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

OPEN ACCESS

Review Article

AI In Personalized Medicine and Digital Transformation

Sejal Dalvi*, Yash Kini, Sanam Mestry, Samali Raut

Department of Pharmacy, Y.N.P College of Pharmacy, Vangoan, Dahanu.

ARTICLE INFO

Published: 15 Dec 2025
Keywords:
Artificial intelligence, Clinical Pharmacy, Health care, Patient Counselling
DOI:
10.5281/zenodo.17939115

ABSTRACT

The term artificial intelligence (AI) describes a machine's capacity to carry out tasks that frequently call for human intelligence. Artificial intelligence can be applied across numerous pharmaceutical applications, resulting in reduced time and cost efficiencies. Innovations in Artificial Intelligence (AI) are transforming clinical pharmacy practices, especially in the areas of medication management and patient counselling. Artificial intelligence (AI) is revolutionizing personalized medicine by improving drug efficacy and minimizing adverse effects, heralding a new era of precision healthcare. Within the pharmaceutical sector, the use of AI in teaching, pharmaceutical design, and tailored therapy is very important. This encompasses the processes of searching for and developing new drugs, personalizing pharmacotherapy, and training specialists involved in these areas. Predictive analytics powered by AI can track how well a patient is responding to treatment over time and instantly modify medication dosages to maintain ideal therapeutic levels. This is especially helpful in the treatment of long-term illnesses, including diabetes, high blood pressure, and cancer, where proper medication administration is essential to successful illness management. Enhancing pharmacist skills while keeping an eye on patient-centred, evidence-based treatment delivery is where AI in clinical pharmacy truly shines. By customizing medicines to each patient's unique profile, AI is at the forefront of personalized medicine, improving medication efficacy and minimizing side effects. Realizing the full promise of customized medicine will require ongoing developments in AI technology and supportive regulatory frameworks, which will ultimately result in safer and more effective healthcare solutions.

INTRODUCTION

Data analytics and computer science combine to create artificial intelligence (AI), a technology "designed to enhance productivity within the field in which it's applied."[1] AI has become a game-changing technology that has transformed numerous sectors across the globe. AI has been at the vanguard of innovation in a variety of

***Corresponding Author:** Sejal Dalvi
Address: *Department of Pharmacy, Y.N.P College of Pharmacy, Vangoan, Dahanu.*
Email ✉: sejaldalvi559@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.

industries, including manufacturing, transportation, healthcare, and finance, enabling previously unthinkable advancements.[2] The ability of machines to do functions like perception, cognition, learning, and decision-making that frequently need human intelligence is known as artificial intelligence (AI). For example, ChatGPT is a cutting-edge AI-powered tool. It uses language models to converse openly with people, answering questions, providing information, and producing perceptive answers with ease.[3] Artificial Intelligence (AI) is causing a fundamental shift in the healthcare industry, and clinical pharmacy is becoming a crucial area for technological advancement. The delivery of patient-centred care has grown in importance as healthcare systems work to meet the various demands of their patients while preserving effectiveness and quality. Clinical pharmacy procedures are being completely transformed by AI technologies, which make data-driven decision support, improved patient engagement, and accurate medication management possible. Clinical pharmacists examine patient data, identify high-risk individuals, and create focused intervention strategies using AI-powered tools. Large volumes of clinical data are processed by these systems in order to direct drug therapy and tailor instructional strategies according to the unique characteristics of each patient. Natural language processing (NLP) has made it possible for intelligent chatbots and virtual assistants to communicate with patients in a sophisticated way, removing language barriers and offering real-time help.[4] Based on the technology's capabilities and range of applications, artificial intelligence can be broadly categorized. The term "narrow" or "weak" artificial intelligence describes the creation of technology intended to carry out specific, repetitive activities. "Machine learning" is a commonly employed method in this sector in the healthcare industry. It has been used recently in fields like disease outbreak prediction and treatment strategy stratification in the context of customized medicine development. The use of machine learning to these repetitive and frequently predictively modelled tasks has shown notable reductions in therapeutic and diagnostic errors frequently found in human medical practice through the collection of baseline data on patient- and disease-specific variables.[1]

Personalized medicine, sometimes referred to as precision medicine, is a revolutionary approach to healthcare that seeks to customize medical care to each patient's unique needs.[5] In order to maintain people's health, personalized medicine uses specific medical data to create methods and treatments for identifying and treating diseases. In order to make precise diagnoses and create individualized treatment plans based on those findings, physicians in this type of practice integrate all available patient data, including symptoms, the outcomes of standard tests, the patient's medical and family history, and some genomic data.[6] Precision medicine uses artificial intelligence (AI) approaches to investigate new data on genetics and phenotypes. Early diagnosis, screening, and a customized treatment plan for each patient based on genetically oriented traits and attributes are the primary goals of precision medicine.[7] Another remarkable accomplishment is the incorporation of artificial intelligence in the medical field, with the main benefactors being cardiology, cancer, and dermatology.[8] It is impossible to overestimate the importance of customized medicine in modern healthcare since it promises to transform patient care and illness management by developing highly effective treatment programs with possibly fewer adverse effects. The speed at which technology is developing and its significant effects on healthcare highlight the need of researching AI's role in customized medicine. The landscape of medical

research, diagnosis, and therapy is constantly changing as AI technologies advance, opening up new possibilities for tackling difficult health issues. Given the growing use of AI tools in healthcare settings and their potential to further develop the concepts of customized medicine, this study is pertinent and current. This study aims to illustrate the revolutionary effects of technology innovation on healthcare practices and patient outcomes by exploring the relationship between AI and personalized medicine. It also highlights the necessity of a forward-thinking strategy in medical research and practice.[5]

The development of customized medicine has revolutionized healthcare by moving away from conventional treatment paradigms and toward methods that specifically address the unique needs of each patient. Underpinned by technical advancements and a thorough understanding of genes, epigenetics, the individual's lifestyle, and environmental factors, this shift principally helps the objective of enhancing treatment effectiveness while avoiding side effects. By incorporating these factors into clinical judgments, personalized medicine significantly increases the accuracy of therapeutic therapies.[9] Information technology has made tremendous strides in recent few decades. Digital technology integration in healthcare has been made easier by technological advancements. For instance, in their day-to-day job, healthcare professionals (HCPs) now utilize mobile devices.[10] Changes in digital technology that benefit society and the healthcare sector are referred to as "digital transformation." For innovative ways to enhance healthcare delivery and address medical issues, healthcare institutions must leverage digital technology.[11] The global pharmacy sector is undergoing a significant transformation due to digital technology, which aims to increase healthcare delivery's productivity, efficiency, and flexibility.[12] Advanced Artificial Intelligence (AI) technology is being incorporated into healthcare through digital transformation, which is changing the medical services landscape. Clinical outcomes are being improved, operational efficiency are being maximized, and healthcare delivery is being revolutionized through the strategic integration of AI.[13] The healthcare industry is undergoing a massive upheaval as a result of the combination of digital technologies and advanced data analytics. One of these technologies that particularly stands out as a potent catalyst for altering the way we track and treat illnesses is artificial intelligence. This AI-powered digital health revolution is pushing the limits of healthcare with the promise of better patient outcomes, tailored treatment plans, and more accurate diagnosis. Reactive approaches have historically defined healthcare, with interventions occurring after symptoms or the onset of a disease become apparent. But a paradigm shift in Favor of proactive and customized healthcare has been brought about by the deployment of AI technologies. By leveraging AI's capabilities in data analysis, pattern recognition, and predictive modelling, healthcare providers can better detect diseases early, tailor treatment regimens for individual patients, and empower individuals to take charge of their own health.[14] To the best of our knowledge, this study is the first to evaluate pharmacists' attitudes and desire to employ this technology at their pharmacy, as well as the obstacles that stand in their way. The results of this study should offer baseline information on pharmacists' willingness and perceptions regarding the use of AI and its associated aspects, as well as the barriers that impede the implementation of AI technology in pharmacies, given the dearth of research on this topic.[3]

IMPORTANCE:

1. The effectiveness of AI in detecting adenomas during a colonoscopy is presently being evaluated. In order to help endoscopists identify colorectal cancer during a colonoscopy, computer-aided detection (CAD) artificial intelligence (AI) technologies have been tested.[15]

2. At the core of customized medicine is the processing and interpretation of complicated biological data, a task for which artificial intelligence has become a key component. AI can go through enormous databases of genetic data, electronic medical records, and biomedical imaging using complex algorithms, finding patterns and correlations that are impossible to find using conventional analytical techniques.[5]

3. Artificial intelligence (AI) has been demonstrated to affect computed tomography (CT) and lower the required radiation dosage. At specific radiation levels, manufacturers have developed DL-based reconstruction methods for spatial resolution and CT picture smoothing.[15]

4. By integrating cutting-edge Artificial Intelligence (AI) technology across multiple domains, digital transformation in healthcare is changing the face of medical services.[13]

5. AI examines patient electronic records, applies its knowledge, and applies coding standards and guidelines to evaluate disease features and find "intelligent" diagnoses.[16]

6. AI is ushering in a new era of personalized medicine, where treatment plans are tailored to each patient's specific profile. By evaluating large datasets and considering a patient's genetic composition, medical history, and other relevant data, AI systems can recommend the most effective treatment options. By reducing adverse effects and enhancing therapeutic results, this degree of accuracy not only improves patient wellbeing.[14]

7. Compared to clinical decision-making methods and traditional analytics, AI has several advantages. As algorithms work with training data, they can grow more exact and accurate, giving people hitherto unheard-of insights into patient outcomes, care processes, treatment variability, and diagnoses.[16]

8. These models use AI algorithms to evaluate health data, identify high-risk patients, and support sickness prevention and early intervention. For example, AI-powered predictive analytics can forecast disease outbreaks, efficiently allocate healthcare resources, and improve patient outcomes.[14]

AI IN PERSONALIZED MEDICINE

➢ AI in disease diagnosis:

Numerous AI technologies, particularly machine learning and deep learning algorithms, have been shown to improve diagnostic efficiency. AI can identify patterns and connections that a clinician would not be able to identify by using information from a patient's genetics, history, and photos, among other data inputs. For instance, the use of AI to image identification can help detect minute variations in X-ray or MRI images for the detection of neurological conditions, cancer, and cardiac conditions.[17] The accuracy and speed of medical diagnostics have significantly increased with the introduction of AI-powered diagnostic technologies. Conventional diagnostic procedures are inevitably liable to mistakes and variability since they frequently depend on the subjective interpretation of medical pictures and tests.[5] In

order to reduce diagnostic errors and improve early disease diagnosis, models trained on large amounts of clinical data are able to spot patterns and correlations that are frequently invisible to human assessors.[18] Another advantage of AI is its ability to analyse and integrate the enormous amount of data collected from several sources. [17]

- **AI in disease treatment**

AI is useful not just for diagnosing illnesses but also for treating them with the appropriate interventions. AI methods are frequently used to assess a patient's response to a particular medicine and determine the best course of treatment based on the patient's clinical and genetic characteristics.[17] AI systems are able to modify dosage schedules in real time, guaranteeing optimal effectiveness and reducing adverse effects. Chemotherapy dose schedule optimization has been used in cancer therapies.[19] For instance, the AI algorithms may watch the patient's condition and suggest adjustments to the treatment plan using information from the wearable and other digital health records.[17]

- **AI in drug discovery**

The process of finding and creating novel pharmaceutical substances for the market is known as drug discovery.[19] One of the key components of the concept of personalized medicine is drug discovery, which is another area where AI is used. Usually, only a small percentage of candidates are successful after a lengthy and costly process of medication production. AI has the potential to be used in drug development, which includes identifying the targets of the medications, forecasting their safety and efficacy, and even designing clinical trials. In order to determine which molecules have the best probability of surviving the clinical development process, artificial intelligence (AI) can assist with genetic research, clinical trials, and empirical data.[17] For instance, the 3D structure of proteins has been predicted by using the AI tool AlphaFold to examine the angles of peptide bonds and amino acid sequences.[20]

- **Artificial Neural Network:**

The diagnosis, imaging, back pain, dementia, pathology and prognosis assessment of appendicitis, myocardial infarction, acute pulmonary arrhythmias, or mental illnesses are just a few of the medical applications of artificial neural networks (ANNs).[21] Artificial Neural Networks (ANNs) are complex structures that were created using a model of the human nervous system. The fundamental building blocks of these networks, known as "perceptron's," are streamlined representations of biological neurons in humans that replicate how electrical impulses are transmitted in the brain.[22] Real-time alert techniques tailored to each patient were developed using neural networks and decision trees. They noted that in order to identify harmful clinical and medical problems, alerts are constructed retroactively using datasets that include thousands of patients.[21]

- **Genomic data analysis for tailored therapies:**

The creation of customized therapeutics is being transformed by developments in genomic data analysis, which is opening the door to more potent patient-specific medications. Researchers can find genetic variants that affect treatment response and illness risk by utilizing bioinformatics tools and large-scale sequencing methods. By using a precision medicine approach, doctors can prescribe treatments based on each patient's unique genetic composition, greatly increasing therapy efficacy while reducing side effects.[23]

➢ **Ethical Implications of Algorithmic Decision-Making:**

The use of AI algorithms in medicine raises a number of ethical issues, including accountability, transparency, and equity in decision-making. Large datasets can be analysed and predictions can be made by AI algorithms, but their propensity for bias may exacerbate healthcare disparities.[8]

➢ **Pharmacogenomics:**

The study of genetic differences that impact drug metabolism and effects is known as pharmacogenomics. For instance, a patient's body's ability to metabolize antidepressants or anticancer medications may be impacted by certain mutations in the CYP450 genes.[24] Pharmacogenomics is the study of genetic predispositions, their ramifications, and how to use them to improve therapeutic interventions, diagnostic evaluations, and preventative strategies. These can result in medication side effects that are lessened or eliminated, as well as increased treatment efficacy.[25] The goal of pharmacogenomics is to comprehend how genetic variants affect the safety, effectiveness, and metabolism of drugs. Drugs' absorption, distribution, metabolism, and excretion within the body can all be impacted by genetic variations. Different enzyme activity, for instance, can result from differences in particular genes, which can affect a drug's breakdown rate or ability to reach its intended spot. This information makes it possible to tailor medicinal therapy so that each patient gets the right drug at the right dosage according to their genetic profile.[26]

3D PRINTING OF PERSONALIZED MEDICINE:

One technology that works well for creating customized medications is 3D printing. It has the adaptability required to modify the dosage, the release profile, and the physical characteristics of drug delivery devices (such as size, shape, colour, and embossing) to suit the needs of each patient.[27] An innovative technology for prototyping Solid dosage forms with various densities and diffusivities, intricate internal geometry, and a variety of medications and excipients can be created using three-dimensional technology. It layers material onto a substrate using computer-aided drafting (CAD) technology and programming to create a three-dimensional (3D) object.[28] Despite being around for decades, three-dimensional printing (3DP) has lately acquired popularity again because of its enormous potential to overcome a number of the limitations of the current method in therapeutic treatments. For instance, a fit-for-all clause governs the regimen of traditionally produced dosage forms such as tablets and capsules.[25] 3D printing technology makes it possible to customize medications to meet the needs of individual patients. Although there are a number of 3D printing methods, nozzle-based extrusion, laser writing systems, and powder binder jetting are used to print the majority of dosage forms and medical devices. Solid, semi-solid, and locally administered or implanted medications are among the many potential uses for 3D printing that have been demonstrated.[29]

DIGITAL TRANSFORMATION

➢ **Definition and concept:**

The term "digital transformation" (DT) describes how digital technologies, which integrate digital technologies and business processes, affect businesses. These days, DT is thought to be the force behind the transformation of the corporate landscape. By coordinating supply chain management, marketing, consumer behaviour, and strategic direction, DT essentially enhances business performance from a dynamic

capabilities' standpoint. Through a review of the supply chain management literature, Stroumpoulis and Kopanaki (2022) emphasize the critical significance of DT in the creation of sustainable supply chain strategies. All areas of the company use digital technologies to enhance operational performance, customer interactions, and business processes.[30] Advanced Artificial Intelligence (AI) technology are being incorporated into healthcare through digital transformation, which is changing the medical services landscape. Clinical outcomes are being improved, operational efficiency are being maximized, and healthcare delivery is being revolutionized through the strategic integration of AI.[13] The way physicians treat their patients is evolving due to digital healthcare. This involves the use of wearable technology, electronic health records (EHRs), telemedicine, and health management systems to provide a variety of healthcare services.[31]

Digital health apps and other data sources can be integrated by these systems. This platform's adaptability in connecting to different digital devices and mobile health apps, as well as its ability to provide tailored suggestions based on historical data and forecasts, can greatly enhance the influence of digital tools on the results of the health system.[32] Digital healthcare management has transformed healthcare and is accurate and efficient.[31]

- **The importance of digital transformation in the pharmaceutical industry:**

The quick development of digital technology is causing a major upheaval in the pharmaceutical sector. Pharmaceutical firms that want to increase productivity, improve product quality, and keep a competitive edge in a more complicated and regulated market must strategically embrace digital technologies. Digital transformation includes a wide range of activities, such as using artificial intelligence and big data analytics for process optimization and quality control, automating manufacturing processes, and putting electronic batch records into place. One of the most strictly regulated industries, the pharmaceutical sector must meet strict standards for product efficacy, safety, and quality. In this regard, pharmaceutical businesses can achieve these standards while increasing operational agility and efficiency thanks to digital transformation.[33]

A critical phase in the research and development of new drugs is the creation of pharmaceutical formulations. By creating drug formulations, pharmaceutical professionals can control important aspects of novel drugs, such as improved bioavailability and targeted distribution. The traditional approach to drug formulation is based on a recurring process of trial and error, which necessitates investigations in living organisms and laboratories that take a lot of time and money.[34]

Technology breakthroughs and the global COVID-19 pandemic have caused a dramatic shift in pharmacy practice and education in recent years. A shift in customer behaviour toward online pharmacies is revealed by a study that highlights the growing consumer trust in online pharmaceutical purchases before, during, and after the epidemic.[12]

By encouraging innovation, strengthening partnerships and stakeholder participation, and improving patient outcomes, digital transformation helps businesses meet these problems.[33]

AI-powered tools, like computational fluid dynamics (CFD), can automate a lot of operations and use sophisticated simulation technology to

assess the effects of variables like pressure and mixing inside equipment (like stirred tanks).[35]

In order to guarantee an effective medicinal product, the pharmaceutical industry is currently focusing on cutting production costs, enhancing process design, and shortening the time it takes to manufacture a pharmaceutical product.[22]

Cost-effectiveness, improved patient care, and increased efficiency and openness in the research and production of pharmaceuticals are all important.[12]

➢ **Digital transformation in global healthcare:**

The incorporation of digital technologies is primarily responsible for these changes, which are redefining the instruments and techniques employed in biomedical science, health, and medicine with the ultimate goal of establishing a healthier future for people everywhere. Current advancements in digital transformation in the global healthcare sector are radically changing the pharmacy and healthcare services environment.[12] Drug monitoring plays a significant role in patients' healthcare. Electronic drug monitoring systems (eDMS) are used to measure the clinical documentation time of nurses. It is done because of safety concerns, the high possibility of mistakes, and the fact that information and communication technology (ICT) can help. The electronic drug monitoring systems (eDMS) include electronic and manual components.[28] There is great potential for the application of AI in healthcare. AI in healthcare makes it feasible to improve patient diagnosis, prevention, and treatment; boost cost-effectiveness; and provide fair access to care. Computers (e.g., AI, including machine learning, deep learning, neural networks, and reinforcement learning) that are trained to think and behave like people are used to simulate human intelligence in order to create new knowledge, tools, and concepts.[23]

➢ **Reasons for Digital Transformation to Enhance Quality Management Systems:**[33]

- Enhancing traceability and data integrity
- Improving process monitoring and control
- Facilitating quality analytics and decision-making in real-time
- Simplifying training and document management
- Encouraging innovation and ongoing progress

ADVANTAGES:

- The pharmaceutical sector now has the chance to use artificial intelligence to solve issues that were previously impossible to resolve with basic data analysis.[36]
- It has been demonstrated that AI affects computed tomography (CT) and lowers the required radiation dosage.[15]
- Enhancing Online and In-Person Consultations Clinical Support and Drug Administration.[37]
- AI helps to improve accuracy with more precision and reduce errors.[38]
- In terms of clinical trial patient selection, it also assists the industry and allows businesses to detect efficacy and safety problems with substances at a far earlier stage.[36]
- The most well-known AI-based idea is IBM Watson, which helps oncologists analyse patient data to determine whether it is properly

formatted and use that information to inform treatment decisions.[37]

- The realization of a fully automated library is now possible because to developments in robotics and other technology.[36]
- Deep learning and natural language processing are two ways AI is redefining drug discovery by comprehending and analysing enormous amounts of bioscience data.[36]

DISADVANTAGES:

- Building, repairing, and rebuilding AI can be very expensive and time-consuming.[36]

The growing use of AI in healthcare has raised serious societal concerns, with privacy becoming a top priority.[15]

- Experience doesn't make things better: Experiences can strengthen human resources. On the other hand, AI-powered robots cannot be improved by experience. They are incapable of telling which person works hard and which does not.[38]
- Medical robots lack the capacity to express these essential emotions, which are integral to patient care and recovery.[15]
- When machines fall into the wrong hands, they can quickly cause havoc. That is, a worry shared by many people.[36]
- Large-scale unemployment could result from the extensive use of AI technology across all industries. Employees may lose their work habits and creativity as a result of unemployment.[38]

APPLICATION:

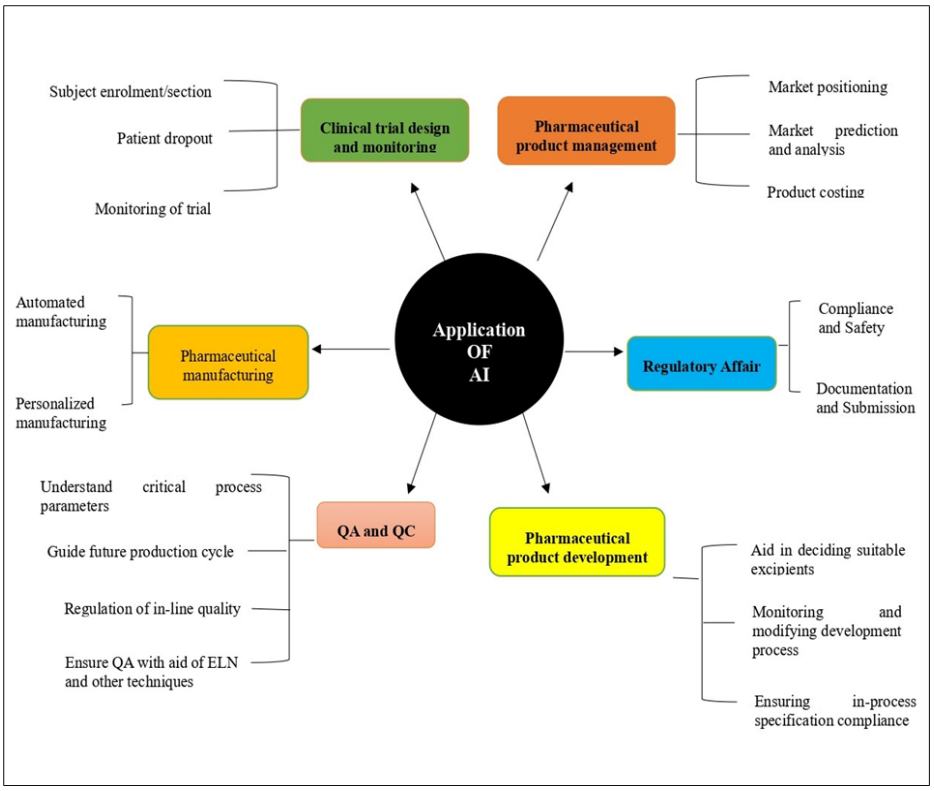

Fig.1: Application of AI in Pharmacy

- **Research and development:**

The formulation of the new therapeutic molecule in accordance with the intended delivery criteria is the only way to justify its invention. Therefore, in order to give it as a suitable dosage form that satisfies its predicted criteria, effective formulation development is required.[22] Additionally, researchers are investigating a novel strategy that combines a simple formulation design with little doses of the active therapeutic ingredient.[35]

- **Clinical trials design and monitoring:**

Clinical trials for novel drug discovery are conducted for specific diseases or infections in order to develop or assess a medicine's safety and effectiveness.[37] It has been demonstrated that AI techniques are crucial to pharmaceutical pre-market safety, especially when it comes to toxicity assessment. A critical phase in the medication design process is figuring out a medicine's toxicity, or how harmful a chemical is to people, animals, plants, and the environment.[35] AI systems in clinical pharmacy are intended to help pharmacists and medical professionals provide effective, efficient, and individualized patient care.[40] Clinical trial design, patient recruitment and selection, site selection, monitoring, data collection, and analysis are all steps in the execution and conduct of clinical trials.[41] These developments are speeding up medical discoveries, cutting expenses, and increasing productivity at different phases of medication development.[42] A third of the clinical trial's time is spent enrolling subjects. Finding the right patients to participate in a clinical trial is crucial because failing to do so results in 86% of failure situations. Through patient-specific genome–exposome profile analysis, AI can help select only a certain diseased population for recruitment in Phase II and III clinical trials. This can aid in the early prediction of the possible therapeutic targets in the selected patients. The early prediction of lead molecules that would pass clinical trials while taking into account the chosen patient population is aided by preclinical molecule discovery and the prediction of lead compounds prior to the commencement of clinical trials using other facets of AI, such as predictive machine learning and other reasoning techniques.[39]

- **Quality control and Quality assurance:**

The process of developing a pharmaceutical formulation within the allotted time frame while maintaining quality is intricate and calls for a methodical, scientific approach.[22] To maintain the desired product, the products must pass quality control tests and batch-to-batch consistency checks. There is a need for AI implementation because this approach is probably not the optimal one for every circumstance.[37] Information is gathered about the characteristics of drug ingredients, excipients, how they interact with one another, how units work, and what equipment is used.[22] AI integration has reduced errors and expedited the inspection process. As a result, AI has improved the safety and standing of newly released products while preserving the health of patients.[34] Product quality is guaranteed by computerized systems such as Electronic Lab Notebooks. In Total Quality Management, data mining and clever techniques enhance decision-making and develop cutting-edge technology for superior products.[43]

- **Regulatory affairs:**

Products are often approved by regulatory bodies based on information and documentation provided at every stage, from product development to medicine discovery.[39] Automation and artificial intelligence (AI) can speed up this process by

lowering the amount of time needed to gather, separate, and standardize data from records and by lowering the amount of human intervention in the documentation process.[34]

- **Pharmaceutical manufacturing:**

One effective strategy for reducing batch-to-batch differences is continuous manufacturing. To lessen variation in the finished product and patient outcomes, the FDA advocates for continuous manufacturing. To track continuous manufacturing, a variety of process analytical technology (PAT) technologies are available. These PAT gadgets can continuously monitor the production process and are economical and effective. The manufacturing process may benefit from the use of AI in conjunction with PAT.[22] Artificial Intelligence (AI) is revolutionizing the pharmaceutical manufacturing sector by using machine learning algorithms to evaluate large datasets, optimize intricate drug formulation procedures, and boost production efficiency. By analysing past data and forecasting times of high demand, machine learning algorithms can enhance production scheduling, leading to more efficient resource allocation and higher productivity. For example, these algorithms may examine large datasets to find inefficiencies and suggest changes that improve pharmaceutical manufacturing's production efficiency. To boost productivity, cut costs, and improve product quality, this may entail modifying variables like temperature, pressure, ingredient quantities, and mixing times.[44]

- **Pharmaceutical product management:**

Given that AI can support rational drug design, aid in decision making, identify the best course of treatment for a patient, including personalized medications, manage the clinical data generated, and utilize it for upcoming medication development, it can be involved in the creation of a pharmaceutical product from the laboratory to the patient's bedside. Eularis created the analytical and decision-making AI platform E-VAI, which employs machine learning algorithms and an intuitive user interface to generate analytical roadmaps based on competitors, important stakeholders, and current market share in order to forecast important factors influencing pharmaceutical sales, hence assisting marketing executives in correcting poor sales, allocating resources for the greatest increase in market share, and anticipating where to invest.[39] Artificial intelligence (AI) can be used to develop pharmaceutical products in the areas of enhanced decision-making, sophisticated drug design procedures that serve as a foundation for future research, and clinical data generation for proposed studies.[37] When a new therapeutic molecule is discovered, it must then be added to an appropriate dosage form with the required delivery properties. AI can take the place of the more traditional trial-and-error method in this field. Numerous computational methods can be used with QSPR to handle formulation design challenges such as stability, dissolution, porosity, and so on. Using rule-based systems, decision-support tools choose the kind, kind, and amount of excipients based on the drug's physicochemical characteristics. They also use a feedback mechanism to track the entire process and make intermittent modifications.[39]

FUTURE PERSPECTIVES:

One emerging concept in personalized medicine is preventive medicine.[21] In an effort to increase production, efficiency, and regulatory compliance, the pharmaceutical sector is going through a major digital revolution.[33] The revolutionary effect of digital technology on healthcare delivery has a significant impact on future trends for the digital transformation of pharmaceutical companies worldwide. To improve patient care, telemedicine,

electronic health records, and mobile health apps must be integrated. By facilitating better data exchange and teamwork among medical experts, these technologies help to improve the effectiveness of healthcare services.[12] Close cooperation between businesses, regulators, and trade groups is necessary for the pharmaceutical industry's QMS digital transformation to be effective. The demand for industry-wide standards and norms that guarantee the consistency, dependability, and security of digital quality data and procedures is increasing as digital technologies continue to advance and upend conventional quality management approaches.[33]

CONCLUSION:

AI has demonstrated significant advantages in the pharmaceutical industry and can be applied to robots. Although there are still restrictions, AI is exhibiting encouraging growth in the pharmaceutical industry. Despite having access to almost all available data, the AI still does not reach that level of precision. Adopting digital technologies has become a strategic priority for pharmaceutical companies looking to maintain their competitive edge and meet the changing expectations of patients and regulators as the industry faces record-breaking challenges like the need for personalized medicine, faster drug development, and global supply chain visibility. Healthcare delivery is being drastically altered by the digital revolution of the pharmaceutical industry, which is being fueled by the incorporation of cutting-edge technology like blockchain and artificial intelligence. AI algorithms are crucial to the application of personalized medicine. The medical field would be perfected and many lives would be saved if personalized medicine were successfully implemented.

REFERENCES

1. Jessica H, Britney RFig.1: Application of AI in Pharmacy , Sarira E den, Parisa A, Joe Z, B CB. Research in Social and Administrative Pharmacy Applications of artificial intelligence in current pharmacy practice : A scoping review. Res Soc Adm Pharm. 2025;21(3):134–41. Available from: https://doi.org/10.1016/j.sapharm.2024.12.007
2. Harsha S, Syed J, Ramesh M, Patil V, Kumar TMP. Exploratory Research in Clinical and Social Pharmacy Artificial intelligence in the field of pharmacy practice : A literature review. Explor Res Clin Soc Pharm [Internet]. 2023;12(July):100346. Available from: https://doi.org/10.1016/j.rcsop.2023.100346
3. Jarab AS, Al-qerem W, Alzoubi KH, Obeidat H, Abu S, Mukattash TL, et al. Artificial intelligence in pharmacy practice : Attitude and willingness of the community pharmacists and the barriers for its implementation. Saudi Pharm J [Internet]. 2023;31(8):101700. Available from: https://doi.org/10.1016/j.jsps.2023.101700
4. Anandharaj G, Saravanakumar A, Manivasakam P, Mohanraj S, Archana V, Kavin S, et al. Review article A Review on Applications of Artificial Intelligence in Clinical Pharmacy. 2025;(3048).
5. Udegbe FC, Ebulue OR, Ebulue CC, Ekesiobi CS. Ai ’s Impact on Personalized Medicine : Tailoring Treatments for improved Health Outcomes. 2024;5(4):1386–94.
6. Parekh A duhaa E, Shaikh OA, Manan S. Arti fi cial intelligence (AI) in personalized medicine : AI-generated personalized therapy regimens based on genetic and medical history : short communication. :5831–3.
7. Rezayi S, Kalhori SRN, Saeedi S. Review Article Effectiveness of Artificial Intelligence for Personalized Medicine in Neoplasms : A Systematic Review. 2022;2022.

8. Gatla TR. An Innovative Study Exploring Revolutionizing Healthcare With AI : Personalized Medicine : Predictive Diagnostic Techniques And Individualized Treatment. 2024;2(2):61–70.
9. Chianumba EC, Ikhalea N, Mustapha AY, Forkuo AY. Developing a Framework for Using AI in Personalized Medicine to Optimize Treatment Plans. 2022;(2012):57–71.
10. Park T, Muzumdar J, Kim H. Digital Health Interventions by Clinical Pharmacists : A Systematic
11. Stoumpos AI, Kitsios F. Digital Transformation in Healthcare : Technology Acceptance and Its Applications. 2023;
12. Almeman A. The digital transformation in pharmacy: embracing online platforms and the cosmeceutical paradigm shift. J Heal Popul Nutr. 2024;43(1):1–22.
13. Yasmin B. Digital Transformation in Healthcare : Strategic Integration of AI Technologies. :35–43.
14. Ahmadi A. Digital Health Transformation : Leveraging AI for Monitoring and Disease Management. 2023;3(1):10–24.
15. Sartschev E, Reyes J. Pharmacy and Wellness Review Artificial Intelligence (AI) in Pharmacy Artificial Intelligence (AI) in Pharmacy. 2025;15(1).
16. Kwon IWG, Kim SH. Digital Transformation in Healthcare Digital Transformation in Healthcare. 2024;(March 2021):4–6.
17. Ugo E, Okechukwu A, Chima P. Artificial intelligence in personalized medicine : transforming diagnosis and treatment. Discov Appl Sci [Internet]. 2025; Available from: https://doi.org/10.1007/s42452-025-06625-x
18. Jawahar N, Reddy G. Nanoparticles: A novel pulmonary drug delivery system for tuberculosis. J Pharm Sci Res. 2012;4(8):1901–6.
19. Serrano DR, Luciano FC, Anaya BJ, Ongoren B, Kara A, Molina G, et al. Artificial Intelligence (AI) Applications in Drug Discovery and Drug Delivery : Revolutionizing Personalized Medicine. 2024;
20. Bilgin GB, Bilgin C, Burkett BJ, Orme JJ, Childs DS, Thorpe MP, et al. Theranostics Theranostics and artificial intelligence : new frontiers in personalized medicine. 2024;14(6).
21. Awwalu J, Garba AG, Ghazvini A, Atuah R. Artificial Intelligence in Personalized Medicine Application of AI Algorithms in Solving Personalized Medicine Problems. 2015;7(6).
22. Kalyane D, Sanap G, Paul D, Shenoy S, Anup N, Polaka S, et al. Artificial intelligence in the pharmaceutical sector : current scene and future prospect [Internet]. The Future of Pharmaceutical Product Development and Research. INC; 2020. 73–108 p. Available from: http://dx.doi.org/10.1016/B978-0-12-814455-8.00003-7
23. Macha KB. Integrating AI , ML , and RPA for end-to-end digital transformation in healthcare Integrating AI , ML , and RPA for end-to-end digital transformation in healthcare. 2025;(January).
24. Dovzhuk V, Konovalova L, Dovzhuk N, Konovalov S, Konoshevych L, Motorna N. Prospects for the Use of Artificial Intelligence in Personalized Medicine, Pharmaceutical Design and Education. SSP Mod Pharm Med. 2025;5(2):1–13.
25. Amekyeh H, Tarlochan F, Billa N. Practicality of 3D Printed Personalized Medicines in Therapeutics. Front Pharmacol. 2021;12(April):1–15.
26. Ejike Innocent Nwankwo, Ebube Victor Emeihe, Mojeed Dayo Ajegbile, Janet Aderonke Olaboye, Chukwudi Cosmos Maha. AI in personalized medicine: Enhancing drug

efficacy and reducing adverse effects. Int Med Sci Res J. 2024;4(8):806–33.
27. Beer N, Hegger I, Kaae S, De Bruin ML, Genina N, Alves TL, et al. Scenarios for 3D printing of personalized medicines - A case study. Explor Res Clin Soc Pharm. 2021;4.
28. Mannan A, Mubeen H. Digitalisation and Automation in Pharmaceuticals From Drug Discovery To Drug Administration. Int J Pharm Pharm Sci. 2018;10(6):1.
29. Serrano DR, Kara A, Yuste I, Luciano FC, Ongoren B, Anaya BJ, et al. 3D Printing Technologies in Personalized Medicine, Nanomedicines, and Biopharmaceuticals. Pharmaceutics. 2023;15(2).
30. Ma JY, Shi L, Kang TW. The Effect of Digital Transformation on the Pharmaceutical Sustainable Supply Chain Performance: The Mediating Role of Information Sharing and Traceability Using Structural Equation Modeling. Sustain. 2023;15(1):1–21.
31. Akinola S. Sustainable Digital Transformation in Healthcare : Advancing a Digital Vascular Health Innovation Solution. 2023;
32. Periáñez Á, Fernández A, Río D, Nazarov I, Jané E, Rastogi A, et al. The Digital Transformation in Health : How AI Can Improve the Performance of Health Systems The Digital Transformation in Health : How AI Can Improve the Performance of ABSTRACT. Heal Syst Reform [Internet]. 2024;10(2). Available from: https://doi.org/10.1080/23288604.2024.2387138
33. Pravin Ullagaddi. Digital Transformation in the Pharmaceutical Industry: Ensuring Data Integrity and Regulatory Compliance. Int J Bus Manag. 2024;12(1):31–43.
34. Huanbutta K, Burapapadh K, Kraisit P, Sriamornsak P. European Journal of Pharmaceutical Sciences Artificial intelligence-driven pharmaceutical industry : A paradigm shift in drug discovery , formulation development , manufacturing , quality control , and post-market surveillance. Eur J Pharm Sci [Internet]. 2024;203(June):106938. Available from: https://doi.org/10.1016/j.ejps.2024.106938
35. Shettima U, Farogh U, Alanjiro M, Yahaya S, Jibrin B, Dallatu A, et al. Revolutionizing drug development and beyond. 2025;(January):1–17.
36. Sharma T, Mankoo A, Sood V. Artificial intelligence in advanced pharmacy. 2021;
37. Agarwal S, Gupta RK, Kumar S. Arti icial Intelligence in the Pharmacy Profession. 2021;12(3):2269–79.
38. Das S, Dey R, Nayak AK. Artificial Intelligence in Pharmacy. 2021;55(2).
39. Paul D, Sanap G, Shenoy S, Kalyane D, Kalia K, Tekade RK. Artificial intelligence in drug discovery and development. Drug Discov Today [Internet]. 2021;26(1):80–93. Available from: https://doi.org/10.1016/j.drudis.2020.10.010
40. Info A. Artificial intelligence in clinical pharmacy : enhancing drug safety , adherence , and patient-centered care Received : 25-12-2022 Accepted : 27-01-2023 Page No : 814-822. 2018;814–22.
41. Bhattamisra SK, Banerjee P, Gupta P, Mayuren J, Patra S, Candasamy M. Artificial Intelligence in Pharmaceutical and Healthcare. 2023;
42. Allam H. Prescribing the Future : The Role of Artificial Intelligence in Pharmacy. 2025;
43. Papia SA, Rashid MA, Nath TD, Uddin Z, Ibrahim M, Hossen S. Artificial Intelligence and Machine Learning for Pharmacy Students and Pharmaceutical Professionals : a Narrative Review. 2025;28(2):228–39.
44. Rajesh MV, Elumalai K. The transformative power of artificial intelligence in pharmaceutical manufacturing: Enhancing

efficiency, product quality, and safety. J Holist Integr Pharm [Internet]. 2025;6(2):125–35. Available from: https://doi.org/10.1016/j.jhip.2025.03.007.

HOW TO CITE: Sejal Dalvi*, Yash Kini, Sanam Mestry, Samali Raut, AI In Personalized Medicine and Digital Transformation, Int. J. of Pharm. Sci., 2025, Vol 3, Issue 12, 2448-2462 https://doi.org/10.5281/zenodo.17939115