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IMPORTANCE AND APPLICATION OF ARTIFICIAL INTELLIGENCE IN PHARMACEUTICAL SECTOR

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ABSTRACT

Artificial Intelligence (AI) is a branch of study that deals with intelligent machine learning, primarily intelligent computer programs that produce outcomes that resemble human attention processes. The ability of machines and computers to think, act, behave, and function like humans is referred to as artificial intelligence. Beyond drug development, AI improves medication management and customizes patient care to revolutionize pharmacy operations. Community pharmacists can use digital technology and artificial intelligence (AI) to transform patient care in a number of ways. In order to forecast drug activity at every scale, AI systems can examine intricate correlations between pharmacological characteristics, formulation elements, and physiological parameters. In pharmaceutical research, artificial intelligence (AI) has become a potent tool for predicting the physicochemical stability of oral dosage forms. Potential applications of artificial intelligence include patient education, physical activity suggestions, personal dietary intervention, and behavioural coaching. In recent years, artificial intelligence (AI) in medicinal chemistry has drawn a lot of attention as a potential way to transform the pharmaceutical sector. Additionally, medication candidates' toxicity has been predicted using AI-based techniques. Predicting the toxicity and effectiveness of possible therapeutic molecules is one of the main uses of AI in medicinal chemistry.

KEYWORD: Artificial Intelligence, Work of AI in Pharmacy, Robotic Dispensing Integrated with AI Technology, Lifestyle Management and Counseling.

INTRODUCTION

Artificial Intelligence

Artificial Intelligence (AI) is a branch of study that deals with intelligent machine learning, primarily intelligent computer programs that produce outcomes that resemble human attention processes.[1] AI technology is used to achieve both helpful interpretation and more accurate analysis.[2] AI technology is becoming an essential component of the industry for practical uses in numerous technical and scientific domains. Even in the face of pharmacist shortages, rising operating costs, and decreased reimbursements, pharmacies have done a fantastic job of meeting the rising demand for prescription drugs over the past 25 years.[3] Since the 1980s, computers have been used in pharmacies for a variety of purposes, including data collection, retail pharmacy management, clinical research, drug storage, pharmacy education, clinical pharmacy, and much more. With the development of artificial intelligence, it is impossible to predict how much the pharmacy industry will change over time.[4] The terms robotics and automation are frequently used interchangeably with artificial intelligence (AI), also referred to as machine intelligence. AI refers to the display of human-like behaviours or intelligence by any computer or machine, whereas robotics is merely the development of machines capable of performing challenging repetitive tasks.[5] The long-term objective of the AI community is to build machines that can perform all cognitive tasks better than humans on their own. General AI, often known as Strong

AI, is the type of AI that entails building machines that are capable of all human cognitive functions.[6]

The ability of machines and computers to think, act, behave, and function like humans is referred to as artificial intelligence. Apple's SIRI (On the iPhone), Amazon's Alexa, and Google, Mercedes, BMW, and Tesla's self-driving cars are a few well-known instances of AI-controlled systems. AI-powered data analytics can be used to forecast a patient's future medication purchases. The pharmacist can make better stock procurement decisions by using AI to predict the patient's drug purchase.[7] Analysing the connections between treatment or preventative strategies and patient outcomes is the main goal of health-related AI applications. AI programs have been created and used in a variety of fields, including patient monitoring and care[10], personalized medicine[9], diagnosis procedures, and treatment protocol building.[8] Through a variety of activities like medication reconciliation, medication review, medication therapy management (MTM), providing drug information, patient education, adverse drug reaction (ADR) monitoring, and interprofessional collaborations, pharmacy practice is an essential component of the healthcare system that guarantees safe and effective medication management and optimal patient care.[11] Pharmacists can make precise and evidence-based healthcare judgments with the use of tools and systems made possible by the integration of AI technologies. Pharmacists can swiftly examine vast volumes of patient data, such as test results, medical records, and prescription profiles, by utilizing AI algorithms and ML. This enables them to evaluate the safety and effectiveness of medications, spot any drug-drug interactions, and provide well-informed advice specific to each patient.[12] Innovation in the pharmaceutical sector is usually based on thorough research and development in a number of areas, including as manufacturing technology, packaging considerations, and customer-focused marketing tactics.[13]

The use of AI in study design aids in both optimization and accretion for the tasks involved in developing a patient-centric design. AI employs methods for gathering the massive volumes of data produced by those clinical trials, which lowers the number of data workers needed for the same. In order to address the patient's need for regular face-to-face engagement, these technologies use wearable technology in conjunction with body sensors to record vital signs and other important data remotely. Throughout the research process, wearable technology-based AI algorithms offer real-time insights.[14]

AI offers advanced technologies for analysing this kind of multilayer data. A deeper comprehension of the research units will result from the analysis's thoroughness. In order to find the best results, the methodically applied model and parameter evaluation rely on a variety of criteria at each stage of the research, including simulation, scoring, and refining. AI may offer an automated method that can be used for all of these tasks to enhance guesswork and anticipate data refinement for steady development. The system biology type of the databases indicates that a thorough understanding of the drug-biological interaction is necessary for improved AI training in the biological environment. Numerous cutting-edge AI technologies, including artificial neural networks, can be used to conduct pharmacokinetic investigations. In addition, AI provides a variety of databases, including phonotypical, genomic, and chemical databases, which may be used to effectively research the complicated unit roles of molecules and gain a better knowledge of medication interactions. In order to have a thorough grasp of the medication's disposition and toxicity, several of the techniques are also used to investigate how the drug delivery system affects the drug's pharmacokinetics. Prior to conducting actual studies, many novel approaches to medication delivery systems entail designing quality qualities in addition to important attributes and analysing their effects on experimental trials. AI has the advantage of gathering data from many sources and giving recommendations for the chosen drug delivery system to function in accordance with the expected outcomes. The assessment of molecular data, patient data, and pharmacokinetic data is regarded as a component of the complicated data for analysis in order to potentially choose the most effective active pharmaceutical against patient conditions or needs. In order to identify molecular entity traits and compare them to those of known molecules, passive AI is used. Accurate medication delivery system selection, which is made possible by AI, is essential to effective treatment. Both the drug repurposing approach and the drug discovery process benefit from AI. This deals with applying the current treatments to the new illness. Formulation, pharmacokinetics, and medication development are significantly influenced by patient requirements and disease conditions. The availability of databases with comprehensive information is one of the main obstacles to the complete application of AI in the development of delivery systems. This is necessary for the models and parameters to be evaluated objectively. AI uses present knowledge to assist future applications. AI tools can handle or digest a lot of data for a better approach to the product's logical design. Excellent self-supervised trial outcomes and appropriate parameter recording can be achieved with a more rigorous coding inside the knowledge database.[15–21]

AI offers unmatched accuracy and efficiency in drug discovery, speeding up the identification of medicinal molecules. Early-stage medication development is streamlined and drug repurposing is made possible by machine learning models that reliably anticipate compound efficacy and safety. These capabilities improve the accuracy of results while drastically cutting the time and expenses related to conventional drug discovery techniques.[22] Beyond drug development, AI

improves medication management and customizes patient care to revolutionize pharmacy operations. Pharmacists are given data-driven tools that facilitate accurate clinical decision-making through the integration of AI-driven technologies. In order to predict adverse drug events, adjust dosages, and streamline workflows-all of which ultimately improve patient outcomes-these systems evaluate large datasets, including patient medical records and medication histories.[23,24] AI is quickly transforming businesses all around the world, and one of the main areas benefiting from its developments is healthcare. AI has the potential to revolutionize pharmacy, especially in terms of improving medication administration and individualized patient care.[25]

Role of AI in Pharmacy

Community pharmacists can use digital technology and artificial intelligence (AI) to transform patient care in a number of ways. In the near future, gathering and analysing vast volumes of patient data to learn more about prescription use, side effects, and treatment results may become simpler. Patients' health outcomes could be improved by using this information to improve patient safety and provide tailored therapies.[26] First of all, they can help with medication adherence, which is a big problem in the medical field. Medication reminders, educational materials, and notifications for repeat prescriptions are already provided by digital tools.[27] These resources can facilitate easier access to care by bridging the gap between patients and pharmacists.[28] The advantages of pharmacists having access to patient records are being observed in nations like the UK and Australia.[29] Although pharmacists in the UK have access to a summary of a patient's medical history (but not the ability to edit it), new technology combined with legislative and regulatory changes may enable community pharmacists to play a larger role in patient care and strengthen their relationships with other members of the multidisciplinary healthcare team.[30] The identification, optimization, and design of new therapeutic candidates might be streamlined and accelerated by AI-driven methodologies in drug research and development, which would ultimately result in more effective and efficient drugs.[31]

In order to forecast drug activity at every scale, AI systems can examine intricate correlations between pharmacological characteristics, formulation elements, and physiological parameters. This makes it possible to comprehend medication delivery mechanisms more thoroughly and helps create effective drug delivery systems. It aids in the prediction of the medication's stability, in vitro drug release profile, and physicochemical characteristics. Along with in vivo-in vitro correlation research, the same technique is also used for improved evaluation of in vivo pharmacokinetic parameters and drug distribution. Early in the development phase, researchers can detect possible dangers and difficulties related to medication delivery systems by employing the appropriate collection of AI technologies. This makes it possible to make proactive changes and adjustments to reduce risks and improve medication efficacy. By reducing the need for costly and time-consuming trial-and-error trials, artificial intelligence (AI) and computer modelling lower the likelihood of unexpected results.[32,33] AI uses sophisticated hardware and software to develop human-like abilities. Many industries, including the pharmaceutical sector, have benefited from this kind of innovation in recent years, particularly during the product development stage. The application of these technology advancements can reduce the amount of time, money, and resources needed for production and appropriate supply chain distribution to final consumers. Additionally, it offers a more comprehensive framework for comprehending how process parameters affect product development and manufacture. To create a classification model that further aids in differentiating between the spring and parachute types of dissolution profiles, they employed a random forest algorithm. Additionally, it helped sustain supersaturation with 85% accuracy and 86% sensitivity. The regression model produced by the random forest technique was used to estimate the time-dependent drug release.[34] AI algorithms can create customized pharmacological regimens by optimizing the design and formulation of 3D-printed dosage forms based on patient-specific variables like age, weight, and medical history. AI can quickly prototype and optimize medication release profiles, dose strengths, and geometries by using machine learning and computational modelling to examine massive datasets and mimic the behaviour of 3D-printed dosage forms. AI also helps with quality monitoring, printing parameter optimization, and anticipating and resolving possible manufacturing issues. Additionally, by learning from real-time data and improving accuracy, repeatability, and scalability, AI-driven feedback systems may constantly enhance the 3D printing process. All things considered, the use of AI in 3D-printed dosage forms has enormous potential to advance personalized medicine and enhance patient outcomes.[35,36]

In pharmaceutical research, artificial intelligence (AI) has become a potent tool for predicting the physicochemical stability of oral dosage forms. AI models may evaluate elements including drug degradation, excipient interactions, and environmental influences on formulation stability. AI's incorporation into stability prediction helps make drug development processes more effective and economical, which eventually results in patients receiving safe and effective treatments.[37] Medication errors that present significant hazards to patients and are a major concern in the healthcare industry include adverse drug events, adverse drug reactions, and drug interactions.[38] The use of AI technology presents a viable way to improve these reactions' control and prediction. In a 2022 study, Westerman and associates examined machine learning

methods and the U.S. To better identify adverse events linked to novel drug combinations, the FDA Adverse Event Reporting System (FAERS) database was utilized. Using dimensional reduction and a convolutional neural network algorithm, the researchers found patterns that connected drugs to particular side effects. These patterns were then encoded into a compressed representation called "latent space," which made it easier to analyse and interpret adverse event profiles.[39,40] AI is essential for detecting and controlling medication interactions. AI algorithms can check for possible medication interactions, including drug-drug and drug-disease interactions, and inform patients and healthcare providers. For instance, AI can assess possible drug interactions and notify pharmacists when a patient is administered a new prescription while currently taking another for a different medical condition. It can then recommend dosage adjustments or alternative treatments. Furthermore, artificial intelligence can detect pharmaceuticals that could exacerbate pre-existing diseases, screen for drug-disease interactions, and offer relevant recommendations and alerts.[41]

Robotic Dispensing Integrated with AI Technology

One of the most important technologies that significantly contributes to the development of hospital pharmacy systems is pharmacy dispensing robotics.[42] Due to their heavy workloads and high levels of stress, pharmacists may make mistakes when distributing prescriptions, such as those that sound or look alike and endanger the patient's health.[43] In 2022, Mirates Health Services also unveiled the robotic pharmacy, which uses AI-integrated technology to function independently. This sophisticated system improves the efficacy and efficiency of the dispensing process by identifying and locating thousands of different drugs.[44] 2021 saw the introduction of Fred AID (Artificial Intelligence Directions), an AI-integrated distributing robot in Australia. By helping pharmacists spend less time on repetitive duties like recording prescription instructions, this technology increases the amount of time pharmacists spend caring for patients, thus improving patient safety.[45]

Lifestyle Management and Counseling

Potential applications of artificial intelligence include patient education, physical activity suggestions, personal dietary intervention, and behavioural coaching.[46] Personalized food planning is one important area where AI has demonstrated promise. According to research, people are more likely to stick to a diet plan for a longer amount of time if it is customized to their unique requirements and preferences, taking into account things like dietary preferences, cultural background, and lifestyle choices.[47] Healthcare providers can find any vitamin deficiencies that can be causing patients' health problems thanks to this individualized method. An AI system, for example, can identify a patient who has a history of anaemia and suggest a plant-based diet that might benefit from including more foods and supplements high in iron. Additionally, artificial intelligence can detect possible intolerance, which makes it possible to develop death plans that steer clear of triggers and improve people's health outcomes.[48]

AI has shown promise in helping people stop smoking. AI-powered tools like Persuasive Communication Tailoring and Quit Coach, for instance, have effectively provided customized therapy with better results than conventional methods. These platforms aid people who are trying to stop smoking by sending them personalized messages, helping them set a deadline for quitting, offering support when they have cravings, and helping them deal with circumstances where they used to smoke. Additionally, these cutting-edge applications use interactive dialogue with virtual characters to increase awareness of the negative effects of tobacco use.[49,50]

Similar software, ChatGPT, is crucial in giving patients important information and helpful support, such as advice on how to take their medications and details on any side effects. This is particularly important for those with mental problems who might find it challenging to interact with others in person. Patients are empowered to seek the help they require and are encouraged to actively participate in therapy due to the accessibility provided by AI-based solutions.[51-53] Beyond their traditional role as pharmacy managers, pharmacy professionals play an important role in patient-centred care, especially in the management of chronic diseases. They act as coaches, assisting patients in quitting smoking, adopting healthy eating habits, and addressing active lifestyles.[54] The integration of AI technology gives pharmacists a thorough understanding of each patient's specific needs, enabling personalized interventions.[55]

Opportunity in AI System

Drug Discovery

In recent years, artificial intelligence (AI) in medicinal chemistry has drawn a lot of attention as a potential way to transform the pharmaceutical sector.[56] The process of finding and creating new drugs, known as drug discovery, is a difficult and drawn-out undertaking that has historically relied on labour-intensive methods like high-throughput screening and trial-and-error research. However, by making it possible to analyse vast volumes of data more accurately and efficiently, AI methods like machine learning (ML) and natural language processing have the potential to speed up and enhance this process.[57] The authors have recently documented the successful application of deep learning (DL) to accurately forecast pharmacological compound efficacy.[58]

Additionally, medication candidates' toxicity has been predicted using AI-based techniques.[59] Predicting the toxicity and effectiveness of possible therapeutic molecules is one of the main uses of AI in medicinal chemistry. In order to evaluate a compound's possible effects on the human body, traditional drug discovery processes frequently depend on labour-intensive and

time-consuming experiments. AI approaches like machine learning can get around these restrictions. ML systems can find patterns and trends based on the examination of vast amounts of data that human researchers might miss.[60]

Numerous case studies have shown the potential of AI in the context of drug discovery. For instance, Gupta, R., et al. recently reported on the successful application of AI to find new chemicals for cancer treatment.[61] These authors used a sizable dataset of known cancer-related substances and the biological activity that goes along with them to build a deep learning algorithm. The ability of this strategy to find new therapeutic candidates was demonstrated by the production of novel compounds with high promise for future cancer treatment. It has recently been reported that ML can be used to find small-molecule inhibitors of the protein MEK.[62] Although the creation of potent inhibitors has been difficult, MEK is another potential target for cancer treatment. New inhibitors for this protein were found by the ML algorithm. Another example is the use of an ML algorithm to identify new inhibitors of beta-secretase (BACE1), an enzyme implicated in the development of Alzheimer's disease.[63] Additionally, AI has been effectively used to find novel antibiotics.[64] Despite AI's potential advantages in drug research, there are a number of obstacles and restrictions to take into account. The availability of appropriate data is one of the main obstacles.[65] AI-based methods usually need a lot of data for training.[66] The accuracy and dependability of the results can frequently be impacted by the quantity of data that is available, or the data may be inconsistent or of poor quality.[67] One crucial issue that needs to be addressed is ensuring the ethical and equitable application of AI for the creation of novel medicinal molecules.[68]

Quality Control and Quality Assurance

Through its application in quality control (QC) and assurance programs, artificial intelligence (AI) has fundamentally altered how industries uphold product standards and ensure operational excellence. Physical testing, human judgment, and manual inspections are often the foundation of conventional QC methods, which can be time-consuming, prone to error, and inefficient for large-scale production.[69] AI enhances predictive quality control by using algorithms that learn from past production data to anticipate potential problems, optimize the inspection schedule, and enhance maintenance procedures.[70] Incorporating AI into quality assurance (QA) and control programs would improve the end product's quality while boosting overall operational effectiveness, cutting expenses, and enabling continuous manufacturing process development.[71] AI improves accuracy, efficiency, and predictive capabilities, transforming QA and QC.[72]

Real-time defect detection, automated inspections, and predictive maintenance are made feasible by AI-powered technologies like computer vision, machine learning, and robotic process automation (RPA), which reduce operating expenses and human error. While AI-based natural language processing (NLP) examines compliance paperwork, sentiment analysis evaluates customer input in QA to enhance goods and services. Predictive analytics powered by AI also aids in spotting industry trends that lower errors and improve supply chains. Businesses can guarantee improved customer satisfaction, regulatory compliance, and product quality while being more effective and economical by using AI into QC and QA procedures.[73,74]

AI makes it possible to monitor production operations in real time while maintaining quality. This enables timely remedial action, preventing mistakes and maintaining consistency.[75] In chemical production, for instance, AI keeps an eye on temperature and pressure levels to guarantee ideal circumstances and reduce the possibility of deviations that could affect the final product's quality/.[76] AI-driven imaging systems can detect minute defects in turbine blades, ensuring structural integrity, safety, and dependability.[77] Industries can improve accuracy, eliminate errors, and guarantee the highest quality by integrating AI into QC. These tools guarantee improved quality control by identifying flaws that human inspectors could overlook. For instance, AI can identify scratches on car body panels and detect minute flaws in semiconductor manufacturing wafers to stop faulty items from being sold. Errors and inefficiencies become typical because traditional QC/QA approaches are frequently inadequate, reactive, and subjective.[78]

Important Artificial Intelligence Technologies Used in Quality Control/Quality Assurance

By analysing and understanding visual data from their environment, computers may simulate human vision through computer vision. In QA and QC, it is utilized for automated visual inspection and fault identification, which includes finding surface imperfections, misalignments, or incorrect assembly. By employing DL techniques, such as convolution neural networks (CNNs), to examine photos and videos and find even the tiniest flaws that human inspectors would overlook, AI plays a critical part in this process.[79] A kind of artificial intelligence called machine learning (ML) uses historical data to train computers to identify patterns, forecast outcomes, and adjust to new data. In order to predict potential defects or failures, ML models are employed in QA and QC to assess sensor, inspection, and manufacturing line data.[80]

NLP is used in QC and QA to analyse and extract valuable information from unstructured data sources, including customer feedback, reports, and maintenance logs. AI's role in this process is to examine enormous volumes of text data and identify quality-related defects or recurring problems that require correction. Some of the primary applications of NLP in QC/QA are as follows: Sentiment analysis, which analyses customer

reviews and feedback to identify quality concerns and drive product improvements; root cause analysis, which looks at maintenance logs and incident reports to find recurrent causes of defects; and automated report generation, which processes inspection data to automatically generate reports or alerts about quality issues.[81]

In order to automate complex or repetitive quality assessment tasks, AI is quickly being integrated with robotics and automation. Robots with AI capabilities can do quick and precise jobs such precise part handling, assembly verification, and visual inspection. The purpose of AI is to enable these robots to work autonomously, detect defects, and even make changes while production is in progress without the need for human help.[82]

"Digital twins" are virtual replicas of genuine systems or processes that are designed to replicate real-world performance and behaviour. In order to simulate production processes and foresee any quality issues in QA and QC, digital twins are crucial. AI is essential for discovering and predicting quality issues utilizing simulations and real-time data by analysing data from the physical system and its digital twin.[83] For example, the aerospace industry uses digital twins to simulate the airplane assembly process, allowing producers to foresee certain defects or issues before they arise on the actual production line. AI technologies are transforming the QC/QA environment by improving the accuracy, scalability, and efficiency of quality management processes. By eliminating quality issues before they occur and enhancing defect detection and process optimization, these solutions ultimately improve operational efficiency, customer happiness, and product reliability.[84,85]

Pharmaceutical 3D Printing

The creation of pharmaceutical items has undergone a revolutionary change thanks to the combination of 3D printing and artificial intelligence (AI).[86] With a focus on individualized medication, additive manufacturing is replacing traditional mass production in the pharmaceutical industry thanks to three-dimensional printing technologies.[87] Treatment efficacy and adherence can be significantly increased by using this technology to customize drug combinations, release mechanisms, and dosages to each patient's unique needs.[88,89] The enormous potential of 3D printing technology in producing a wide range of medications has been revealed by the ground-breaking research on its creative application in pharmaceuticals. Fused Deposition Modelling (FDM) is one of the most extensively studied and utilized 3D printing technologies in the pharmaceutical industry. These studies have shown that 3D printing can be used to develop rapidly dissolving or dispersible formulations[90], controlled release preparations[91], gastro retentive tablets[92], suppositories[93], minitablets[94], medical devices, and flexible multi-drug combinations.[95] The capacity to design complicated dose forms that promote patient compliance, a wide range of materials employed, and a reasonably easy and affordable setup are the reasons for this significance.[96,97,98] Innovative pharmaceutical dosage forms, such as topical patches or dispersible forms, dissolving oral films, implantable devices, or multilayer pills, have been made possible by three-dimensional printing technology in an effort to improve patient compliance, increase drug efficacy, and provide new drug delivery mechanisms.[99-101] Over the past few decades, the pharmaceutical industry has made significant strides in integrating artificial intelligence (AI), which has revolutionized drug research, discovery, and customized treatment.[102,103]

Drug design, formulation optimization, and production efficiency could all be enhanced by the use of AI in 3D drug printing.[104] By forecasting the best material qualities, excipient combinations, and structural arrangements for 3D-printed medications, artificial intelligence improves computer-aided drug design.[105] Although the use of 3D printers in hospitals for personalized treatment is a major advancement, issues including the expense of installation, the requirement for qualified staff, and maintaining quality control still exist.[106] Patient compliance is improved by gastro-retentive drug delivery systems (GRDDS), which offer prolonged drug release in the stomach. Rapid prototyping with 3D printing has allowed for the effective preparation of a variety of capsular devices with distinct topologies, demonstrating possibilities for modified release drug delivery devices.[107-109] In order to minimize side effects, 3D printing makes it easier to create patches that are directly inserted into pancreatic cancer and contain chemotherapy medications.[110] Understanding a drug's physicochemical qualities and ADMET features is essential for preclinical research that focuses on pharmacology, pharmacokinetics, and toxicology.[111] Due to the paucity of clinical studies for paediatric applications, paediatric patients' particular needs for safe drug products and adherence necessitate particular considerations in drug design.[112] Despite the advantages, the widespread use of 3D printing in pharmaceuticals is hampered by issues with technology, dosage form manufacturing, safety, quality control, and regulatory factors.[113,114] The FDA is currently conducting research to obtain a thorough grasp of the technology and recognizes the growing problems with 3D printing.[115] Physical and technical limitations result from the limited availability of a variety of raw materials for 3D printers.[116] Regulatory agencies like the FDA may think about more expedited procedures for approving 3D-printed drugs due to the rapid advancement of 3D printing technology. To guarantee the safety, effectiveness, and quality of 3D-printed pharmaceuticals, new standards and norms need be established. This could entail developing frameworks that can adjust to the great variability and customisation possibilities of 3D-printed drugs, possibly through adaptive licensing techniques. These regulations ought to

cover topics including patient safety, medication stability, and production consistency.[117]

AI In Pharmacology

The simulation of human intelligence in computers that have been programmed to think and behave like humans is known as artificial intelligence (AI). It entails creating algorithms and computer programs that can carry out activities like speech recognition, visual perception, language translation, and decision-making that normally need human intelligence.[118] Target identification, hit identification, absorption, distribution, metabolism, elimination, toxicity prediction, lead optimization, and drug repositioning are just a few of the stages of drug discovery where AI is used.[119] The conventional "one drug, one target" method to drug discovery has given way in recent years to a more comprehensive and systems-level approach known as multi-target drug discovery.[120,121]

The increasing understanding that complex diseases including cancer, neurological diseases, and metabolic syndromes frequently entail the dysregulation of numerous genes, proteins, and pathways is what is driving this change.[122] Therefore, a well-designed multi-target intervention can increase efficacy, decrease resistance, and improve safety profiles, while modifying a single molecular target may have limited therapeutic benefit. This idea is consistent with the principles of systems pharmacology, which combines computer modelling, pharmacokinetics/pharmacodynamics (PK/PD), and network biology to comprehend drug action at the systems level.[123] Synergistic developments that overcome present constraints will probably influence multi-target drug discovery in the future. Creating standardized, high-quality datasets and more comprehensible machine learning models to offer more lucid biological insights are important topics.[124] By bridging the gap between computational and experimental pipelines, the field is moving toward a more cooperative approach. As we move toward a future of precision polypharmacology, it is anticipated that the creation of tailored, multi-target medicines will be accelerated by the introduction of generative AI, federated learning, and the integration of patient-level omics data.[125]

Medication Therapy Management (MTM)

In order to maximize drug therapy results, guarantee patient safety, and minimize adverse drug responses, medication therapy management is essential. Conventional MTM methods mostly rely on clinical knowledge, pharmacist-led consultations, and manual intervention. However, these traditional approaches have drawbacks include human error, ineffective medication regimen monitoring, and trouble tailoring therapies for a variety of patient populations. Digital health technology and artificial intelligence have become revolutionary tools in the healthcare industry, providing creative ways to improve pharmaceutical therapy management.[126]

When it comes to healthcare, artificial intelligence includes a wide range of technologies, such as neural networks, machine learning, and natural language processing.[127] Smart pill dispensers, conversational agents, and predictive analytics platforms are examples of AI-enabled medication management systems that can aid with adherence problems, improve dose, and lower avoidable medication-related consequences in older persons.[128] Artificial intelligence's ability to personalize and predict risks is a key benefit for managing many drugs, especially for older persons. By examining a person's medical history, co-morbidities, renal function, and even genomic data when available, AI systems using machine learning techniques have proven to be able to customize dosage regimens.[129] By utilizing vast amounts of data from electronic health records (EHRs), artificial intelligence (AI), especially machine learning (ML), has made new methods for customized medication possible.[130]

ML-based dosing models have been created for a number of drugs, including vancomycin, β-lactam antibiotics, and insulin control (Glucose).[131] A required part of the Medicare Part D drug benefit program, medication therapy management (MTM) helps patients with numerous chronic diseases, high prescription expenditures, and high utilization enhance the efficacy and safety of their medication therapies. Patients can choose to participate in the program, but authorized prescription drug plans (PDPs) are required to provide it.[132] A few research on the effects of MTM employed different kinds of quasi-experimental approaches. A pre-post-trial of a community-based long-term MTM program for patients with CV disorders was carried out by Bunting et al.[133] The risk of a cardiovascular event decreased by 53% over the research period, and the risk of an ED visit or hospital admission linked to cardiovascular disease decreased by more than 50%. Reductions in (a) mean systolic blood pressure, (b) mean diastolic blood pressure, (c) the percentage of patients meeting blood pressure goals, (d) mean low-density lipoprotein (LDL) cholesterol, (e) the percentage of patients meeting LDL cholesterol goals, (f) mean total cholesterol, and (g) mean serum triglycerides show that CV health improved during the study. However, the lack of a control group restricts the ability to draw conclusions about causality from the study's results. Small scale pre-post-cohort research by Wittayanukorn et al. looked into MTM services for CVD patients.[134]

AI In Medical Diagnosis

Effective treatment planning requires a thorough diagnosis of the disease, which is largely dependent on the patient's medical history, numerous laboratory reports, imaging tests, and biopsies. "Medical diagnostics" is the collective term for these elements.[135] Healthcare professionals frequently struggle to provide an accurate diagnosis due to the complexity of the diagnostic procedure, which puts patients through needless suffering and jeopardizes their wellbeing.

However, the danger of human mistake in disease diagnosis has greatly decreased with the advent of artificial intelligence (AI) and the digitization of healthcare.[136] Numerous AI-based techniques, from machine learning to deep learning, have been created to enhance clinical systems, maintain patient records, identify illnesses, and treat different conditions.[137] AI algorithms have proven to be incredibly effective in improving patient outcomes, reducing the financial burden of malignant diseases in the healthcare system, and identifying some cancers in their early stages, such as liver or gastrointestinal cancer.[138,139]

Convolution neural networks (CNNs) are in high demand for image processing in the current AI era due to their hierarchical data interpretation from the deepest layers that resemble human brain neurons. They are extremely precise, comparable to human competence.[140] Disease diagnosis has accelerated thanks to the integration of AI with traditional medical imaging methods. For example, early diagnosis of diabetic retinopathy is aided by AI-assisted retinal image processing.[141] Furthermore, textual clinical records can be quickly analysed using natural language processing (NLP), which provides information for precise diagnosis and patient care.[142] AI systems in radiology have demonstrated competence in deciphering medical images and helping radiologists identify a range of illnesses. AI-powered systems may identify abnormalities in MRIs, CT scans, and X-rays, leading to quicker and more precise illness diagnosis.[143,144] When it comes to medical diagnosis, AI has many benefits. The ability of this approach to increase diagnostic accuracy is one of its key advantages. Large volumes of medical data can be accurately analysed by machine-learning-based AI systems, especially in radiology.[145]

AI is also skilled at managing big datasets. AI has obvious limitations, but it can handle a wide variety of healthcare data and give medical professionals a multitude of insights for well-informed decision-making. The absence of human comprehension and judgment is one obvious flaw. AI may make poor decisions because it lacks common sense, clinical judgment, and intuitive understanding, in contrast to human decision-making. Another problem is reliance on training data. If the training data is not representative and diverse, AI machine-learning systems may yield biased results.[146] Furthermore, traditional medicine is excellent at treating acute and serious illnesses, offering timely and focused interventions-such as surgeries and drugs-to meet pressing medical demands. However, the traditional method of diagnosing illnesses has drawbacks. A significant disadvantage that results in delayed or incorrect diagnoses is the emergence of diagnostic mistakes. Diagnostic errors are caused by the complex healthcare environment as well as possible over-reliance on particular diagnostic tests.[147] AI has revolutionized our capacity to identify people who are vulnerable to certain diseases and recognize early, subtle signs of illness.[148] AI customizes preventative strategies, enabling early intervention and screening for people with elevated disease risk, by integrating genetic information, medical history, and lifestyle data. AI recognition technology can help doctors detect for lung cancer early by performing multi-parameter cluster analysis and simplifying images.[149]

New information technology (IT)-dependent systems have been developed as a result of the healthcare system's problems brought on by the particular difficulties of modern medical procedures and the wide variety of diagnostic methods. AI is already helping medical experts and enhancing disease diagnosis. For example, it is used to identify ectopic pregnancies early and give gynaecologists the first alternatives for therapy. At the moment, machine learning-based AI technology has a number of drawbacks. The primary constraint is to the differences in the testing and detection equipment used in different countries, areas, and medical facilities. This leads to differences in the resolution and quality of the obtained images, which unavoidably affect the accuracy of the diagnostic results and the precision of the image analysis. Inspection equipment must be harmonized and standardized in order to meet this task. It is challenging to accomplish this, though. Second, training and verification datasets for the majority of machine-learning techniques are insufficient. Transferring learning, which involves gaining expertise using an advanced model trained on data from a large source domain, such natural photographs, is one promising strategy. After then, the model is refined using information from the target domain, where there are very few annotated images-especially medical images-available.[150]

CONCLUSION

AI systems are a technology that allows us to address any issue. Additionally, by employing this approach, we monitor and rectify our errors. Every industry is currently using AI systems, and our pharmacy industry is finding them to be quite helpful. AI has the potential to completely transform the pharmacy sector and offer several advantages to both patients and pharmacists. This study examines how artificial intelligence (AI) is being used in the pharmacy industry, how it is helping the medical area, and how a pharmacist can use AI to pursue a career in medicine. This research article discusses a few medical fields that apply AI, including drug development, drug quality control testing, pharmaceutical quality assurance, 3D printing, fused deposition modelling, medical diagnostics, and medical therapy management. A pharmacist can finish his work without making any mistakes by utilizing AI. By combining AI and 3D printing, we can produce a product that is both excellent and profitable. Additionally, pharmacists have enhanced our understanding of 3D printing, which makes it easier for them to diagnose and treat any illness. By speeding up drug discovery and customizing treatment, artificial intelligence is

transforming the pharmaceutical sector. It shortens the time it takes to launch a new medication. The most-costly stage of medication research is clinical trials, but AI makes this process easier by evaluating patient data to find the best candidates and forecast bad events. AI quickly evaluates current medications to find novel therapeutic effects. Additionally, it lowers prescription errors and improves professional practice and patient safety. AI improves healthcare decision support systems and raises pharmaceutical safety. AI is capable of scanning patient data, medical records, and treatment histories to deliver quality care. AI protects patient medical history privacy and patent data.

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