2019;25(1):44-56.
31. Wang C, Li Y, Shen J, Wang Y, Jia L. Artificial intelligence in drug design and discovery. Future Med Chem. 2019;11(18):2439-59.
32. Wienrich C, Latoschik ME. eXtended artificial intelligence: new prospects of human-AI interaction research. Front Virtual Reality. 2021;2:686783.
33. Yu KH, Beam AL, Kohane IS. Artificial intelligence in healthcare. Nat Biomed Eng. 2018;2(10):719-31.
34. Zhou J, Troyanskaya OG. Predicting effects of noncoding variants with deep learning–based sequence model. Nat Methods. 2015;12(10):931-934.
35. Johnson KB, Wei WQ, Weeraratne D, Frisse ME, Misulis K, Rhee K, Zhao J, Snowdon JL. Precision Medicine, AI, and the Future of Personalized Health Care. Clin Transl Sci. 2021;14(1):86-93.
36. Schork NJ. Artificial intelligence and personalized medicine. In: Van Hoff DD, Han H, editors. Precision medicine in cancer therapy. Cham (Switzerland): Springer International Publishing; 2019. pp. 265-83.
37. Kumar R, Saha P. A review on artificial intelligence and machine learning to improve cancer management and drug discovery. Int J Res Appl Sci Biotechnol. 2022;9:149-56.
38. Krittanawong C, Zhang H, Wang Z, Aydar M, Kitai T. Artificial intelligence in precision cardiovascular medicine. J Am Coll Cardiol. 2017;69:2657-64.
39. Uddin M, Wang Y, Woodbury-Smith M. Artificial intelligence for precision medicine in neurodevelopmental disorders. NPJ Digit Med. 2019;2:1910.
40. Subramanian M, Wojtusciszyn A, Favre L, Boughorbel S, Shan J, Letaief KB, Pitteloud N, Chouchane L. Precision medicine in the era of artificial intelligence: implications in chronic disease management. J Transl Med. 2020;18(1):472.
41. Paul D, Sanap G, Shenoy S, Kalyane D, Kalia K, Tekade RK. Artificial intelligence in drug discovery and development. Drug Discov Today. 2021;26:80-93.
42. Gkouvas N, Gkouvas N. Precision medicine and pharmacogenomics: personalized medication in neuropsychiatric disorders using AI and telepsychiatry. Eur Psychiatry. 2022;65(1):S678.
43. Bello BK, Bundey Y, Bhave R, Khotimchenko M, Baran SW, Chakravarty K, Varshney J. Integrating AI/ML models for patient stratification leveraging omics dataset and clinical biomarkers from COVID-19 patients: a promising approach to personalized medicine. Int J Mol Sci. 2023;24:6250.
44. Andrews SM. Emerging role of artificial intelligence and machine learning in precision medicine. Int J Eng Technol Manag Sci. 2023;7:622-626.
45. Sanchez P, Voisey JP, Xia T, Watson HI, O'Neil AQ, Tsaftaris SA. Causal machine learning for healthcare and precision medicine. R Soc Open Sci. 2022 Aug 3;9(8):220638.
46. Xu Z, Biswas B, Liu L, Amzal B. AI/ML in precision medicine: a look beyond the hype. Ther Innov Regul Sci. 2023;57:133-42.

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