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A Review on Artificial Intelligence (AI) in Pharmacy

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INTRODUCTION:

AI, or artificial intelligence, is a branch of science focused on creating smart computer programs that work in ways similar to how humans think and pay attention. These systems collect data, process it, make decisions or draw conclusions (even if they're not perfect), and then adjust or improve themselves over time. In simple terms, AI helps machines "learn" and improve their tasks, like analyzing information or solving problems. In the pharmaceutical industry, AI is bringing big changes by making drug development and manufacturing faster, more efficient, and cost-effective. With advanced data analysis and smart algorithms, AI helps improve how drugs are designed, ensures better product quality, and streamlines production processes, leading to better and more affordable medicines.[4]

Artificial intelligence (AI) is said to have started in 1956 when a famous conference was held at Dartmouth College. But even before that, in 1955, the first AI system called Logic Theorist was created by Allen Newell and Herbert A. Simon. This system was able to prove nearly 40 theorems from a famous math book called Principia Mathematica, though the creators couldn't get their work published at the time. Today, AI has become an important part of many industries, including pharmacy. Over the past 25 years, the pharmacy field has worked hard to meet the rising demand for prescriptions, despite challenges like pharmacist shortages, higher costs, and lower payments. Pharmacies have made good use of automation technology to improve workflows, reduce costs, and make sure that medications are handled safely and accurately. Automated systems allow pharmacists to spend more time helping patients, which leads to better health outcomea[6]

Machine learning (ML), a method that enables computers to learn from data and gradually enhance performance, has drawn special attention under the general heading of artificial intelligence (AI). The ability of large language models (LLMs), a subset of machine learning (ML), to produce text that is human-like makes them an indispensable tool for processing and interpreting enormous volumes of text-based biomedical data, such as patient records, clinical trials, and scientific literature. [7,8,9] The earliest known use of a computer in a pharmacy was probably in the 1980s. Since then, computers have been used for a wide range of purposes, including data collection, clinical research, drug storage, pharmacy education, clinical pharmacy, and much more. With the rise of artificial intelligence, it is impossible to predict how much the pharmacy industry will change in the future. To help doctors with medical diagnosis, a number of expert systems have been developed

Fig. 1: Graphical Abstract

This article talks about the many ways AI models are being used in the pharmaceutical industry, focusing on how they can bring benefits, face challenges, and help drive new innovations that improve patient access to safer and more effective medicines. In healthcare, AI tools are already helping doctors make faster and more accurate diagnoses in areas like radiology, pathology, dermatology, cardiology (like reading ECGs), and even in ICU predictive systems and clinical decision support tools. AI can also analyze health records using natural language processing (NLP). For example, AI-powered programs can study medical images from X-rays, CT scans, and MRIs to detect problems, lesions, or early-stage diseases that might be difficult for human eyes to notice, helping catch illnesses earlier and improving patient care..[12]

AI Classification:

AI can be classified in two different ways[13,14]

a) According to caliber

b) According to the presence…**(Shown Tab. 1)**

Table 1: Classification of AI

Based On The Caliber	• Weak intelligence • Artificial narrow intelligence • Artificial general intelligence • Artificial super intelligence
Based On Presence	• Type 1 reactive machine • Type 2 limited memory system • Type 3 is based on the theory of mind • Type 4 self-awareness

Based on their caliber, AI system is classified as follows:

1. **Weak intelligence or Artificial narrow intelligence (ANI):**

his type of AI system is built and trained to do just one specific job, like recognizing faces, driving a car, playing chess, or controlling traffic signals. For example, Apple's Siri works as a virtual personal assistant, and social media platforms use AI to automatically tag people in photos. These systems are very good at their one task but can't do things outside of what they were designed for.

2. **Artificial General Intelligence (AGI) or Strong AI:**

this type of AI is called Human-Level AI or Artificial General Intelligence (AGI). It can match human thinking abilities and handle many different tasks, not just one specific job. That means if it faces a new or unfamiliar problem, it can figure out how to solve it, just like a human would. In short, AGI can do anything that humans can do, using reasoning, learning, and problem-solving across a wide range of situations.

3. **Artificial Super Intelligence (ASI):**

This type of AI is called superintelligence. It is much smarter than the best human minds in every area—whether it's art, math, science, or space. It can be just a little smarter than humans or even trillions of times more intelligent. Superintelligent AI would be able to think, create, and solve problems far beyond what any human could do.

Arend Hintze[15], an AI scientist classified the AI technology based on its presence and not yet present. They are as follows:

Type 1:this type of AI is called a reactive machine. For example, IBM's Deep Blue, the chess program that beat world champion Garry Kasparov in the 1990s, is a reactive machine. It can look at the pieces on the chessboard and predict the best moves, but it doesn't remember past games or use past experiences to improve. It's built for a specific task and can't be used in other situations. Another example of this kind of AI is Google's AlphaGo, which was designed just to play the game Go.

Type 2: this type of AI is called a limited memory system. It can use past experiences to help make decisions for current and future problems. For example, in self-driving cars, some decisions are made using this kind of AI. The car uses past observations, like noticing cars in other lanes, to help decide when to change lanes. However, these observations are only kept for a short time and are not saved permanently in memory.

Type 3: This type of AI is called the "theory of mind." It refers to the idea that humans have their own thoughts, intentions, and desires that affect how they make decisions. An AI with theory of mind would need to understand and respond to human emotions and thoughts. But right now, this kind of AI does not exist — it's something scientists are still working toward for the future..

Type 4: This type of AI is called self-aware AI. It means the AI would have its own sense of self and consciousness, just like humans do. If a machine were self-aware, it could understand its own feelings and also understand what others are thinking. However, this kind of AI doesn't exist yet — it is still just an idea for the future

IMPORTANCE OF AI IN PHARMACY

A survey in the U.S. showed that pharmacists are among the top paid professionals, ranking 13th with an average salary of about $120,950 and a low unemployment rate of 1.6%. For many years, pharmacists' main job was to make sure prescriptions were filled with the right medicine and dosage, and to check that different medicines taken together wouldn't cause harmful reactions. But in the last five years, things have changed a lot. Thanks to big data and AI, robots have become more trusted by doctors, and many hospitals and pharmacies now use robots, supervised by humans, to do tasks that people used to do by themselves..[16]

Pharmaceutical companies have access to many compounds that might help treat different diseases, but they often don't have the tools to easily identify which ones will work. Developing and producing a new drug is very difficult and expensive — it can cost around $2.6 billion and take 12 to 14 years to complete. This is where AI is a big help. AI can speed up the drug development process, which lowers the time and money needed. This not only increases the company's return on investment but can also help reduce the final cost of the medicine for patient.[17]

One big advantage of AI is that it is much better than humans at analyzing huge amounts of data — far more than regular computers can handle. Right now, AI is mostly being used in research areas. Its powerful processing ability makes it the best tool available for tasks like studying gene mutations, where it can quickly go through massive piles of data and find the important details researchers need.[18]

TOOLS OF AI

Many AI tools have been developed to meet the current needs of the pharmaceutical industry, and they have shown very promising results. Some of these tools have become especially popular and widely used in the pharmaceutical sector because they help improve and speed up various processes. Below are some examples of these well-known AI tools.

IBM Watson for oncology

IBM has created a supercomputer called Watson, which combines artificial intelligence (AI) with advanced analytical software. Watson is specially designed to understand and answer questions, making it a powerful tool for solving problems and providing useful information..[19]

Robot pharmacy

To improve patient safety, UCSF Medical Center uses robots to prepare and track medications. So far, this technology has prepared 350,000 doses without making any mistakes. The robots are better than humans in both size and accuracy when it comes to delivering the right medicines. They can prepare both pills and injectable drugs, including dangerous chemotherapy medicines. Thanks to this, the pharmacists and nurses at UCSF can spend more time using their skills to care directly for patients and work closely with doctors.[20]

In UCSF's automated pharmacy system, computers first receive medication orders electronically from the doctors and pharmacists. Then, robots pick, package, and dispense the correct doses of pills. After that, machines organize these doses onto a bar-coded plastic ring, which holds all the medicines a patient needs to take over 12 hours. The system can also prepare sterile chemotherapy drugs and fill syringes with the right medicines, making sure everything is accurate and safe..[20]

MEDi Robot

MEDi stands for Medicine and Engineering Designing Intelligence. It is a pain management robot created through a project led by Tanya Beran, a professor at the University of Calgary. She got the idea after seeing how scared and upset children can get during medical procedures. MEDi helps by first building trust with the kids and then explaining what will happen during the procedure. While the procedure is happening, the robot guides the children on what to do, how to breathe, and how to handle the experience, helping them stay calm and cope better. [22]

Even though MEDi cannot truly think, plan, or reason on its own, it can be programmed to act like it has AI. Made by Aldebaran Robotics, MEDi has built-in facial recognition and can speak 20 different languages, making it very flexible in different situations. The basic retail price of the robot is $9,000, but when you add the special applications needed for it to help with medical procedures, the total cost goes up to between $15,000 and $30,000.18]

Erica robot

Erica is a new care robot developed in Japan by Hiroshi Ishiguro, a professor at Osaka University. The project was done together with the Japan Science and Technology Agency, Kyoto University, and the Advanced Telecommunications Research Institute (ATR). Erica can speak Japanese and has a mix of European and Asian facial features, making her look more lifelike and relatable[24]

Just like a normal person, Erica says it enjoys animated movies, dreams of visiting Southeast Asia, and even wishes for a life partner to talk with. Although the robot can't walk on its own, it has been designed to understand questions and respond with human-like facial expressions, making its interactions feel more natural and lifelike.. [25]

APPLICATIONS OF AI

AI is being used in hospitals to help with diagnosing illnesses and creating treatments that are specially designed for each patient's genetic makeup. It helps organize the right medicine doses for individual patients and chooses the best way to give the medicine or the best treatment plan. This makes healthcare more personalized and effective.

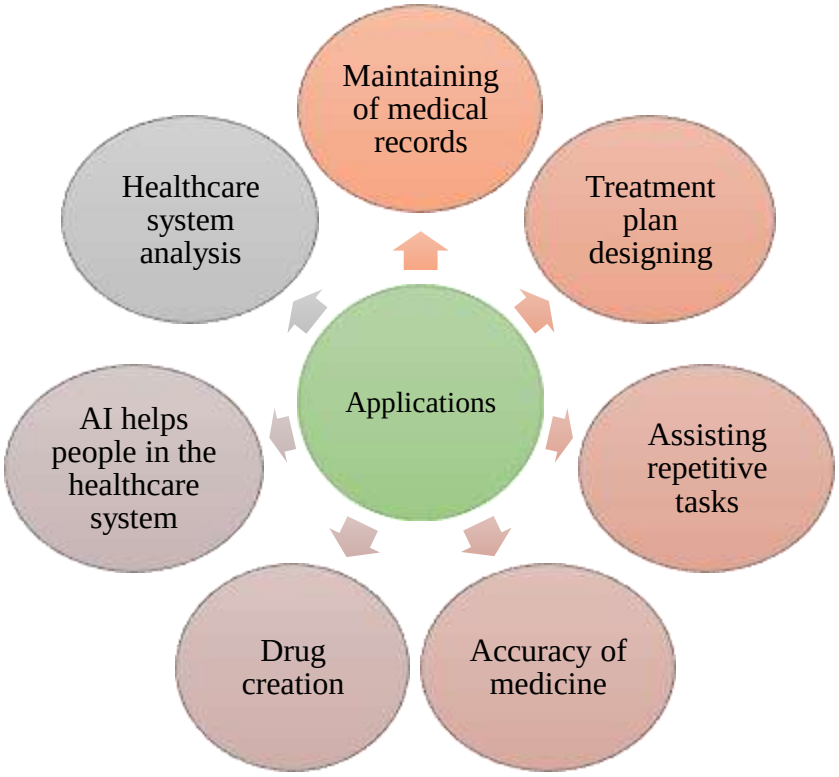

Fig 2. Applications of AI

I. Maintaining of medical records:

Keeping track of patients' medical records is a hard and complicated job. But AI systems make it easier to collect, store, organize, and find this information quickly. One example is Google's DeepMind Health project, which helps find important medical records very fast. This makes healthcare better and faster. For example, Moorfields Eye Hospital in the UK uses this project to improve eye treatments

II. Treatment plan designing:

AI technology helps doctors create better treatment plans, especially when a patient's condition is serious and choosing the right treatment is hard. The AI looks at all past patient data, medical reports, and expert knowledge to suggest the best options. One example is IBM Watson for Oncology, a smart computer system that compares a patient's data with thousands of past cases and works closely with cancer doctors from Memorial Sloan Kettering Cancer Center. It gives treatment suggestions backed by research from medical journals and textbooks, helping doctors make better and more informed decisions for cancer patients..[27]

III. Assisting in repetitive tasks:

Deep learning can be used for almost all types of imaging analyses, such as X-ray, CT scan, ECHO, ECG, etc. AI technology also helps with some repetitive tasks, like examining the X-ray imaging, radiology, ECHO, ECG, etc., for the detection and identification of diseases or disorders. Medical Sieve[28] (an algorithm launched by IBM) is a "cognitive assistant" with good analytical and reasoning abilities. A medical start-up is necessary for the improvement of the patient's condition by combining deep learning with medical data..

IV. Accuracy of medicine: Medical accuracy:

AI has a positive effect on genetic development and genomics. An AI system called Deep Genomics[29] can be used to find mutations and connections to diseases by looking for patterns in genomic data and medical records. This technique tells physicians what happens inside a cell when genetic variation changes the DNA. Craig Venter, the creator of the human genome project, has developed an algorithm that uses a patient's DNA to provide information

about their physical attributes [30]. In its early stages, "Human Longevity" AI technology can pinpoint the precise location of vascular disorders and cancer**.**

V. Drug creation:

Pharmaceutical development or production costs billions of rupees and takes over ten years. An AI tool called "Atomwise"[31] that makes use of supercomputers is helpful in determining the treatments from the molecular structure database. It launched an online search for a safe and efficient Ebola virus treatment using currently available medications. Two medications that caused Ebola infections were detected by the technology. In contrast to months or years of laborious analysis, this analysis was finished in a single day. A biopharma company in Boston uses big data and AI to help manage patient care. They collect and study patient biological data to figure out why some people survive certain diseases. By comparing healthy conditions with those that lead to disease, they can better understand what makes a difference. This helps them discover and design new drugs, improve healthcare, and find solutions to medical problems.

VI. AI helps people in the health care system:

The “open AI ecosystem” was listed among the top 10 most promising technologies in 2016. This system is helpful because it collects and compares data using social awareness algorithms. In healthcare, where huge amounts of information are stored — like a patient’s full medical history and treatment records from childhood onward — the ecosystem can analyze all this data and provide helpful suggestions about the patient’s lifestyle and habits to improve their health..

VII. Healthcare system analysis:

In the healthcare system, when all data is stored digitally, it becomes much easier to access and retrieve information. For example, the Netherlands keeps 97% of its medical invoices in digital form, including details like treatment data, doctor names, and hospital names. A local company called Zorgprisma Publiek uses IBM Watson’s cloud technology to analyze these invoices. If any issue or error is detected, the system quickly identifies it and takes the right action. This helps improve care and can even prevent patients from needing to be hospitalized..

ADVANTAGES OF AI TECHNOLOGY

The use of AI is quite complex because it combines different fields like computer science, math, and other sciences. Thanks to advanced programming, AI systems can copy or imitate how humans think and make decisions. Here are the main benefits of AI:

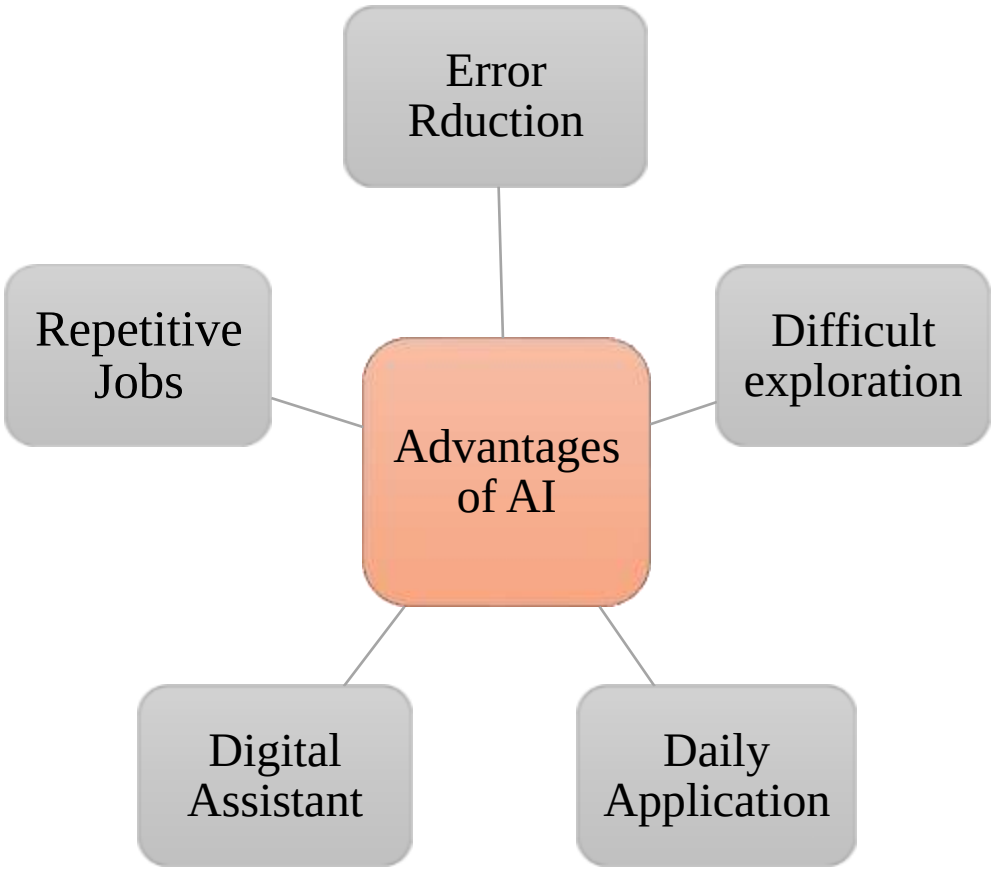

Fig 3. Advantages of AI

1) Error reduction

- AI helps people make fewer mistakes and increases the chances of getting more accurate and precise results..
- Robots with AI are better for space exploration because their metal bodies can handle the tough and harsh conditions in space better than humans can.

2) Difficult exploration

- AI is used in mining and fuel exploration. It helps overcome human limits and makes it possible to explore and study the deep ocean more effectively.
- By programming robots, they can do tough and complicated tasks easily and without getting tired.

3) Daily application

- AI is used in many ways in our daily lives.

AI systems are useful for long drives. In smartphones, AI helps by predicting what you want to type and fixing spelling mistakes. Examples of such helpful robots are Cortana and Apple's Siri.

4) Digital assistants

- Companies use artificial intelligence (AI) systems, also called "avatars," which are virtual assistants, to reduce the need for human workers.
- Avatars reason logically and make good decisions because they don't have emotions. Human feelings often affect moods, which can hurt judgment and lower work performance.
- This problem does not occur with artificial intelligence.

5) **Repetitive jobs**

- A person can only do one task at a time, but machines can do many tasks quickly and think faster than humans.
- Machines can do dangerous jobs, and their settings like speed and time can be adjusted.

AI in pharmacology

I. In recent years, artificial intelligence (AI) has grown in popularity in the healthcare industry, with pharmacology being one of the many domains where it is widely used. [36] AI is now used in almost every facet of pharmacology research and clinical practice, from early medication development to real-world data mining. [12,37] When assessing data from multiple sources, including disease features, clinical patient characteristics, genomic data, and medication chemical structures, AI and ML are particularly useful. The quantity of articles on the topic indicates the growth of AI applications in pharmacology. [3]

II. AI in Pharmaceutical Sciences

III. AI in clinical trials and real-world evidence

IV. AI in medical Diagnosis

V. AI in Drug Treatment Optimization

VI. AI in drug repurposing

I. AI in Pharmaceutical Sciences

Pharmaceutical sciences involve many scientific steps to discover and develop new medicines. Improving healthcare needs a lot of work, and AI offers advanced solutions to make healthcare better. AI helps doctors, patients, insurance companies, and regulators manage the best healthcare options. It uses data from many places like universities, research groups, companies, hospitals, and pharmacies to do this.

II. AI in clinical trials and real-world evidence

The clinical trial phase of a new treatment starts after the early testing stage, but it comes with extra costs. One of the hardest parts of clinical trials is choosing and finding enough patients. If enough patients are not recruited, the trial might have to stop. AI can help with this by going through large amounts of electronic health records (EHR) to find patients who meet the requirements and are most likely to join. This saves time and money.

AI can also help monitor patients during the trial by looking at EHR data or checking real-time information from devices like smartwatches. Lastly, AI can help collect useful real-world evidence by analyzing EHR data and turning it into important clinical insights.

III. AI in medical Diagnosis

Skin cancer, neurological conditions, strokes, Alzheimer's disease, acute ischemic stroke, and other medical conditions can all be properly diagnosed with AI. The AI-based least square support vector machine (LSSVM) is used to diagnose cancer, and natural language processing (NLP), the first reading device to offer exceptional flexibility for clinicians to study the descriptors of X-rays on the chest, is also used to treat infectious infections. [44, 45] Breast flaws can be identified using the particle swarm-optimized wavelet neural network (PSOWNN). [46]

IV. AI in Drug Treatment Optimization

For many commercially available medications, it is crucial and advantageous to tailor the course of treatment for each patient. For instance, medications with a limited therapeutic window might have their dosages customized through the use of therapeutic drug monitoring (TDM). TDM data is frequently interpreted using statistical prediction models to determine drug exposure and the best way to treat patients. Compared to drug discovery, the application of AI in this field is less developed. This is mostly due to the fact that training the models necessitates access to big clinical datasets. [47, 48]

V. AI in drug repurposing

New drug development is a labor-intensive, costly, and time-consuming process. Drug repurposing is a great technique to use existing candidates for various therapeutic purposes by utilizing the potential that a known candidate can target several target sites. [49] For clustering algorithms, this unsupervised method and the topographical pharmacophore descriptor (CATS) are frequently employed. However, the prediction accuracy offered by unsupervised learning is only moderate. The semi-supervised learning paradigm may effectively model a large number of unlabeled data and a small amount of labeled training sets. LapRLS, for instance, develops algorithms for drug-target interactions while keeping in mind that FDA approval was predicated solely on target predictors. Nonetheless, this approach receives a high rating due to its simultaneous prediction capabilities. Other techniques include the BLM-NII, Net CBP, and LPMIHN. Furthermore, the use of AI-based drug repurposing is still in its infancy. The system must first surpass the forecast accuracy attained by experts manually in order to guarantee its wide range of applications in the area. [50]

LIMITATIONS OF AI

Trying to create rules to control AI systems is not easy and comes with some problems. There are several important downsides or challenges when it comes to making AI regulations.

- It’s important to find a balance between letting AI grow and improve while also setting rules to stop it from being used in harmful or unfair ways. Too many strict rules can slow down progress, but no rules at all can lead to misuse.51
- Making good rules for AI is complicated because it needs a deep understanding of how AI works. Creating these rules takes careful and smart thinking to make sure they cover everything properly.
- It is challenging to set up clear systems to watch over and make sure that AI follows the rules properly. Making sure everyone obeys the rules is not easy and takes careful work.
- It is a constant challenge to keep up with new and growing dangers that come from the misuse of AI systems. As AI becomes more advanced, the risks also become more complicated.

FUTURE PERSPECTIVES:

1) Drug Discovery & Development

a) **Faster screening of compounds:** AI can study huge collections of chemicals and predict which ones are most likely to work with a specific target, helping save years of testing and guessing.

b) Predictive modelling: Machine learning (ML) can predict how new drugs will act inside the body — like how they are absorbed, spread, broken down, removed, and if they might be harmful.

2) Clinical Trials Optimization

a) Patient recruitment: AI can look through electronic health records (EHRs) to find the best patients for clinical trials, making the process faster and more diverse.

b) Adaptive trial design: AI can look through electronic health records (EHRs) to find the best patients for clinical trials, making the process faster and more diverse.

3) Personalized Medicine

a) Tailored drug regimens: AI helps watch clinical trials in real time and make quick changes, which saves money and makes the trials more likely to succeed.

b) Biomarker discovery: AI can create personalized treatment plans by looking at a person’s genes, metabolism, and lifestyle.

4) Pharmacovigilance & Safety Monitoring

a) Adverse event detection: Natural Language Processing (NLP) can read medical reports, social media posts, and articles to quickly find early warning signs of drug side effects.

b) Risk prediction: AI can identify patients who are more likely to have problems or side effects from medicines, helping to keep them safer.

5) Supply Chain & Manufacturing

a) Smart manufacturing: AI can watch and manage complicated medicine-making processes to make sure the quality is good and to reduce any waste.

b) Supply chain optimization: Predictive algorithms help keep track of medicine supplies, stop running out of drugs, and make sure medicines are sent to the right places on time.

CONCLUSION:

Future prospects for AI in pharmacy are extremely promising. AI has the potential to transform pharmacy practice in a number of areas, including pharmacovigilance, supply chain management, medication management, personalized medicine, and drug development. By using AI technologies, pharmacists can improve patient outcomes, increase productivity, and provide tailored treatment. However, it's crucial to consider patient privacy, ethical concerns, and the need for human oversight when implementing AI in pharmacy. Artificial intelligence (AI) should be viewed as a tool to enhance pharmacists' knowledge and decision-making, not as a replacement for human judgment. If AI is properly analyzed and applied, it has the potential to significantly advance pharmacy practice, which would ultimately benefit patients and medical professionals..

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