IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

ARTIFICIAL INTELLIGENCE IN PHARMACY MANAGEMENT

Nithin Rajan R[1], Gautham Krishna [2], Dr. Dhanya Dharman,[3] Prof (Dr) Shaiju S Dharan [4]

Department of Pharmacy Practice, Ezhuthachan College of Pharmaceutical Sciences, Thiruvananthapuram.

1.Pharm D intern, Ezhuthachan College of Pharmaceutical Sciences, Thiruvananthapuram.

2.Pharm D intern, Ezhuthachan College of Pharmaceutical Sciences, Thiruvananthapuram.

3. Associate professor, department of Pharmacy Practice, Ezhuthachan College of Pharmaceutical Sciences, Thiruvananthapuram.

4.Principal & HOD, department of Pharmacy Practice, Ezhuthachan College of Pharmaceutical Sciences, Thiruvananthapuram.

ABSTRACT

The practice of digital health has grown at an incredible rate and has undoubtedly been catalyzed by the COVID-19 pandemic. The terms "digital health" and "artificial intelligence" have become the most searched topics both in and outside of healthcare. As we begin to see more AI technologies being adopted in healthcare around the world, it is critical that pharmacists are involved. Digital health is becoming an important part of managing long-term conditions, whether it's monitoring symptoms, monitoring adherence or even the treatment itself, so pharmacists can play a key role in implementing technologies that improve patient experience and care. The pharmaceutical industry is also undergoing a digital revolution fueled by artificial intelligence. It is used to improve drug development, to personalize medicine, and it also leads to a significant reduction in medical costs.

Keywords: Artificial intelligence, Digital health, proof-of-concept.

INTRODUCTION

Artificial intelligence (AI) is the simulation of human intelligence processes by machines, especially computer systems. Which involves the perceiving, synthesizing, and inferring of information, demonstrated by machines, as opposed to intelligence displayed by humans or by other animals [1]. It can also be defined as the ability of a computer or a computer controlled robot for doing tasks that are usually done by the humans only because they require a human intelligence and discernment. Although there are no AIs that can perform the wide variety of tasks an ordinary human can do, some of them are able to match humans in certain tasks. Machine learning (ML) is a technique of AI that involves training a model (or algorithm) to make predictions based on data input [3] . AI has variety of potential uses both in the clinical and industry setting, and some of the interesting real-world cases will help to illustrate these opportunities. However, there is also a need for further education on AI in the health care curriculum.The practice of digital health has been growing at an unbelievable rate and has undoubtedly been catalyzed by COVID-19 pandemic.The terms "Digital health" as well as"artificial intelligence" has became there most searched topics both within and outside the health care sector. As we begin to see more of the artificial intelligence technologies implemented among health care settings across the globe, it is very essential for the pharmacists to be involved into the same. Pharmacists are frontline health care professionals who have consistent touchpoints with patients. With digital health becoming a core component of chronic disease management, whether it be in symptom monitoring, adherence tracking, or even delivery of therapy itself, pharmacists play an integral role in leveraging technologies to improve patient experiences and outcomes [4]. A strong voice of pharmacists are required at the table while discussing about the development and implementation of AI algorithms and the necessity to advocate for the integration of a more reliable AI component in the pharmacy sector. The registered Pharmacists can also encourage students and other practicing pharmacists to be curious regarding the utilization of AI among their practice.

METHODOLOGY

Based on a literature search in the major medical and epidemiological databases. The keywords "artificial intelligence", "mechanical intelligence" and "digital health"were used. Articles that addressed the discussion of AI in pharmacy and written only in English were included. Editorials, comments, letter to the editor, articles that were not fully available or those who lacked accurate information were excluded.

A Brief History of Artificial Intelligence

Here's a brief timeline of the past six decades of how AI evolved from its inception.

- 1956 - John McCarthy coined the term 'artificial intelligence' and had the first AI conference.
- 1969 - Shakey was the first general-purpose mobile robot built. It is now able to do things with a purpose vs. just a list of instructions.
- 1997 - Supercomputer 'Deep blue' has designed, and it defeated the world champion chess player in a match. It was a massive milestone by IBM to create this large computer.
- 2002 - The first commercially successful robotic vacuum cleaner was created.
- 2005 - 2019 - Today, we have speech recognition, robotic process automation (RPA), a dancing robot, smart homes, and other innovations make their debut.
- 2020 - Baidu releases the LinearFold AI algorithm to medical and scientific and medical teams developing a vaccine during the early stages of the SARS-CoV-2 (COVID-19) pandemic. The algorithm can predict the RNA sequence of the virus in only 27 seconds, which is 120 times faster than other methods[2].

Advantages and Disadvantages of AI

Artificial intelligence has its pluses and minuses, much like any other concept or innovation. Here's a quick rundown of some pros and cons.

Pros

- It reduces human error
- It never sleeps, so it's available 24x7
- It never gets bored, so it easily handles repetitive tasks
- It's fast

Cons

- It's costly to implement
- It can't duplicate human creativity
- It will definitely replace some jobs, leading to unemployment
- People can become overly reliant on it [2]

CLINICAL APPLICATIONS

Pharmacists in several healthcare settings have used AI to deliver data-driven interventions through clinical decision support systems (CDSS). This type of technology helps the pharmacist collect data and take action to prevent medication errors, minimize patient complications and save costs. For example, one company, Arine, created a platform that provides pharmacists with the information needed to provide comprehensive patient care services such as personalized medication management, lifestyle counseling and care coordination through telehealth [5] . Another company, Cricket Health, is using ML to support patients with chronic kidney disease (CKD). Cricket Health's models are designed to predict estimated glomerular filtration rate (eGFR) without laboratory data. A cohort study was designed using the Cricket Health training program with 37 participants (total 61) in the intervention group. Study results showed that more Cricket Health patients started dialysis on an outpatient basis and showed better knowledge about the disease (pandlt;0.001) [6]. In particular, in a similar study with Cricket Health, which was an educational program for patients with CKD stage 4 and 5. 5 will help determine what treatment would be best for their kidney health. Patients had a greater choice of peritoneal dialysis, kidney transplantation (as opposed to conservative therapy) and general knowledge of the disease state [7]. CDSSs were also implemented in local pharmacies. A literature review of six different studies showed a 31% reduction in drug-drug interactions (DDI) and a reduction in inappropriate medications for pregnant or elderly patients. However, the study found that clinical inertia and vigilance fatigue hindered the use of CDSS in the community [8,9]. AI can also be seen in outpatient treatment. A systematic review by Sennesael et al. analyzed 16 different studies involving CDSS and patients requiring anticoagulation. Some positive features of CDSS included integration with EMRs, no additional data entry, and referrals (as opposed to only assessments) required by the physician. The study also revealed negative aspects of CDSS, such as lack of formal incentives to use the technology, lack of decision support results for patients, and lack of regular feedback to clinicians, all of which may hinder CDSS implementation. in practice. AI can be useful for acute care pharmacists, as highlighted in a study by Calloway et al., which describes an acute care facility using CDSS to guide pharmaceutical interventions in antimicrobial stewardship. These interventions included de-escalation of antibiotic regimens, identification of inappropriate antibiotics based on cultures or patient laboratory data, dose optimization, and switching from intravenous to oral administration. The authors also reported that the CDSS alerted the diabetes educator when abnormal blood glucose values were found in health records. The use of CDSS thus increased the clinical interventions of pharmacists by more than 100 per month, saving approximately $1.5 million per year [10] .

AI in diagnosis and targeted genomic treatments

Medical Records Management: Maintaining patient medical records is a complex task. Data collection, storage normalization and tracking are made easy by implementing an artificial intelligence system. Google's healthcare project Deep Mind[11] (developed by Google) helps to mine patient data in a short time. Therefore this project is useful for better and faster treatment. Moor fields Eye Hospital NHS is supporting this project to improve eye care.

Preparation of treatment plan: Preparation of effective treatment plans is possible with the help of artificial intelligence technology. When a patient's critical condition occurs and choosing an appropriate treatment plan becomes difficult, artificial intelligence is needed to manage the situation. All previous information and reports, clinical expertise, etc., are considered when developing a treatment plan recommended by this technique. IBM Watson for Oncology Software as a Service [12] is a cognitive computer decision support system that analyzes patient data from thousands of historical cases and thousands of hours of work with doctors at Memorial Sloan Kettering Cancer Center and provides treatment options to help. Oncologists make informed decisions. These treatment options are supported by the literature maintained by Memorial Sloan Kettering and more than 300 medical journals and 200 textbooks, providing nearly 15 million texts [12].

Help in repetitive tasks: AI technology helps to detect and detect diseases or disorders also in some repetitive tasks like X-ray, Radiology, ECHO, EKG exams etc. Medical Sieve [13] (an algorithm pioneered by IBM) is a "cognitive assistant" with good analytical and reasoning skills. A medical startup is essential to improving patient conditions by combining deep learning with medical knowledge. A special computer program is available for each part of the body that is used for certain diseases. Deep learning can be used in almost all types of image analysis such as X-ray, CT scan, ECHO, EKG, etc.

Health support and medical assistance: In recent years, the use of artificial intelligence technology in health services and also in medical assistance has been recognized as effective. Molly [14] (a virtual nurse designed by a startup) is given a pleasant voice and a hearty face. It aims to help guide patient care and support chronic disease patients during doctor visits. Ai Cure[15] is a smart webcam application that monitors patients and helps them manage their condition. This application is useful for patients with serious drug-related situations and patients participating in clinical trials.

Medical precision: AI has a good impact on genomics and genetic development. The artificial intelligence system Deep Genomics [16] is useful for tracing patterns in genetic information and patient data to identify mutations and associations with diseases. This system informs doctors about what happens in the cell when a genetic variation changes the DNA. Craig Venter[17], the father of the Human Genome Project, developed an algorithm

that provides information about physical characteristics of patients based on their DNA. "Human Longevity" AI technology is useful for pinpointing the exact location of cancer and vascular diseases in their early stages.

Drug creation: Drug development or creation takes more than ten years and spends billions of rupees. The artificial intelligence technology "Atomwise"[18], which uses supercomputers, is useful for finding drugs from the molecular structure database. It launched a virtual search program for a safe and effective treatment of the Ebola virus with existing drugs. The technology identified two drugs that caused the Ebola infection. This analysis was completed in a day compared to months or years of manual analysis. A Boston-based biopharmaceutical company has developed big data for patient care. It backs up the data to find reasons why some patients survive their illnesses. They used patients' biological data and artificial intelligence technology to determine the difference between healthy and unhealthy atmospheric conditions. It helps in drug discovery and design, treatment and problem solving.

AI helps people in the healthcare system: "Open AI Ecosystem"[19] was one of the ten most promising technologies in 2016. It is useful to collect and compare data on social awareness algorithms. Extensive information is stored in the health system, which includes the patient's medical history and treatment information from childhood to this age. This huge data can be analyzed through ecosystems and recommendations can be made about the patient's lifestyle and habits.

Health Care Analysis: In a health care system, when all the information is in the computer, it is easy to get the information. The Netherlands stores 97 percent of invoices in digital form[20] containing treatment information, names of doctors and hospitals. Therefore, they can be easily applied. Local company Zorgprisma Publiek analyzes invoices using IBM Watson cloud technology. When an accident occurs, he immediately recognizes it and takes the right measures. Thanks to this, the hospitalization of the patient is improved and avoided.

AI in medical cost reduction

Artificial intelligence and data are also useful in reducing costs in the healthcare sector. Artificial intelligence is used, for example, to develop new ways to treat chronic diseases. In one study, researchers used artificial intelligence to develop a new program that helped diabetics manage their condition more effectively. The program, now used in many hospitals, could save millions of dollars in healthcare costs.

Artificial intelligence will also improve the efficiency of the health sector. It is used, for example, in the current development of new appointment scheduling and patient data management capabilities. It is also used to develop new capabilities to automate operations such as billing and coding[21-25].

The role of artificial intelligence in market forecasting and monitoring

The prosperity of a company depends on the constant promotion and increase of its business interests. Although large funds are used, the performance of RandD in the pharmaceutical industry decreases due to the inability of companies to adapt to current marketing methods [26]. Synchronized with the fourth industrial revolution, the development of digital technology facilitates a new type of digitized marketing through a multimodal decision-making system that collects and evaluates statistical and mathematical data and performs human interpretations so that AI-supported decision-making paradigms can search for new ones. such commercial prospects [27].

Artificial intelligence also makes it possible to study in detail the basic needs of the product from the point of view of the customer, as well as to understand the market requirements, which helps in decision-making with the help of predictive models. This process is also able to forecast sales and evaluate the market. The software includes artificial intelligence to engage consumers and raise awareness among healthcare professionals by displaying advertisements that target a product segment with one click [28]. In addition, these approaches use natural language processing (NLP) algorithms to look at keywords entered by buyers and associate them with the possibility of purchasing a product [29,30].

Many business-to-business (B2B) companies have announced self-service platforms that allow free inspection of healthy products, easy to find by sending their specifications, receive orders and control their own transport logistics. Pharmaceutical organizations also provide their own websites such as "1mg", "Medline", "Netmeds" and "Ask Apollo" to address the unmet needs of patients [31]. Sales forecasting is also important for many pharmaceutical companies that can apply AI in this field, such as "Business Smart Sales Forecast Analysis", which uses a combination of time series forecasting and real-time usage. . This helps pharmaceutical companies to predict product sales to avoid the cost of storage or to avoid the disadvantage of buyers due to shortage [32].

The embodiment of artificial intelligence in nanomedicine

Nanomedicine uses nanotechnology and medicines to diagnose, treat and control complex diseases such as malaria, cancer, HIV, many inflammatory diseases and asthma. Later, nanoparticle-modulated drug delivery assumed a dominant position in the therapeutic and diagnostic arena due to their improved therapeutic efficacy [33–38]. Combining nanotechnology with artificial intelligence can provide answers to various formula development questions [39].

Methotrexate nanosuspension was algorithmically methodized by studying the energy of the mixing of drug molecules and investigating the factors that can contribute to the agglomeration of the formulations [40]. "Coarse-grained simulation" combined with chemical evaluation can help interactively evaluate the drug dendrimer and evaluate the encapsulation of the drug in the dendrim. In addition, software such as LAMMPS and GROMACS4 can be used to study the effect of surface chemistry on the cellular uptake of nanoparticles [41].

AI enabled the formation of silicasomes, which are a mixture of internalizing arginine-glycine-aspartic acid (iRGD) sequences, a tumor-penetrating peptide, and multifunctional mesoporous silica nanoparticles loaded with irinotecan. This silicasome internalization can be increased threefold or fourfold because iRGD promotes silicasome transcytosis, improving treatment results and favorable long-term survival [42-44].

Artificial intelligence in pharmaceutical practice in hospitals and community pharmacies

Machine learning models enable email personalization with speed and accuracy greater than any human. Chatbots[45] can be used to improve service delivery. Chatbots can mimic customer service interactions between customers and sales staff. Chatbots can automatically resolve customer complaints and questions, and difficult questions are transferred to employees. This principle can be applied in retail pharmacies. Chatbots can be programmed to mimic interactions between a pharmacy and a patient.

Walgreen [46-49] partnered with telehealth company Medline to create a way to help patients communicate with healthcare professionals via video chat. Artificial intelligence can also be useful in inventory management. As a retail pharmacy, imagine being able to predict what your patients will need in the near future, stock them and send customized software to send emails to remind the patient of medication needs. Data analytics based on artificial intelligence can be used to predict a patient's future drug purchase. Predicting a patient's drug purchase using artificial intelligence helps the pharmacy make the right stock purchase decisions.

However, there are inventory management software and applications that are used in retail pharmacy inventory management such as Mckessons; Freedom; Winpharm; PrimeRx; and WinRx, not all use artificial intelligence or machine learning. For example, AI company Blue Yonder developed software for the Otto Group [50], a German online and catalog retailer. This software can predict with 90° accuracy what Otto will sell in 30 days. This reduced the delivery schedule for purchased products from a week or more to two days, allowing a product to be shipped directly from the supplier to the consumer without going through a warehouse. The University of California, San Francisco Medical Center (UCSF) is working to improve patient safety and is using robotic technology to prepare and monitor medications. According to them, the technology perfectly produced 3,50,000 doses of medicine. The robot has proven to be far superior to humans in size and ability to deliver precise medications. Robotics capabilities include the production of oral and injectable drugs, including toxic chemotherapy drugs. This gave UCSF pharmacists and nurses the freedom to use their expertise to focus directly on patient care and collaboration with physicians. In the pharmacy's automated system, computers first electronically receive drug orders from UCSF physicians and pharmacists. Robotics then picks up, packs and dispenses the individual pill doses. After that, the machines collect the parts on a plastic ring with a barcode. The thin plastic ring contains all the medication the patient needs to take within 12 hours. The functionality of the automated system is enhanced by their ability to prepare sterile formulations for chemotherapy and fill intravenous syringes with the correct drugs [51].

The role of artificial intelligence in quality management and assurance

The production of a primary product from raw products requires the harmonization of several criteria [52]. Strict quality control of products and keeping them constant between batches requires manual intervention. This may not be the ideal method in every case, which suggests the need for AI involvement in this era [53]. The FDA has updated "current good manufacturing practices (cGMP)" by proposing a "Quality by Design" system that understands the basic function of a drug and clear standards that govern the final nature of the drug [54-55]. A combination of human power and artificial intelligence was used to examine the first round of data from production lines and create decision trees. These were later transliterated into axioms and studied by users to later facilitate the production cycle [56]. The research looked at the dissolution properties, a barometer of the batch-to-batch constant of theophylline pellets, using an ANN that accurately predicted the dissolution of the study formulation, with inaccuracy and lt; 8% [57].

Artificial intelligence can also be used to control production systems to achieve desired product quality [58]. ANN-guided control of the freeze-dehydration method is used, which implements a combination of self-adaptive evolution with local search and back-propagation algorithms. Such methods can be used to predict the temperature and thickness of the dried cake at a later stage (t Dt) for a certain group of performance characteristics, ultimately facilitating the verification of potential product standards [59]. An automatic data entry algorithm such as the "Electronic Lab Notebook" with complex, ingenious mechanisms can ensure product quality[60]. In addition, data mining and multiple data service methods of "total quality management (TQM)" expert processes can be used as useful tools for complex evaluations and the development of advanced technologies for intelligent quality management [61].

The Role of Artificial Intelligence Algorithms in Designing Clinical Trials

Clinical trials aim to prove the safety and effectiveness of a drug in humans for a specific disease and require 6-7 years with significant funding. However, only 10% of the molecules tested in such trials achieve fruitful approval, which is a huge setback for the industry [62]. These losses may be due to poor patient selection, lack of technical infrastructure and poor facilities. However, due to the availability of huge digital medical data, these failures can be mitigated by artificial intelligence [63].

Patient recruitment consumes approximately 33% of the duration of the clinical trial. Conducting a clinical trial can be facilitated by appropriate patient recruitment, which on the contrary leads to an approximately 86% infertility scenario [64]. AI can help select only a selective affected population for participation in phase II and III clinical trials using patient relevant genomic exposure, which can facilitate more accurate prediction of existing drug targets in selected individuals [65, 66]. Preclinical screening of molecules as well as identification of lead compounds before starting clinical trials using additional AI capabilities such as predictive ML and alternative inference algorithms will contribute to more accurate prediction of lead molecules, which would reduce clinical trials at selected sites. Patient population [67].

Patient attrition in clinical trials accounts for about one-third of clinical trials failing, leading to additional recruitment needs during peak study periods, leading to a lack of time and funding. Such problems can be avoided by carefully monitoring patients and facilitating their adherence to a legal clinical trial protocol [68]. AiCure implemented a mobile app that monitored routine medication use in patients with schizophrenia in a phase II trial, resulting in a 25% increase in patient compliance, ensuring a fruitful clinical trial [69].

Advancing the advancement of AI pharmaceuticals

The identification of a new drug compound depends on its subsequent implementation in a suitable drug formulation with favourable delivery properties. From this perspective, AI can replace the earlier trial-and-error method [70]. Many computational techniques can solve formulation design problems such as stability, porosity, solubility, etc. using quantitative structure-property relationship (QSPR) [71]. Decision support systems use rule-based algorithms to decide on the class, properties and amount of excipients based on the physicochemical properties of the drug, and work with a feedback system to monitor and periodically adjust the entire mechanism [72-75].

Integrating "Model Expert Systems (MES)" with ANNs has been reported to provide a hybrid approach to facilitate direct filling of hard gelatin pyrocicam capsules according to its dissolution parameters. MES determines options and proposals for further development of the formulation according to the input criteria. In contrast, ANN uses back-propagation training to combine formulation criteria with primary feedback, which is simultaneously controlled by the control module to ensure smooth formulation progress [76,77].

Several mathematical methods such as Computational Fluid Dynamics (CFD), Discrete Element Modelling (DEM) and Finite Element Method (FEM) have been used to study the effect of powder flow characteristics on mould filling and method. tablet packaging [78,79]. In addition, CFD can be used to investigate the effect of tablet shape/size on dissolution parameters [80]. Combining such mathematical paradigms with artificial intelligence can prove to be of great benefit in the rapid production of pharmaceutical products.

DISCUSSION

The development of information processing and technology has crossed all dimensions of science. Artificial intelligence (AI) is one of the main branches of computer science, which has spread to all arenas of science and technology, from nuclear technology to medicine. Thus, artificial intelligence has found its way to applications in medicinal chemistry and healthcare. Traditional drug design methods have recently been replaced by computer-aided drug design. Artificial intelligence is widely used to improve drug techniques and timing. In addition, AI can conveniently identify target proteins, which improves the success of the planned drug. Artificial intelligence technology is used at every stage of drug development, which reduces the health risks associated with preclinical studies and also significantly reduces costs. Artificial intelligence is a powerful data mining tool based on massive

pharmacological data and machine learning. Therefore, AI has been used in new drug development, activity evaluation, virtual screening, and in silico evaluation of drug molecular properties (absorption, distribution, metabolism, excretion and toxicity). Several pharmaceutical companies have partnered with AI companies to accelerate progress in drug development and the healthcare system. Artificial intelligence has the potential to greatly impact and shift the focus of pharmacists from dispensing medications to a wider range of patient services. A pharmacist can use artificial intelligence to help people get the most of their medications and keep them healthy. Most importantly, AI offers pharmacies the ability to work more collaboratively across multiple units serving the same patient. In addition to potentially better healthcare services provided by professionals to patients, AI can be a useful tool in providing guidance on how and where to receive the most cost-effective healthcare and how best to communicate with healthcare professionals. Optimizing the value of portable data; provide daily lifestyle guidance; combining diet and exercise; and supporting enrollment and adherence to treatment.

CONCLUSION

Artificial intelligence combines human knowledge and artificial intelligence resources. As AI research and its many interesting applications continue, it can be seen as a necessary evil even by those who see it as an enemy. Therefore, it is highly recommended that pharmacists acquire the necessary hard skills that will contribute to the increase of artificial intelligence. Training and exposure to artificial intelligence is essential in all areas of pharmaceutical practice. Advances in artificial intelligence, along with its impressive capabilities to regularly reduce the bottlenecks faced by pharmaceutical organizations that affect drug development pipelines and long-term product life cycles, could justify an increase in new companies. in this arena [81]. There are many perverse threats in current health care, such as rising drug and medical costs, and society demands definite, significant action in these areas. As a result of the inclusion of artificial intelligence in the production of pharmaceutical products, personalized drugs with appropriate dosage, release properties and various necessary aspects can be prepared according to the demand of a particular patient [82]. The use of current algorithms assisted by AI should reduce the time to market goods and also improve the quality of goods and the general security of the production schedule, and increase the use of available resources along with costs. . -effective, emphasizing and recommending the critical importance of mechanization [83].

The most important fear for the inclusion of these platforms is the expected job cuts and strict policies regarding the implementation of artificial intelligence. However, these techniques were proposed to make the task effortless and not to completely exclude humans [84]. In addition to facilitating the fast and hassle-free determination of relevant compounds, AI can also provide recommendations on synthetic routes for these substances, predict favourable chemical structures and understand drug-target combinations and relevant SAR value.

AI can also suggest dominant inputs to incorporate the original drug into the appropriate formula and refine it with quick decision-making, culminating in rapid batch production of high-quality products. AI can also improve the safety and efficacy of substances in clinical trials and ensure optimal market alignment and pricing through

comprehensive market surveillance and forecasting. Despite the fact that currently there are no drugs derived from AI-enabled systems on the market, there are clear challenges in the implementation of this technology, it is possible that AI will mature into a valuable tool in the pharmaceutical industry in the near future. Pharmacy students must become familiar with the basics of information technology and artificial intelligence during their medical education through the health informatics curriculum. Pharmacists must also be able to develop an understanding of artificial intelligence through ongoing training. Data science courses or pharmacy residencies focused on AI topics should be offered to pharmacists who want more hands-on involvement in the development, management and use of AI. As these technologies evolve rapidly, the pharmacy education system must remain nimble to ensure that our profession is prepared to lead these changes in care.

Ethics approval and consent to participate: Not applicable.

Consent for publication: All authors approved the manuscript.

Competing interests: All authors declare no competing interests

Funding: None

Author contributions: All authors listed have made a substantial and intellectual contribution to the work and approved it for publication.

REFERENCE

1.https://dl.acm.org/doi/abs/10.5555/30424

2.https://www.simplilearn.com/tutorials/artificial-intelligence-tutorial/what-is-artificial-intelligence.

3.Vatanka P. Preparing the Next Generation of Pharmacists for their Role in Digitally Enabled Care. Digital Health presented by CPhA. Published November 8, 2021.

4.Amelung K. Pharmacists' Responsibility in Assessing the Value of Digital Tools for their Patients. Digital Health presented by CPhA. Published September 7, 2021.

5.Prescribing Physician Analytics. Arine. https://www.arine.io/prescriber-analytics?hsLang=en

6.Kaiser P, Pipitone O, Franklin A, et al. A Virtual Multidisciplinary Care Program for Management of Advanced Chronic Kidney Disease: Matched Cohort Study. J Med Internet Res. 2020.

7.Dubin R, Rubinsky A. A Digital Modality Decision Program for Patients With Advanced Chronic Kidney Disease. JMIR Form Res. 2019.

8.Curtain C, Peterson GM. Review of computerized clinical decision support in community pharmacy. J Clin Pharm Ther. 2014.

9.Sennesael AL, Krug B, Sneyers B, Spinewine A. Do computerized clinical decision support systems improve the prescribing of oral anticoagulants? A systematic review. Thrombosis Research. 2020.

10.Ekins S, Puhl AC, Zorn KM, et al. Exploiting machine learning for end-to-end drug discovery and development. Nat Mater. 2019.

11.Deep Mind's health team. [cited 2022 13 June]; Available from: https://www.deepmind.com/blog/deepminds-health-team-joins-google-health.

12.IBM Watson for Oncology.; Available from: https://www.ibm.com/common/ssi/cgi-bin/ssialias?appname=skmwww&htmlfid=897%2FENUS5725-W51&infotype=DD&subtype=SM&mhsrc=ibmsearch_a&mhq=IBM%20WATSON%20ONcology#:~:text=IBM%20Watson%20for%20Oncology%2C%20software,Center%20physicians%20and%20other%20analysts.

13. IBM. Medical Sieve.. [cited 2022 13 June]; Available from: https://researcher.watson.ibm.com/researcher/view_group.php?id=4384.

14. MOLLY, THE VIRTUAL NURSE. [cited 2022 13 June]; Available from: http://adigaskell.org/2015/03/20/meet-molly-the-virtual-nurse/.

15. AiCure. THE RIGHT DOSE FOR THE RIGHT PATIENT. [cited 2022 13 June]; Available from: https://aicure.com/.

16. Deep Genomics. Programming RNA Therapies Any Gene, Any Genetic Condition. [cited 2022 13 June]; Available from: https://www.deepgenomics.com/.

17. Shampo, M.A. and Kyle R.A., J. Craig Venter—The Human Genome Project. Mayo Clinic proceedings, 2011. 86(4): p. e26-e27. [PMC free article] [PubMed] [Google Scholar]

18. Atomwise. Artificial Intelligence for Drug Discovery.; Available from: https://www.atomwise.com/.

19. Open AI Ecosystem.; Available from: https://www.scientificamerican.com/article/open-ai-ecosystem-portends-a-personal-assistant-for-everyone/.

20. eInvoicing in The Netherlands.; Available from: https://ec.europa.eu/digital-building-blocks/wikis/display/DIGITAL/eInvoicing+in+The+Netherlands.

21. Dasta, J., *Application of artificial intelligence to pharmacy and medicine.* Hospital pharmacy, 1992.

22. Deopujari, S., et al., Algoman: Gearing up for the "Net Generation" and Era of Artificial Intelligence, One Step at a Time. The Indian Journal of Pediatrics, 2019.

23. Dasta, J.F., *Application of artificial intelligence to pharmacy and medicine.* Hosp Pharm, 1992.

24. Honavar, V., *Artificial intelligence: An overview.* Artificial Intelligence Research Laboratory, 2006

25. Lopes, V. and Alexandre L.A., *An overview of blockchain integration with robotics and artificial intelligence*, 2018.

26. Jalkala A.M., Keränen J. Brand positioning strategies for industrial firms providing customer solutions. J. Bus. Ind. Mark. 2014

27. Ding M., Eliashberg J., Stremersch S. Innovation and Marketing in the Pharmaceutical Industry. Springer; New York, NY, USA: 2016.

28. Dou W., Lim K.H., Su C., Zhou N., Cui N. Brand Positioning Strategy Using Search Engine Marketing. MIS Q. 2010

29. Chiu C.-Y., Chen Y.-F., Kuo I.-T., Ku H.C. An intelligent market segmentation system using k-means and particle swarm optimization. Expert Syst. Appl. 2009

30. Toker D., Tozan H., Vayvai O. A Decision Model for Pharmaceutical Marketing and a Case Study in Turkey. Econ. Res.-Ekon. 2013

31. Singh J., Flaherty K., Sohi R.S., Deeter-Schmelz D., Habel J., Le Meunier-FitzHugh K., Malshe A., Mullins R., Onyemah V. Sales profession and professionals in the age of digitization and artificial intelligence technologies: Concepts, priorities, and questions. J. Pers. Sell. Sales Manag. 2018

32. Milgrom P.R., Tadelis S. How Artificial Intelligence and Machine Learning Can Impact Market Design. National Bureau of Economic Research; Cambridge, MA, USA: University of Chicago Press; Chicago, IL, USA: 2019.

33. Davenport T., Guha A., Grewal D., Bressgott T. How artificial intelligence will change the future of marketing. J. Acad. Mark. Sci. 2020

34. Syam N., Sharma A. Waiting for a sales renaissance in the fourth industrial revolution: Machine learning and artificial intelligence in sales research and practice. Ind. Mark. Manag. 2018.

35. Duran O., Rodriguez N., Consalter L.A. Neural networks for cost estimation of shelland tube heat exchangers. Expert Syst. Appl. 2009.

36. Medarević, D.P., et al., Combined application of mixture experimental design and artificial neural networks in the solid dispersion development. Drug development and industrial pharmacy, 2016.

37. Barmpalexis, P., et al., Development of PVP/PEG mixtures as appropriate carriers for the preparation of drug solid dispersions by melt mixing technique and optimization of dissolution using artificial neural networks. European Journal of Pharmaceutics and Biopharmaceutics, 2013.

38. Pharma News Inteligence.. Available from: https://pharmanewsintel.com/.

39. GNS Healthcare.; Available from: https://www.gnshealthcare.com/.

40. AtomNet. How we do it.; Available from: https://www.atomwise.com/how-we-do-it/.

41. Insilico Medicine. ARTIFICIAL INTELLIGENCE FOR EVERY STEP OF PHARMACEUTICAL RESEARCH AND DEVELOPMENT.; Available from: https://insilico.com/.

42. Insilico Medicine. Insilico Medicine launches trial for AI-discovered drug.; Available from: https://www.outsourcing-pharma.com/Article/2021/12/15/Insilico-Medicine-launches-trial-for-AI-discovered-drug.

43. Chatbots. Medicine Delivery.; Available from: https://hellotars.com/chatbot-templates/healthcare/Hk8N4h/medicine-ordering-chatbot.

44. Walgreen. Convenient virtual care. Available from: https://www.walgreens.com/findcare/category/acute-telehealth.

45. Otto Group.. Available from: https://www.ottogroup.com/en/about-us/konzernfirmen/Otto-Group-Solution-Provider.php.

46. UCSF Robotic Pharmacy Aims to Improve Patient Safety. [cited 2022 10 Janaury]; Available from: https://www.ucsf.edu/news/2011/03/9510/new-ucsf-robotic-pharmacy-aims-improve-patient-safety.

47. Dilsizian, S.E. and Siegel E.L., Artificial intelligence in medicine and cardiac imaging: harnessing big data and advanced computing to provide personalized medical diagnosis and treatment. Current cardiology reports, 2014.

48. Li, L.-R., et al., Artificial Intelligence for Personalized Medicine in Thyroid Cancer: Current Status and Future Perspectives. Frontiers in Oncology, 2021.

49. Davoudi, A., et al., The intelligent ICU pilot study: using artificial intelligence technology for autonomous patient monitoring.2018.

50. Yu, K.-H., Beam A.L., and I.S. Kohane, Artificial intelligence in healthcare. Nature biomedical engineering, 2018.

51. Musib, M., et al., Artificial intelligence in research. Science, 2017.

52. Ahuja, A.S., The impact of artificial intelligence in medicine on the future role of the physician. PeerJ, 2019.

53. Han, E.-R., et al., Medical education trends for future physicians in the era of advanced technology and artificial intelligence: an integrative review. BMC medical education, 2019.

54. Henstock, P.V., Artificial intelligence for pharma: time for internal investment. Trends in pharmacological sciences, 2019.

55. Mitchell, J.B., Artificial intelligence in pharmaceutical research and development. 2018.

56. Neill, D.B., Using artificial intelligence to improve hospital inpatient care. IEEE Intelligent Systems, 2013.

57. Klumpp, M., et al.. Artificial intelligence for hospital health care: Application cases and answers to challenges in european hospitals. In Healthcare. 2021.

58. Nelson, S.D., et al., Demystifying artificial intelligence in pharmacy. American Journal of Health-System Pharmacy, 2020.

59. Kostić, E.J., Pavlović D.A., and Živković M.D., Applications of artificial intelligence in medicine and pharmacy: Ethical aspects. Acta Medica Medianae, 2019.

60. Koromina M., Pandi M.T., Patrinos G.P. Rethinking drug repositioning anddevelopment with artificial intelligence, machine learning, and omics. *Omics.* 2019

61. Park K. A review of computational drug repurposing. *Transl. Clin. Pharmacol.* 2019

62. Zeng X., Zhu S., Lu W., Liu Z., Huang J., Zhou Y., Fang J., Huang Y., Guo H., Li L., et al. Target identification among known drugs by deep learning from heterogeneous networks. *Chem. Sci.* 2020

63. Achenbach J., Tiikkainen P., Franke L., Proschak E. Computational tools for polypharmacology and repurposing. *Futur. Med. Chem.* 2011

64. Ke Y.-Y., Peng T.-T., Yeh T.-K., Huang W.-Z., Chang S.-E., Wu S.-H., Hung H.-C., Hsu T.-A., Lee S.-J., Song J.-S., et al. Artificial intelligence approach fighting COVID-19 with repurposing drugs. *Biomed. J.* 2020;

65. Li X., Xu Y., Cui H., Huang T., Wang D., Lian B., Li W., Qin G., Chen L., Xie L. Prediction of synergistic anti-cancer drug combinations based on drug target network and drug induced gene expression profiles. *Artif. Intell. Med.* 2017

66. Reddy A.S., Zhang S. Polypharmacology: Drug discovery for the future. *Expert Rev. Clin. Pharmacol.* 2013

67. Li Z., Li X., Liu X., Fu Z., Xiong Z., Wu X., Tan X., Zhao J., Zhong F., Wan X., et al. KinomeX: A web application for predicting kinome-wide polypharmacology effect of small molecules. *Bioinformatics.* 2019

68. Cyclica Launches Ligand Express™, a Disruptive Cloud–Based Platform to Revolutionize Drug Discovery. *Business Wire.* Nov 30, 2017.

69. Hessler G., Baringhaus K.-H. Artificial Intelligence in Drug Design. *Molecules.* 2018

70. Corey E.J., Wipke W.T. Computer-Assisted Design of Complex Organic Syntheses. *Science.* 1969

71. Grzybowski B.A., Szymkuć S., Gajewska E.P., Molga K., Dittwald P., Wołos A., Klucznik T. Chematica: A Story of Computer Code That Started to Think like a Chemist. *Chem.* 2018

72. Klucznik T., Mikulak-Klucznik B., McCormack M.P., Lima H., Szymkuć S., Bhowmick M., Molga K., Zhou Y., Rickershauser L., Gajewska E.P., et al. Efficient Syntheses of Diverse, Medicinally Relevant Targets Planned by Computer and Executed in the Laboratory. *Chem.* 2018

73. Segler M.H.S., Preuss M., Waller M.P. Planning chemical syntheses with deep neural networks and symbolic AI. *Nature.* 2018

74. Chan H.C.S., Shan H., Dahoun T., Vogel H., Yuan S. Advancing Drug Discovery via Artificial Intelligence. *Trends Pharmacol. Sci.* 2019

75. Putin E., Asadulaev A., Ivanenkov Y., Aladinskiy V., Sanchez-Lengeling B., Aspuru-Guzik A., Zhavoronkov A. Reinforced adversarial neural computer for de novo molecular design. *J. Chem. Inform. Modeling.* 2018

76. Segler M.H.S., Kogej T., Tyrchan C., Waller M.P. Generating Focused Molecule Libraries for Drug Discovery with Recurrent Neural Networks. *ACS Cent. Sci.* 2017

77. Popova M., Isayev O., Tropsha A. Deep reinforcement learning for de novo drug design. *Sci. Adv.* 2018

78. Merk D., Friedrich L., Grisoni F., Schneider G. *De Novo* Design of Bioactive Small Molecules by Artificial Intelligence. *Mol. Inform.* 2018

79. Schneider G., Clark D.E. Automated de novo drug design: Are we nearly there yet? *Angew. Chem.* 2019

80. Ashburn T.T., Thor K.B. Drug repositioning: Identifying and developing new uses for existing drugs. *Nat. Rev. Drug Discov.* 2004

81. Shahreza M.L., Ghadiri N., Mousavi S.R., Varshosaz J., Green J. A review of network-based approaches to drug repositioning. *Briefings Bioinform.* 2017

82. Klaeger S., Heinzlmeir S., Wilhelm M., Polzer H., Vick B., Koenig P.-A., Reinecke M., Ruprecht B., Petzoldt S., Meng C., et al. The target landscape of clinical kinase drugs. *Science.* 2017

83. Cabreiro F., Au C., Leung K.-Y., Vergara-Irigaray N., Cochemé H.M., Noori T., Weinkove D., Schuster E., Greene N.D., Gems D. Metformin Retards Aging in C. elegans by Altering Microbial Folate and Methionine Metabolism. *Cell.* 2013

84. De Haes W., Frooninckx L., Van Assche R., Smolders A., Depuydt G., Billen J., Braeckman B.P., Schoofs L., Temmerman L. Metformin promotes lifespan through mitohormesis via the peroxiredoxin PRDX-2. *Proc. Natl. Acad. Sci. USA.* 2014