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The application of artificial intelligence in the domain of pharmaceutical practice

By:

Asma Ahmad Younis
Pharmacist at Ajyad Emergency Hospital in Makkah
&
Kholod Abdulfattah Alhazmi
pharmacist at Maternity and children hospital in Makkah
&
Nourah Mohammed Alomari
pharmacist at Maternity and children hospital in Makkah
&
Abdullah Atallah Almanjumi
Pharmacist at King Faisal Medical Complex in Taif
&
Abdullah saeed Alzahrani
Pharmacy technician at King Faisal Medical Complex in Taif
&
Hassan Mohammad Alharazi
Pharmacy technician at King Faisal Medical Complex in Taif
Ahmed Mesfer Alhumaidi
Pharmacy technician at King Faisal Medical Complex in Taif
&
Rayid Saud Alosaimi
Pharmacist at King Faisal Medical Complex in Taif
&
Nawaf Ahmed Sindi
Pharmacist at King Faisal Medical Complex in Taif
&
Naif Awadh Althubiti
Pharmacy technician at King Faisal Medical Complex in Taif
&
ABDULRAHMAN HUSSIN JAHFALI
Pharmacy technician at King Faisal Medical Complex in Taif
&
ABDULELAH ABDULAZIZ ALZAIDI
Pharmacist at Al - Nakheel Medical Cente

Introduction:

Alan Turing's influential publication, "Computing Machinery and Intelligence," released in 1950, initiated the commencement of the artificial intelligence (AI) discourse. (Turing, 2009) In 2004, John McCarthy provided a definition of Al as "the field of study and application of creating intelligent machines, particularly intelligent computer programmes." (Gonsalves, 2019)

Artificial intelligence (AI) has become a disruptive technology that has completely transformed various sectors on a global scale. Al has been a pioneer in various industries such as banking, healthcare, manufacturing, and transportation, driving remarkable progress that was previously unimaginable. Al has facilitated the implementation of advanced automation, enhanced efficiency, and improved decision-making abilities by utilizing intelligent algorithms, machine learning (ML), and data analytics.

Artificial intelligence (AI) is a revolutionary technology employed across several industries, including healthcare. Al has the capacity to greatly enhance medication management and patient care in the field of pharmacy. Integrating Artificial Intelligence (AI) technologies equips chemists with tools and systems that assist them in making precise and evidence-based clinical judgements. Pharmacists can utilise Al algorithms and Machine Learning to examine extensive patient data, such as medical records, laboratory results, and medication profiles. This helps them identify possible drug-drug interactions, evaluate the safety and effectiveness of medications, and make well-informed decisions. A multitude of Artificial Intelligence (AI) models have been created to forecast and identify harmful drug reactions, aid clinical decision support systems in making medication-related choices, automate medication dispensing in community pharmacies, optimize medication dosages, identify interactions between different drugs, enhance adherence through intelligent technologies, identify and prevent medication errors, offer medication therapy management services, and support telemedicine initiatives.

By integrating Al into clinical practice, healthcare practitioners can enhance their decision-making processes and deliver individualized treatment to patients. Artificial intelligence (AI) facilitates enhanced cooperation among various healthcare providers involved in the treatment of a single patient. Al, or artificial intelligence, can serve as a valuable tool for patients in several ways. It can provide guidance on medication usage, educate patients about their treatment, and encourage adherence to medication schedules. Additionally, Al can help patients find the most cost-effective healthcare options, improve communication with healthcare professionals, optimise health monitoring through wearable devices, offer guidance on daily lifestyle and health choices, and integrate diet and exercise recommendations.

- **The application of artificial intelligence in the field of healthcare.**

Artificial intelligence (AI) is swiftly revolutionizing the healthcare industry, providing inventive solutions in multiple areas. An important use case involves providing support in diagnosing medical conditions. Artificial intelligence algorithms utilize advanced computational techniques to examine medical pictures, including X-rays, MRIs, and CT scans, with unparalleled precision and rapidity. This assists radiologists in identifying irregularities and making diagnoses with exceptional accuracy and efficiency. This feature not only improves the accuracy of diagnoses but also speeds up the start of therapy, resulting in better results for patients. it enables the use of patient data and medical records to do predictive analytics. Using advanced algorithms, artificial intelligence (AI) has the capability to forecast the advancement of diseases, detect individuals with a high likelihood of specific ailments, and suggest customized treatment strategies. By adopting a proactive strategy, healthcare practitioners can intervene at an early stage, which has the ability to avoid the occurrence or advancement of diseases, hence boosting the overall health of the community. (Davenport & Kalakota, 2019)

Artificial intelligence (AI) is crucial in accelerating the medication discovery and development process while also decreasing expenses. AI systems utilise extensive biology data to identify prospective drug candidates, forecast their effectiveness and safety profiles, and expedite the preclinical and clinical trial stages. This not only reduces the time needed to introduce new pharmaceuticals to the market but also improves the likelihood of success in drug development efforts. Furthermore, virtual health assistants driven by artificial intelligence are transforming the way patients interact and obtain healthcare services. Chabot's and virtual assistants offer patients customized health guidance, respond to medical inquiries, arrange appointments, and even send medication notifications. Virtual companions enhance healthcare accessibility, particularly for persons residing in remote or underdeveloped regions, while promoting patient empowerment and compliance with treatment regimens. (Secinaro, et al. 2021)

AI developments are also improving remote patient monitoring. Wearable gadgets and sensors, integrated with artificial intelligence algorithms, consistently track patients' vital signs, activity levels, and other health parameters. Healthcare providers have the ability to monitor patients' health state from a distance, identify early indicators of decline, and take immediate action. This helps to decrease the need for hospitalizations, prevent complications, and improve patients' overall quality of life. It's automation also improves administrative efficiency in healthcare. Algorithms optimise and simplify administrative duties, such as medical coding, invoicing, and scheduling, reducing the workload for healthcare personnel. Through the automation of these procedures, artificial intelligence frees up significant time and resources, enabling healthcare professionals to prioritise patient care and enhance overall operational efficiency. (Bohr & Memarzadeh, 2020)

It's the utilisation in genomic analysis shows potential for precision medicine. AI utilises genomic data analysis to identify genetic differences linked to illness susceptibility, pharmacological reactions, and therapy effectiveness. Having this knowledge allows for customised treatment approaches that are based on an individual's genetic characteristics, which maximises the effectiveness of therapy and minimises any negative side effects. Finally, robotics-assisted surgery demonstrates the merging of artificial intelligence and healthcare. AI-driven surgical robots improve surgical accuracy, agility, and effectiveness, facilitating less invasive operations with exceptional results. Surgeons utilise AI technology to navigate intricate anatomical structures and execute complex manoeuvres, eventually benefiting patients by decreasing recuperation times and enhancing surgical outcomes. (Kaul, et al. 2020)

- **The application of artificial intelligence in pharmacy practice.**

Pharmacy practice is a crucial component of the healthcare system that focuses on ensuring the safe and effective management of medications and improving patient care. This is achieved through activities such as medication reconciliation, medication review, medication therapy management (MTM), providing drug information, patient education, monitoring adverse drug reactions (ADR), and collaborating with other healthcare professionals. (Garcia-Cardenas, et al. 2020)

Due to significant progress in the healthcare industry, there has been a noticeable increase in the number of prescriptions, complex drug regimens, and administrative chores. Consequently, there is a growing

need for sophisticated technical solutions that can aid healthcare workers in their daily duties and enhance the delivery of healthcare services. (Raza, et al. 2022)

Integrating Artificial Intelligence (AI) technologies equips chemists with tools and systems that assist them in making precise and data-driven therapeutic judgements. Pharmacists can efficiently analyse extensive patient data, such as medical records, test findings, and prescription profiles, by employing Artificial Intelligence (AI) algorithms and Machine Learning (ML). This enables them to recognise possible drug-drug interactions, evaluate the safety and effectiveness of medications, and provide well-informed suggestions customised to each patient. (Manikiran, et al. 2019)

The utilisation of Aluminium (Al) in several domains within the realm of pharmaceutical practice has demonstrated encouraging potential. Nevertheless, it is crucial to resolve the current deficiencies in research in order to fully exploit the capabilities of AI technology. The crucial factor is the thorough integration of Artificial Intelligence (AI) services into current pharmaceutical systems and comprehending its influence on health and economic results. This review will examine the several uses of Artificial Intelligence (AI) in the field of pharmacy practice. It will also address the research gaps and obstacles that exist in this area, and provide insights into the future paths for research within the field. (Bohr & Memarzadeh 2020) Below we will explain some applications of artificial intelligence used in the field of pharmacy:

1. *Adverse drug reaction (ADR) detection:*

Pharmacy practice is being transformed by artificial intelligence (AI), especially in the identification and control of adverse drug reactions (ADRs). Pharmacists can increase patient safety and detect adverse drug reactions (ADRs) by utilising AI algorithms.(Mohsen, et al. 2021)

AI-powered systems have the capability to analyse extensive quantities of patient data, such as electronic health records, prescription histories, and test findings, in order to detect patterns that may suggest probable adverse drug reactions (ADRs). These algorithms have the ability to identify tiny connections between medicine usage and negative outcomes that may not be seen by human observers.

This allows chemists to quickly act and reduce harm to patients. (Yalçın, et al. 2022) it enables the continuous monitoring of patient health data and the tracking of drug adherence in real-time. Wearable devices and smartphone applications that use AI algorithms may monitor essential signs, medicine consumption, and symptoms reported by patients. This data can be used by chemists to identify adverse drug reactions (ADRs) at an early stage and make appropriate changes to treatment plans. (Rahmani, et al. 2016) AI-powered predictive analytics can analyse specific patient attributes, such as genetics, coexisting medical conditions, and the effects of different medications, in order to identify those who are more likely to experience adverse drug reactions (ADRs). Pharmacists can utilise this knowledge to individualise prescription therapy, either choosing safer alternatives or modifying dosages to reduce the probability of negative outcomes. (Bean, et al. 2017) AI driven natural language processing (NLP) algorithms have the ability to examine unorganized data sources, such as electronic health records and patient-reported outcomes, in order to extract pertinent information on adverse drug reactions (ADRs). This automated method simplifies the process of extracting data and makes it easier to carry out pharmacovigilance operations. It allows chemists to quickly discover new patterns in adverse drug reactions (ADRs) and take proactive steps to reduce risks. It improves pharmacovigilance efforts by automating the procedures of detecting signals and assessing causality. (Dandala, et al. 2019) Artificial intelligence algorithms have the capability to examine extensive pharmacovigilance databases, such the FDA Adverse Event Reporting System (FAERS), in order to detect possible safety indicators linked to particular pharmaceuticals or categories of drugs. Subsequently, chemists can carry out additional inquiries to evaluate the causation of these signals and establish suitable measures to mitigate risks. (Yang, et al. 2019)

2. *Clinical decision support system (CDSS):*

A clinical decision support system (CDSS) aims to enhance healthcare delivery by augmenting medical decisions with specific clinical expertise, patient information, and additional health data. The CDSS

matches individual patient characteristics with a computerised clinical knowledge base. It then presents patient-specific assessments or recommendations to the clinician for decision-making. This technology empowers pharmacists to analyse data and take action to proactively prevent medication errors, minimise patient difficulties, and achieve cost savings. (Sutton, et al. 2020)

3. *Community Pharmacy*

Healthcare systems are quickly shifting from hospital-based to community-based treatment. Pharmacists can improve hospital and community medication safety and efficacy. Community pharmacy "robotic dispensing system" produces prescribed medicines. It has three components. A pharmacy support staff-operated automated dispensing robot, a powdered medication dispensing robot, and a bar-coded pharmaceutical support system with personal digital help are available. ML models can personalise emails faster and more correctly than humans. Chatbots can boost service delivery. Chatbots mimic customer-service interactions. Chatbots automatically handle consumer complaints and direct complex questions to humans. Community pharmacies can develop chatbots to replicate pharmacist-patient interactions. Al can also help community chemists estimate what their patients will need, stock them, and utilise personalised software to send e-mails to remind them. A patient's future drug purchase can be forecasted using Al-powered data analytics. If Al can foresee the patient's drug purchase, the chemist can better stock up. (Takase, et al. 2022)

4. *Computerized prescriber order entry (CPOE)*

The most prevalent healthcare error is medication errors, which kill 7000 people annually, according to the Institute of Medicine. Drug name mismatches, such as illegible prescriptions, ambiguous dose forms, and misunderstood abbreviations, account for 11.4% of medication errors, according to published studies. Computerised Physician Order Entry (CPOE), also known as Computerised Provider Order Entry or Computerised Practitioner Order Entry, is a computer application that allows physicians to enter and send medication, treatment, laboratory, admission, radiology, referral, and procedure orders instead of paper charts, verbal orders, telephone, and fax. Illegible handwriting and transcribing errors in prescription

instructions are reduced by this procedure. These CPOE systems pick, display, and store drug histories and electronically transmit medicine orders to dispensing chemists and pharmacies. This new paradigm offers many chances to preserve patient safety (e.g., allergy or renal dosage alarms) but also raises the risk of many new predictable and unpredictable prescribing and dispensing problems. (Jungreithmayr, et al. 2021)

5. *Dose recommendations*

Patients can derive advantages from a customised AI/ML-driven dose recommendation system that integrates information from several sources, including safety and efficacy metrics, electronic health records, illness particulars, treatment history, and patient feedback. These systems are designed to enhance the effectiveness of treatment while reducing the occurrence of negative effects. Reinforcement learning algorithms exhibit potential in forecasting and adapting dosages for precision-oriented cancer therapy. A cutting-edge dose optimisation system has been developed as a potential breakthrough in enhancing chronic disease treatment. This innovative platform aims to increase the precision of chemotherapy administration by providing actionable recommendations for optimal dosing. The algorithm takes into account the response to treatment over a period of time, making dynamic predictions about the necessary dosage to maintain the desired level of effectiveness and safety. (Johnson, et al.2023)

6. *Electronic health record (EHR)*

A new predictive EHR algorithm can improve clinical decisions by detecting and alerting when a prescribed drug appears to deviate from its pattern of appropriate use by using large amounts of EHR data and AI to learn medication use patterns. AI could also help choose drugs by automatically classifying patients who are unlikely to have side effects. Patient Safety Learning Laboratory (PSLL) AI in EHR systems may discover, assess, and minimise patient safety hazards.Hospital and health system pharmacies may use NLP and ML to access and analyse unstructured, free-text information in millions of EHRs (e.g.,

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medication safety, patients' medication history, adverse drug reactions, interactions, medication errors, therapeutic outcomes, and pharmacokinetic consultations) to improve patient care and perform real-time drug efficacy evaluations. This technique could help pharmacy and therapeutics (P&T) Committees make risk-sharing agreements and decisions. (Chalasani, et al. 2023)

7. *Medication adherence*

Approximately half of chronic disease patients do not take their prescriptions as prescribed, increasing morbidity and mortality and costing 100 billion USD annually. (Brown, et al. 2011) Although pharmacist-led programmes are the most effective in promoting medication adherence, they are often complex and involve numerous healthcare practitioners and components. AI technology may be a promising part of multifactorial therapies to increase drug adherence, which is complex and varied. Many AI systems promote and monitor medication adherence. The eight technology types were classified by their technical designs and adherence monitoring functions: electronic pillboxes or bags, pill bottles, ingestible sensors, blister pack technology, electronic medication management systems, patient self-report-based technology, video-based technology, and motion sensor technology. (Babel, et al. 2021)

8. *Medication therapy management (MTM)*

The comprehensive medication management (CMM)-Wrap program used a novel AI platform that combined population health and telemedicine to identify and prioritize at-risk members and provide AI decision support for interventions using robust data collection and reporting and proprietary MedRiskScores. A disease therapy management provider used community health and telemedicine to identify and prioritize high-risk patients in this CMMWarp. (Kessler, et al. 2021) Medical assistants and clinical pharmacists specialized in illness management provided remote telephonic services. The research found that trained pharmacists and medical assistants working with advanced AI systems to provide CMM services over the phone reduced healthcare costs, emergency department visits, and hospital admissions. These favorable outcomes may indicate well-being. Shanghai's grade 3 A specialized hospital created an AI-based internet pharmacy service during the COVID-19 epidemic. (Bu, et al. 2022) The online hospital

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system used AI to assess prescriptions, then pharmacists double-checked and distributed them. A "medicine pick-up code" is generated for offline self-pick-up orders, including fragile, high-risk, and

special-storage medications (at 2-8 ◦C). A third-party pharmaceutical corporation controlled other deliverable medications. In an offline hospital or drugstore, patients or volunteers could scan the QR code through the glass and wait for the dispensing machine or pharmacist to distribute the drugs. They also offered free online drug consultations from a volunteer team of professional pharmacists with clinical experience. (Edrees, et al. 2022)

9. *Telehealth*

Telehealth (telemedicine) improves health by exchanging medical data between places. Through NLP, chatbots can speed up and simplify history taking by prompting and asking patients about their symptoms and providing possible diagnoses, including ADE identification, that can be codified and applied to future patient visits. A HIPAA-compliant conversational AI platform developed an adverse event (AE) detection module that uses deep learning and NLP via a virtual assistant to identify and distinguish AEs based on questions and phrases. When an AE is found, the module automatically transcribes, exports, and reports to the pharmaceutical firm and FDA. In telehealth, AI can improve pharmacovigilance. (Belenguer, et 2022) Pharmacists assessed patients who indicated ADEs. AI could forecast screening and contact dates for patients. Other technologies like patient portals and messaging could increase pharmacovigilance efficiency and effectiveness. Patients benefit from tele-monitoring, mobile health apps, and wireless monitoring devices. These include monitoring data, disease information, symptom diaries, medication logs, reminders, nutrition diaries, and communication tools. Wearables and mobile health apps can track personal statistics, physical status, and physiological factors to help with medication regimens. Patients use Fitbit, Apple Watch, portable insulin pumps, and pacemakers. Software programs on various devices allow providers to analyze real-time dynamic data from wearable devices. (Edrees, et al. 2022)

- **Obstacles in implementing AI in pharmacy practice**

1. *Protection of personal data and safeguarding against unauthorized access*

The increased use of AI-based apps has prompted concerns over data privacy and security. Health information is highly confidential and frequently targeted by cyber-attacks resulting in data breaches.

Ensuring the protection of patient data is of utmost importance. Certain patients may have concerns over the potential violation of their privacy through data collecting, leading to the filing of lawsuits in reaction to the sharing of data between major health systems and AI companies. (Murdoch, 2021) Obtaining individual patient consent is crucial in addressing data privacy problems, as healthcare institutions may utilize patient data for AI training on a wide scale without acquiring adequate authorization from each patient. Google acquired DeepMind Health in 2018. The application developed by DeepMind, called Streams, includes an advanced algorithm designed to handle cases of acute kidney injuries in patients. Recently, it gained significant attention when it was discovered that the National Health Services (NHS) had provided DeepMind servers with the medical data of 1.6 million patients, allowing them to train their algorithm without obtaining consent from the patients. (Cohen, et al. 2019)

2. *Bias*

Biases in AI model data collecting can influence outcomes. Due to racial biases in dataset generation, minorities may be underrepresented, resulting in poor prediction performance. AI systems trained on reliable, representative data may encounter issues if the data reflects health-care system biases and inequities. (Belenguer, 2022) An AI system learning from health-care records may recommend lower opioid analgesia doses to African-American patients, despite systemic bias rather than biological reality.

3. *Data integration*

Data collection is followed by AI technology development. The system can overfit when it learns irrelevant patient variable-outcome connections. Too many variable parameters affect outcomes, therefore the system predicts using incorrect features. Some classification and clustering techniques may perform well on small data sets, however this may not be realistic or useful. Data must be preprocessed for AI application. Before use, text data requires considerable natural language processing. One of the biggest obstacles in medical data processing is integrating text, quantitative, image, and video data using the same algorithm. Medical images, 3D video sequences, photographs, and quantitative data can be used to collect medical data. In healthcare data analysis, clean, resilient, and efficient data is difficult. (Ali, et al. 2023)

4. *Patient safety*

The data obtained from hospitals might occasionally exhibit substandard quality or inaccuracy, with certain data points being absent. Data inaccuracy is a significant difficulty in AI-based medical data processing. Another problem arises when machine learning algorithms make incorrect decisions due to the use of an unsuitable algorithm for the provided data or when the data itself is not sufficiently reliable to be employed in classification algorithms like neural networks, decision trees, and Bayesian networks. (Ali, et al. 2023)

5. *Clinical implementation*

The absence of empirical evidence substantiating the effectiveness of AI-based therapies in prospective clinical trials is the primary obstacle to achieving successful application. Most AI research in healthcare primarily focuses on analyzing past data in a controlled setting. Consequently, it is challenging to apply the results to a real-world situation. (Kelly, et al. 2019)

6. *Ethical concerns*

In addition to data privacy and security, another significant concern is accountability. In healthcare, making poor judgments can have significant repercussions, and the prevailing belief is that someone should be held responsible for them. However, the matter of accountability becomes even more significant when contemplating AI applications that strive to enhance medical outcomes, particularly in instances of failure. Consequently, the allocation of responsibility in the event of system failure is ambiguous. While it may seem unjust to hold the physician responsible, given they had no involvement in the development or control of the algorithm, it is also impractical to hold the developer liable, as they are too distant from the clinical setting. (Rodrigues, 2020)

7. *Social concerns*

Healthcare AI will replace occupations, rendering healthcare personnel redundant, a huge social worry. AI-based healthcare interventions are distrusted and opposed because to replacement risk. However, a misunderstanding of AI in its different forms underpins this notion. Healthcare workers have lagged behind in adopting new technologies. Previous healthcare experiences suggest that innovation implementation is crucial. Implementing new AI technologies in healthcare can be hindered by constraints such as restricted data structure and quality in existing electronic health systems. (Ardito, et al. 2023)

Conclusion:

AI can help doctors make better decisions and give patients more individualized treatment. AI improves healthcare service collaboration for a patient. AI may help patients learn how and when to take medications, educate them, and promote medication adherence. It may also help them find the most cost-effective healthcare, communicate with healthcare professionals, optimize health monitoring using wearables, and integrate diet and exercise. Clear rules for safe deployment and evaluation of AI technology in real-world contexts and further study into its capabilities and limitations are needed. While perfect conditions for AI deployment are not yet in place, healthcare AI development can continue. These include rigorous clinical trials to validate AI software and interventions, prospective observational studies to implement and understand the long-term impact of AI on clinical decisions, and relevant bodies and organizations developing ethical and privacy guidelines and frameworks to protect patient data and promote transparency. AI-powered individualized treatment plans and patient engagement research can improve patients' experiences and empower them to actively participate in AI-based pharmaceutical decisions.

We propose "pharmacointelligence," the use of AI/ML and other sophisticated technologies in pharmacy to improve patient care and safety. Incorporating AI/ML principles into the pharmacy curriculum and keeping stakeholders informed of advancements in this field through continuous education. Pharmacist education must adapt to these rapid technological advances to educate our profession to lead care changes.

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