INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES
[ISSN: 0975-4725; CODEN(USA): IJPS00]
Journal Homepage: https://www.ijpsjournal.com

OPEN ACCESS

Review Article

Artificial Intelligence in Pharmaceutical Technology

Sanchit Sanap*, Akshay Fulsunder, Omkar Dhakne, Prasad Gadge, Ankit Pingale

Department of R&D, Samarth Institute of Pharmacy, Belhe, Pune.

ARTICLE INFO

Published: 31 May 2025
Keywords:
Artificial intelligence, Machine learning, Drug discovery, AI technology
DOI:
10.5281/zenodo.15564302

ABSTRACT

The development of new drugs is greatly aided by artificial intelligence (AI). Artificial intelligence (AI) is increasingly being used in various sectors of society, particularly the pharmaceutical industry. Deep neural networks and recurrent networks are the technology driving this field. There have recently been many applications in the field of property or activity predictions, such as physicochemical and ADME properties AI uses personified knowledge and gains knowledge from the solutions it generates to tackle both straightforward and complex issues. The process of developing new drugs may be transformed by increases in computational power and developments in AI technology. Due to rising R&D costs and decreased efficiency, the pharmaceutical industry is currently having trouble finding their drug development programs. In this review, we highlight the use of AI in multiple facets of the pharmaceutical industry, such as drug discovery and development, and clinical trials, among others; such use reduces human workload while meeting targets in a timely manner.

INTRODUCTION

Artificial Intelligence: Things You Need to Understand

Artificial intelligence (AI) is an expanding field that includes the design and development of computer systems capable of replicating human intelligence. Machine learning allows systems to learn and improve based on data, resulting in advances in machine learning for natural language processing, computer vision, and speech recognition. AI applications range from recommendation systems to robotics. (krikorian G 2021-23)As AI advances, addressing issues such as job displacement, security, and ethical concerns becomes increasingly important. Ongoing developments in explainable AI, edge computing, and regulatory frameworks highlight the dynamic nature of this fundamental science and technology, focusing on the importance of keeping up on its multifaceted impacts and applications.

***Corresponding Author:** Sanchit Sanap
Address: *Department of R&D, Samarth Institute of Pharmacy, Belhe, Pune.*
Email ✉: sanchitsanap0202@gmail.com
Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

AI in the Lifecycle of Pharmaceutical Product:

Artificial intelligence (AI) is used at various stages of the pharmaceutical product lifecycle, from drug discovery and development to manufacturing, clinical trials, and post-market surveillance. (Chavda V.P 2023)

Here's an overview of how AI is integrated into each phase:

1. **Drug Development:**

Target Identification and Validation: AI aids in the analysis of biological data in order to identify and validate potential drug targets. AI algorithms predict the likelihood of success for various drug candidates, narrowing the options for further investigation. AI can design novel molecules and predict their properties, speeding up the drug discovery process.

2. **Preclinical Research:**

Toxicology Prediction: Artificial intelligence models analyze data to predict potential toxicity of drug candidates, reducing the need for extensive animal testing. Disease Modeling: AI aids in the development of more accurate disease models, which improves understanding of a drug candidate's efficacy and safety.

3. **Clinical Research:**

Patient Recruitment: By analyzing electronic health records and patient data, AI can help identify suitable candidates for clinical trials. Protocol Optimization: By analyzing historical data, AI can optimize trial protocols, potentially reducing trial duration and costs. Real-Time Monitoring: Artificial intelligence monitors patient data in real time, detecting anomalies and ensuring participant safety.

4. **Manufacturing:**

Process Optimization: Artificial intelligence optimizes manufacturing processes, increasing efficiency and lowering costs. In the Quality Control, AI systems can inspect and analyze product quality to ensure regulatory compliance. Supply Chain Management: AI aids in demand prediction, inventory management, and supply chain optimization in the pharmaceutical industry.

5. **Regulatory Acceptance:**

Data Analysis for Submissions: AI simplifies the analysis of large datasets submitted for regulatory approval, increasing the review process's efficiency. Risk Prediction: AI models assess potential product risks, assisting regulatory decision-making.

6. **Post-Market Monitoring:**

AI monitors real-world data to identify and analyze adverse events associated with pharmaceutical products. AI algorithms aid in the detection of emerging safety signals, prompting further investigation if necessary. Continuous Improvement Based on real world evidence, AI supports ongoing assessment and optimization of product safety and effectiveness. Integrating artificial intelligence throughout the pharmaceutical product lifecycle improves efficiency, lowers costs, and improves decision-making. As technology advances, its role in drug development and healthcare is likely to grow, providing new opportunities for innovation and improving patient outcomes. (Scannell J.W. 2012)

The Role of Artificial Intelligence in Pharmaceutical Product Development:

Artificial intelligence (AI) is helping to transform pharmaceutical product development by providing innovative solutions at each stage. AI accelerates the recognition of target possibilities and

encourages the design of novel molecules in drug discovery, significantly accelerating the early stages of research. AI models predict potential toxicities during preclinical development, reducing the need for traditional animal testing and allowing for a more efficient screening process. AI improves patient recruitment in clinical trials by analyzing diverse datasets and optimizing trial protocols, resulting in more streamlined and cost-effective studies. AI optimizes methods and ensures quality control in manufacturing, increasing efficiency and compliance. (Lessons 2009) Throughout the regulatory approval process, AI assists in analyzing of huge datasets, speeding up reviews and improving decision-making. AI continuously monitors real-time information in post-market surveillance, allowing for the quick identification of adverse events as well as contributing to in progress safety assessments. Overall, the incorporation of AI technologies in pharmaceutical product development has the potential to transform traditional practices by stimulating innovation, efficiency, and improved patient outcomes.

Artificial Intelligence in Pharmaceutical Manufacturing

Artificial intelligence (AI) is transforming pharmaceutical manufacturing, bringing in an exciting period of efficiency, precision, and quality across the entire lifecycle. AI streamlines operations in medication manufacturing by anticipating equipment faults and avoiding downtime through predictive maintenance. AI-powered real-time monitoring assures the uniformity and quality of pharmaceutical products, with technologies capable of detecting irregularities and applying corrective steps as soon as they occur. Artificial intelligence-powered supply chain management and logistics solutions improve efficiency by forecasting demand, improving transportation routes, and reducing inventory imbalances. The capacity of artificial intelligence (AI) to enhance schedules, distribute resources effectively, and expedite batch manufacturing processes enhances production planning, lowering costs and enhancing overall operational agility. As AI undertakes continuous, real-time monitoring and helps root cause investigation in the event of deviations, quality assurance is improved. Regulatory compliance is aided by AI-assisted documenting and reporting, which ensures accuracy and expedites audit answers. AI examines historical data as a tool for continual improvement, providing insights that enable adaptable industrial processes. Artificial Intelligence (AI) in the pharmaceutical manufacturing industry not only increases output but also encourages creativity, economy, and a stronger emphasis on quality assurance, which eventually helps the sector produce and distribute safe and dependable pharmaceuticals. (Mak K K 2018)

Applications of AI in Drug Development:

AI-infused technologies have evolved into flexible instruments that are widely applicable across multiple phases of drug discovery, including target validation and identification, drug design, repurposing, enhancing R&D productivity, gathering and evaluating biomedical data, and streamlining the clinical trial patient recruitment process. These possible applications of AI offer the chance to reduce subjectivity and human interference in the process while addressing the drawbacks and uncertainties that emerge with traditional drug development approaches. Predicting possible manufacturing methods for drug-like compounds, pharmacological qualities, protein features, efficacy, drug combination, drug-target interaction, and drug repurposing are some of the further applications of AI in the development of drugs. DL has shown remarkable success in identifying promising drug candidates,

correctly assessing their characteristics, and foreseeing any potential toxicity concerns. AI technology allows for the conduct of new research to support the rational design of drugs, the discovery of new therapeutic targets, and the modification of existing drugs.

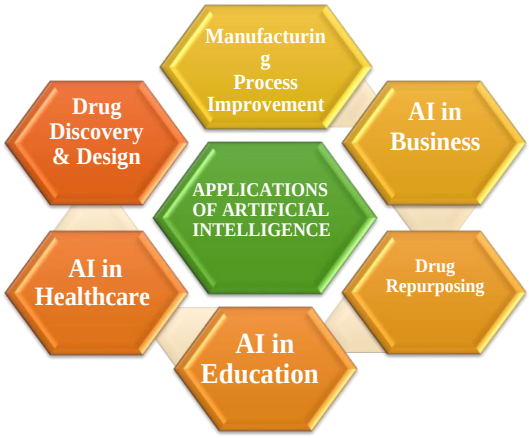

Fig.1 Applications Of Artificial Intelligence

Current Scenario of AI:

Until my most recent knowledge upgrade in January 2023, the pharmaceutical business was a quickly developing field when it came to using AI. AI technologies were being used more and more in the pharmaceutical industry in areas such as drug development and discovery. The following are some important trends:

Drug Discovery and Development: AI was assisting in the identification of possible therapeutic candidates, the prediction of their efficacy, and the optimization of molecular structures, all of which were critical to the process. Large datasets, including genetic information, were being analyzed using machine learning algorithms to look for trends and possible medication intervention targets.

Personalized Healthcare: AI was assisting in the development of individualized healthcare by evaluating patient data to create customized treatment regimens. This includes biomarker discovery, therapeutic customization based on patient-specific genetic profiles, and genomics applications of AI.

Clinical Trials Optimization: Artificial Intelligence (AI) tools were utilized to optimize the planning and conduct of clinical studies. Identifying appropriate patient demographics, forecasting patient enrollment rates, and improving overall trial efficiency were all made possible using predictive analytics as well as machine learning algorithms.

Drug Repurposing: AI is being utilized in the process of repurposing pharmaceuticals to find new therapeutic uses for them. Artificial intelligence (AI) systems have the ability to analyze vast databases and find novel applications for authorized medications, which could expedite the drug development process.

Drug safety and drug surveillance: Artificial intelligence (AI) algorithms were used to track and examine real-world data in order to spot any side effects of medications. To identify and evaluate drug safety concerns, medical articles, social media, and digital medical records were analyzed using machine learning algorithms and natural language processing (NLP).

AI-Driven Diagnostics: The development of AI-powered diagnostic tools for pathology analysis, illness diagnosis, and medical imaging is one of the uses of AI that is being investigated for diagnostic reasons.

Regulatory Compliance: Artificial Intelligence was being utilized to guarantee adherence to industry standards and expedite regulatory procedures. AI was used in quality control and regulatory document management as part of this. It's important to remember that the pharmaceutical industry's use of AI is evolving, and that since my last update, there may have been significant

advancements in the sector. I suggest looking through industry reports, news sources, and recent publications in the AI and pharmaceutical industries for the most up-to-date information.

AI for Pharmacokinetics and Pharmacodynamic:

Drug development is a multi-phase, intricate process that includes regulatory approval, preclinical research, clinical trials, and drug discovery. Important elements of medication creation are pharmacokinetics and pharmacodynamics, which establish the ideal dosage, mode of administration, and safety of a medication within the body. Conventional experimental techniques for pharmacokinetics and pharmacodynamics research can be costly and time consuming, and they might not always yield reliable forecasts of the safety and efficacy of drugs. (Chavda V 2023) Studies on pharmacokinetics and pharmacodynamics have often been carried out through experimental techniques including animal research and human clinical trials. There are several serious problems with these methods, including sample size, interindividual variability, and ethical issues. Moreover, these investigations could not always yield precise forecasts of Human medication pharmacokinetics and pharmacodynamics. In order to get around these restrictions, computer models and artificial intelligence techniques have been created to forecast drug pharmacokinetics and pharmacodynamics more quickly, efficiently, and accurately. In the domains of pharmacokinetics, pharmacodynamics, and drug discovery, artificial intelligence has demonstrated immense promise. AI can open new avenues for PKPD research and their implications for treatment, even though the difficulties associated with massive data and trustworthy datasets are difficult to ignore.

Future Prospects of AI:

In the future, artificial intelligence (AI) could completely transform the pharmaceutical sector by accelerating the creation of new drugs. Automated testing methods will accelerate lead compound identification by quickly analyzing massive chemical libraries and identifying therapeutic candidates with the necessary properties. By employing generative models and deep learning, researchers can produce novel molecules with target-binding properties that enhance drug efficacy and reduce side effects. AI will also enable dose formulations tailored to individual patients. In order to improve treatment outcomes, artificially intelligent systems will optimize medication formulations and distribution strategies by taking into account patient-specific factors including age, weight, genetics, and sickness state. Safety evaluation will be revolutionized by AI algorithms by forecasting the toxicity and negative effects of potential drugs. Biomarkers, genetic profiles, and electronic health data will all be used by AI algorithms to identify suitable individuals, reduce trial costs, and expedite approval. Continuous manufacturing processes will be optimized by AI models' continuous surveillance and oversight of critical parameters. Through data analysis and feedback, AI systems will make pharmaceutical manufacturing consistent and effective. Artificial intelligence is being used more and more in the healthcare industry on a daily basis for anything from diagnosis to clinical risk assessment and counseling. AI in healthcare has the potential to improve healthcare efficiency and diagnosis accuracy. The tremendous time and financial investment in drug research and development calls for the adoption of more creative approaches and strategies. While there are many exciting possibilities presented by this prospective vision, it's vital to understand that in order for AI to fully

realize its possibilities in pharmaceutical product development, issues with data quality, legal frameworks, and ethical requirements must be resolved.

CONCLUSIONS:

Artificial intelligence (AI) has become a disruptive force in the pharmaceutical technology space, changing many aspects of the business. Pharmacokinetics and pharmacodynamics have seen a transformation thanks to AI-based techniques. They are superior to conventional experimental techniques in a number of ways. AI can also play a significant role in the optimization and subsequent integration of the developed medication in the appropriate dosage form. Furthermore, AI can facilitate prompt decision-making, which can expedite the production of higher-quality products and ensure batch-to-batch consistency. AI technologies have significantly boosted personalized medicine by allowing the study of unique patient data to customize treatment strategies based on genomic patterns. In addition, artificial intelligence has been essential in simplifying clinical trials, enhancing trial efficiency overall, and refining patient recruitment techniques. By evaluating and detecting any adverse effects in real-world data, artificial intelligence (AI) enhances drug safety and pharmacovigilance. As the industry adopts these technological developments, ethical issues and appropriate AI practices are crucial to guaranteeing the ongoing value to patients and researchers alike.

REFERENCES

1. Krikorian G., Torreele E. We Cannot Win the Access to Medicines Struggle Using the Same Thinking That Causes the Chronic Access Crisis. Health Hum. Rights. 2021;23:119–127.
2. Chavda V.P., Vihol D., Patel A., Redwan E.M., Uversky V.N. Bioinformatics Tools for Pharmaceutical Drug Product Development. John Wiley & Sons, Ltd.; Hoboken, NJ, USA: 2023. Introduction to Bioinformatics, AI, and ML for Pharmaceuticals; pp. 1–18
3. Scannell J.W., Blanckley A., Boldon H., Warrington B. Diagnosing the Decline in Pharmaceutical R&D Efficiency. Nat. Rev. Drug Discov. 2012;11:191–200. doi: 10.1038/nrd3681.
4. Munos B. Lessons from 60 Years of Pharmaceutical Innovation. Nat. Rev. Drug Discov. 2009;8:959–968. doi: 10.1038/nrd2961.
5. Mak K.-K., Pichika M.R. Artificial Intelligence in Drug Development: Present Status and Future Prospects. Drug Discov. Today. 2019;24:773–780. doi: 10.1016/j.drudis.2018.11.014.
6. Biggest Challenges Facing the Pharmaceutical Industry in 2023. [(accessed on 5 May 2023)]. Available online: https://www.pssindia.com/2023/01/23/biggest-challenges-facing-the-pharmaceutical-industry-in-2023/
7. Chavda V., Valu D., Parikh P., Tiwari N., Chhipa A., Shukla S., Patel S., Balar P., Paiva-Santos A., Patravale V. Conventional and Novel Diagnostic Tools for the Diagnosis of Emerging SARS-CoV-2 Variants. Vaccines. 2023;11:374. doi: 10.3390/vaccines11020374.
8. Zignify. [(accessed on 2 May 2023)]. Available online: https://zignify.net/what-is-supply-chain-disruption-and-what-are-its-causes/#:~:text=LogisticsDelaysandFailures,resultingincongestionanddelays
9. Kgmg. [(accessed on 2 May 2023)]. Available online: https://kpmg.com/xx/en/home/insights/2022/

12/the-supply-chain-trends-shaking-up-2023.html
10. Times of India Pharmaceutical Supply Chain Management: Crises and Innovations. [(accessed on 15 May 2023)]. Available online: https://timesofindia.indiatimes.com/blogs/voices/pharmaceutical-supply-chain-management-crises-and-innovations/
11. Sharma R., Shishodia A., Gunasekaran A., Min H., Munim Z.H. The Role of Artificial Intelligence in Supply Chain Management: Mapping the Territory. Int. J. Prod. Res. 2022;60:7527–7550. doi: 10.1080/00207543.2022.2029611.
12. Grilo A.L., Mantalaris A. The Increasingly Human and Profitable Monoclonal Antibody Market. Trends Biotechnol. 2019;37:9–16. doi: 10.1016/j.tibtech.2018.05.014
13. Sarpatwari A., Barenie R., Curfman G., Darrow J.J., Kesselheim A.S. The US Biosimilar Market: Stunted Growth and Possible Reforms. Clin. Pharmacol. Ther. 2019;105:92–100. doi: 10.1002/cpt.1285.
14. Daka A., Peer D. RNAi-Based Nanomedicines for Targeted Personalized Therapy. Adv. Drug Deliv. Rev. 2012;64:1508–1521. doi: 10.1016/j.addr.2012.08.014.
15. Colombo S., Zeng X., Ragelle H., Foged C. Complexity in the Therapeutic Delivery of RNAi Medicines: An Analytical Challenge. Expert Opin. Drug Deliv. 2014;11:1481–1495. doi: 10.1517/17425247.2014.927439.
16. Müller R. Junghanns Nanocrystal Technology, Drug Delivery and Clinical Applications. Int. J. Nanomed. 2008;3:295–310. doi: 10.2147/IJN.S595.
17. Jain K.K., Jain K.K. The Handbook of Nanomedicine. Springer; Berlin/Heidelberg, Germany: 2017. Nanomolecular Diagnostics; pp. 133–200.
18. Kalepu S., Nekkanti V. Insoluble Drug Delivery Strategies: Review of Recent Advances and Business Prospects. Acta Pharm. Sin. B. 2015;5:442–453. doi: 10.1016/j.apsb.2015.07.003
19. Deloitte Using-Ai-to-Accelerate-Clinical-Trials. [(accessed on 1 May 2023)]. Available online: https://www2.deloitte.com/us/en/blog/health-care-blog/2022/using-ai-to-accelerate-clinical-trials.html
20. Dickherber A., Morris S.A., Grodzinski P. NCI Investment in Nanotechnology: Achievements and Challenges for the Future. Wiley Interdiscip. Rev.
21. National Nanotechnology Initiative NNI Budget Supplements and Strategic Plans. [(accessed on 1 May 2023)]; Available online: https://www.nano.gov/NNIBudgetSupplementsandStrategicPlans
22. Colombo S., Beck-Broichsitter M., Bøtker J.P., Malmsten M., Rantanen J., Bohr A. Transforming Nanomedicine Manufacturing toward Quality by Design and Microfluidics. Adv. Drug Deliv. Rev. 2018;128:115–131. doi: 10.1016/j.addr.2018.04.004

HOW TO CITE: Sanchit Sanap*, Akshay Fulsunder, Omkar Dhakne, Prasad Gadge, Ankit Pingale, Artificial Intelligence in Pharmaceutical Technology, Int. J. of Pharm. Sci., 2025, Vol 3, Issue 5, 5241-5247. https://doi.org/10.5281/zenodo.15564302