The Role of Artificial Intelligence in Pharmacy and Microbiology within Inpatient and Outpatient Settings

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Abstract

Artificial intelligence in medical microbiology addresses issues by automating and it has the potential to convert microbiological diagnostics by offering faster, more defined and more precise methods that enhance patient outcomes and solve the problems with predictable diagnostic techniques. The rapid advancement of artificial intelligence (AI) and natural language processing (NLP) makes it possible for chatbots to be employed in more sectors. Chatbots and application softwares are made to encourage human interaction, which is an essential part of customer service. The hybrid chatbots combining rule based and AI powered systems have been developed in order to deliver a more useful response for a number of applications. Rule based reasoning for basic tasks combine to form efficiency and accuracy of chat bots, whereas AI open up more complicated interaction and learned learning. Pharmacists are able to generate evidence based treatment suggestions using technologies like Path AI quickly because AI is able to quickly review recent findings, guidelines and patient specific information to quickly prescribe them with evidence based treatment in consultations. This strengthens collaborative healthcare processes.

Keywords: Artificial Intelligence, Machine Learning, Pharmacy, Microbiology, In patients, Out patients.

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Introduction

Time-consuming procedures like culture techniques, microscopy, and biochemical testing were needed for the detection and analysis of infections in the past. Despite being the foundation, these traditional methods often face limitations like lengthy procedures, the need for specialized knowledge, treatment delays, cross- infectivity and false- optimistic cultures, a lack of real-time epidemiological investigation, a lack of consistent practices and quality measures, and the potential for human error (Tsitou et al., 2024).

The use of AI in conjunction with matrix-assisted laser desorption/ionization-time of flight mass spectrometry (MALDI-TOF MS) has significantly accelerated and improved the accuracy of pathogen detection In clinical microbiology, At the moment, this technique is quick and precise, which makes it an economical means of identifying cultivated bacteria and fungi. It works just as well as conventional biochemical identification techniques, if not better. Although there are certain limitations when it comes to differentiating between closely related species, this technology has become the preferred method of recognizing anaerobic bacteria and mycobacteria (Vashishth et al., 2025).

The evaluation of the ability with its vast amounts of data and identify trends, artificial intelligence (AI) offers new possibilities for microbiological research and diagnosis. By aiding in the diagnosis, prediction, and individualized healing plans of microbiology, artificial intelligence (AI) holds promise for addressing public health issues like the management of infectious conditions and sepsis. Furthermore, AI's use in infection avoidance and control is notable because it can analyze large health databases, which makes it easier to identify epidemics and create efficient infection control plans (Gurajala, 2024).

The ML, or machine learning is one aspect of AI that enables systems to learn and enhance procedures without the need for formal programming is machine learning (Mohseni & Ghorbani, 2024).

Deep learning (DL) is a subset of machine learning that makes use of multi-layered neural networks, or "deep architectures”. These networks capture complex patterns and characteristics by learning hierarchical representations from data (Das et al., 2021).

The Machine Learning Mechanism

1. Machine learning gathering information and training: This entails the first stage of collecting several kinds of data, including textual material, photographs, numerical values, and so forth. The data, also known as "training data," serve as the foundation for teaching the machine learning algorithm (Jiang et al., 2022).

2. The algorithm: A involvement in learning patterns, correlations, and distinguishing features from the data during the training phase. It entails showing a model various apple images in order to teach it to recognize apples (Mohammed et al., 2025).

3. The creation of algorithms: Data scientists create algorithms for machine learning. The specific task and data being processed determine which algorithm is used. Simple algorithms like linear regression and more complex ones like neural networks are both possible (Theodosiou & Read, 2023).

4. Planning and Generalization: The machine learning algorithm may forecast on new, unseen data after it has been taught. To handle real-world scenarios, the algorithm extrapolates from the training data. For example, it predicts whether or not an image that is received is an apple (Sahayasheela et al., 2022). The capacity of chatbots to respond to inquiries and offer round-the-clock support has altered how companies engage with their clientele. Now they can do tasks, help with complex consumer queries, and can even interact with clients in the natural, human-like way. The first chatbot was created in the middle of 20th century by Joseph Weizenbaum (Kolben et al., 2023) ELIZA in 1966. As a rule, based framework with the help of pattern matching techniques, ELIZA is used to encourage conversation. It based it off of preset criteria and knowing certain words and phrases in the users input and would leave with feedback.

AI-Powered Chatbots

Natural Language Processing (NLP) is the basis of chat bots based on AI lies in a subfield of artificial intelligence, the creation and understanding of human language. The natural language processing methods that are sophisticated have the capacity to consider context, intent, and small details of input besides the meaning of the literal word. It makes interactions with each other less personal exchanges and more natural, engaging conversations as it has this ability to understand nuances and context. Machine learning (ML) made the chatbots capable with machine learning. Chatbots that are updated with discussions may be viable using machine learning algorithms which allow the chatbots to learn from discussions and get better with time. Other than rule-based systems that follow pre-scripted rules AI powered chatbots make use of past data in order to identify patterns and estimate patient requirements (Sallam et al., 2024).

The AI-powered chatbots were made more capable via machine learning (ML). Machine learning algorithms may allow chatbots to learn from discussions and improve over time. The AI-powered chatbots use past data to identify patterns and estimate patient requirements, in contrast to rule-based systems that follow preset scripts. The FDA has approved about 700 devices with AI or machine learning (ML) capabilities. One This illustrates how broad the definition of artificial intelligence is. Specifically, it is the application of models or algorithms to carry out operations and display behaviours like learning, decision-making, and prediction-making. It should come as no surprise, given this criteria, that not all AI/ML-enabled technology marks a revolutionary advancement in medicine. The list includes, for instance, the 2013-approved microbial identification system Vitek MS (Biomerieux). Although this is a valuable tool for clinical treatment, it might not be obvious to doctors examining the tool's outcomes that AI is being used at all (Alowais et al., 2023).

At the most appealing, GPT is the most notable development in creating AI driven chatbots. The GPT-3 and GPT 4.0 models use deep learning for generating the text that is human like when fed with the input, this help chats bots in their dialog and give response accordingly. They allow chat bots to speak in meaningful dialogues and serve contextually appropriate responses. As compared to previous embodiments of chatbot systems, these chatbots are much better because they can generate original material, generate emails and even engage in engaging conversation (Thomas, 2023).

Hybrid chatbots based on rules are reactive to structured or repetitive tasks in a straight forward and predictable way. For instance, they are adept at dealing with issues such as queries, tedious search, or simple requests. To lower the odds of error and produce correct and sincere response rule based approach ensures that these tasks are carried in right way and with an appropriate attitude (Chopra et al., 2023).

The Role of AI in Hospital Pharmacy

The cutting-edge AI technologies have the capacity to completely improve clinical pharmacy practice by combining their responsibilities in a smooth and cooperative way. It provides chemists with an unmatched chance to improve their cooperation with physicians, particularly in hospital environments. By providing real-time updates on patient medications, possible drug interactions, and dose recommendations based on integrated patient data, AI-driven solutions facilitate communication between pharmacists and physicians. Pharmacists are positioned as vital members of healthcare teams by these smooth integrations, which guarantee patient safety and therapeutic efficacy. AI can suggest suitable medicinal therapy, doses, and combination drugs because of its ability to comprehend enormous volumes of patient data and clinical recommendations (Belagodu Sridhar et al., 2024).

One AI-powered technology that helps oncologists identify possible cancer medication therapies based on patient profiles is IBM Watson for Oncology. AI is essential for improving quality as well. AI can provide insights into possible systemic problems by seeing trends in prescription errors and adverse drug responses, which can help guide quality improvement initiatives. For instance, google's AI has proven to be able to anticipate unfavorable hospital events and create preventative strategies, which improves patient safety and the standard of care provided. For instance, google announced a noteworthy development in cardiovascular disease (CVD) research in 2018 (Al Meslamani, 2023).

Another example is Chemical Substructure Representation (CASTER), which is an AI tool that does a comprehensive evaluation of hidden features of medication or the drug combinations in terms of common structures. It then learns using deep learning techniques, a universal representation of these medications. When the steps taken during industrial manufacturing do not render products bioequivalent to the reference, this can enhance the safety and the efficacy of pharmaceutical therapies by designing to predict potential drug interactions and adverse medication reactions (Wang et al., 2023).

Google Deep mind in the past have proven, pharmacists now have a way to better tailor care plans because of such tools that demonstrate the ability to predict hospital readmission rates for patients with heart failure.

Patient education is essential in using AI since it can make complex advice tangible to the patient in his easier understanding. It is a mechanism of providing tailored guidance on medication use, dietary adjustments, and lifestyle changes. They have demonstrated themselves to be indispensable instruments in therapeutic drug monitoring of pharmacological therapy through their ability to continuously analyze patient data, including biomarkers. In order to enhance treatment outcome, Dosis Personalized Dosing, a platform, relies on time-sensitive patient data and recommends the most effective drug dosages based on each patient's specific reaction.

The Role of AI in Community Pharmacy

AI has the capacity to completely affect how community pharmacy adopts and complete their operations, beyond the basic duties pharmacists are accustomed to doing.

Secondly, AI is used to improve supply chain management. Using AI systems that can study a large variety of data, including historical sales, seasonality, regional health trends, and promotional activity and outside factors such as weather patterns or disease outbreaks, it can forecast ultimatum for different pharmaceuticals. If pharmacies keep the ideal inventory, they can reduce overstock and stockouts, i.e. the situations where products aren't sold and may expire before they can be sold. AI also automates the reordering procedures and to keep ideal inventory levels. The system can save staff time while ensuring that always needed pharmaceuticals are easily purchasable and generate purchase demands to replenish inventories at random based on predetermined levels and continuously monitor stock levels (Ogbuagu et al., 2023).

AI systems can also be used to assess suppliers on products quality, cost, delivery time as well dependability. By benefiting pharmacies' ability to maintain high quality inventory while lowering costs, this technology may analyze previous delivery time, cost and quality data from all sources and make the best supplier suggestion for each product.

Secondly, AI can amply improve Automated Dispensing Systems (ADSs). The accuracy and precision of dispensing can be greatly improved and the process can be optimized on an ongoing basis, including by learning from previous mistakes, with such use of machine learning algorithms. From increasing operational efficiency to quick prescription sorting, labelling and more, AI will also allow prescriptions to be quickly labelled, predict when things need maintenance and even adapt dispensing based on patient preference (Batson et al., 2021).

It creates considerable profits that come from achieving increased operational efficiency an inevitable outcome of infusing AI. Automating such routine, labour intensive tasks such as inventory management and dispensing of drugs frees up pharmacy employees to engage in higher value services, such as patient counseling and care. Examples of AI solutions that can help the patient involve themselves are chatbots and automated reminders. An example of such is an AI chatbot that provides tailored pharmaceutical info to its patients. This is to encourage the greater patient adherence (Abu-Farha et al., 2023).

AI is able to save money by preventing equipment failures, which eliminates the requirement of unplanned repairs and brings down the possibility of dispensing errors. In addition, AI increases the ease with which decisions can be made based on data. Medication safety, adherence, and patient centered treatment are one thing that cannot be overemphasized, and even more so when there is an increasing use of intricate drug regimens in the healthcare system. Drug safety ensures that patients do not get any bad drug effects such as adverse drug reaction (ADR), drug interaction or improper prescription (Ranchon et al., 2023).

The strategy will aid to improve patient engagement, care satisfaction, and health outcomes. Using AI in patients' clinical pharmacy procedures allows pharmacists to gain more knowledge of how patients respond to, accept and act upon, these treatments by fitting into patients' requirements, preferences and behaviors. In the following instance, artificial intelligence (AI) can be used for the real time monitoring of a patient's health and informed potential therapeutic modifications leading to a broader approach to introduced into these fields, thereby making pharmaceutical management more targeted, tailored, and effective, which will positively influence health outcomes of patient (Raza et al., 2022).

Personalized medicine that uses medical care to each patient with their own unique traits is gaining more and more recognition as an essential component of healthcare today and since we adapt (or personalize) medical care to each patient's unique traits, the function of AI in clinical decision support and in personalized medicine only makes sense and is highly needed. Today, prescriptive processes for medications in clinical pharmacy have been revolutionized with the development of an intelligent mix that ensures patients receive appropriate, individualized doses to their genetic profile, lifestyle, and environment, using increasingly available data driven from patients, clinicians, and as well as digital devices in patients' homes. The integration of AI into pharmacists' and other healthcare professionals' clinical decision support systems (CDSS) has completely changed the way pharmacists and medicines are being used for individualized drug therapy. This can be of patients' medical history, genomic information, AI systems use and real time health data to generate treatment plans fit for an individual patient (Nguyen et al., 2025).

Therefore, artificial intelligence (AI), for example, can review a patient's genetic variants to predict how these individuals would respond to stock pharmaceuticals. At scale, AI is able to interpret intricate genetic data and with the generation of predictions that it would be difficult for human practitioners to produce, without technological assistance, pharmacogenomics, the study of how genes relate to the way a person responds to drugs is benefiting. AI powered clinical decision support system can also deliver evidence based drug selection, dosage modification and possible drug interaction suggestions for the pharmacists. (Khan et al., 2023).

However, these technologies help people make well informed decisions which health care providers can capitalize on., AI powered clinical decision support systems may provide, and seem likely to provide, possible drug interactions. Such systems incorporate the cutting edge information relating to the progressing treatments, medication security, and clinical results, and always watch the most recent clinical studies (Khan et al., 2023).

The accuracy and precision of clinical judgments can be improved by the capacity of AI to assess multi modal data. (e.g., it allows physicians to more accurately customize medications to patients (based on imaging, lab findings and electronic health records, e.g. (integrating imaging, lab findings, and electronic health records)). Pharmacotherapy is thus improved by taking advantage of artificial intelligence (AI) to personalize medicine from a one size fits all approach to a highly specialized compound that aimed to optimize therapeutic efficacy and minimize risks (Aziz et al., 2024).

Evaluation of Inpatient Medication

Based on standard pharmacological databases, whereas search techniques by chatbots are less clinically accurate, comprehensive, secure and useful. Although the generated responses of the chatbot were as clinically correct as a medication database, the ratings for safety, usefulness, and completeness were not as high. What our results show is that artificial intelligence chat bots have to be constantly trained and upgraded to serve as part of the workflow for clinical use. Chatbots are expected to enhance quickly and chatbots may be a useful adjunct to phy neighbours in supplying prompt, trustworthy answers to questions concerning pharmacologic use (Dawoodbhoy et al., 2021).

Evaluation of Outpatient Settings

Although medications are an essential component of patient care and treatment, they can be extremely harmful if taken improperly or carelessly. Ninety percent of community patients at risk for drug mishaps had at least one medication-related issue, according to research conducted in 2004 by Roughead and colleagues. Patients may experience negative consequences including a delayed recovery or prehospitalization as a result of these issues, which may result in pharmaceutical damage. Furthermore, the costs to healthcare systems of medication-related problems are high. These expenses are thought to account for about 1% of worldwide health spending, or US$42 billion annually. It has been determined that pharmacists are the medical practitioners best equipped to minimize medication-related harm, particularly that which arises during patient care transitions (Knight et al., 2023).

Pharmacist-supported, individualized patient healthcare interventions have been demonstrated to improve insulin management and HbA1C control, as well as to raise satisfaction with patient-clinician relationships. According to this research, including an outpatient pharmacist into a multidisciplinary team that treats patients with chronic liver disease improved the identification of drug-related problems and increased the percentage of high-risk issues that were treated. According to these research and reviews, pharmacists' participation in patients' post-discharge medication management promotes patient-centered care and empowers patients to take care of their medications on their own at home (Li et al., 2021).

There is a clear need for more pharmacist integration into hospital-based clinics generally, given the encouraging patient outcomes linked to the addition of pharmacists to multidisciplinary and discipline-specific hospital outpatient teams (such as hepatology or cancer) and the increasing demand for efficient medication management of patients with complex chronic diseases. The goal of a thorough evaluation of pharmacists is to improve patient outcomes or decrease adverse pharmaceutical occurrences, but it also has a collaborative impact. The impact of bringing outpatient pharmacists to 14 clinics that had never had pharmacist involvement before was assessed using a qualitative methodology, making this study unique. By analyzing the function of pharmacists in the hospital outpatient scenario, this paper will contribute to the body of knowledge already available in pharmacy practice (Raymond et al., 2022).

In order to better understand pharmacists' and their colleagues' perspectives on pharmacists being incorporated into outpatient clinic teams, it is intended to gather important information from those who are experiencing the roles.

Automated Culture Analysis

Artificial intelligence (AI) systems can identify bacterial species by analyzing growth patterns in culture media. AI-enabled automated systems can track cultures in real time, yielding faster outcomes than conventional techniques. These algorithms are trained to recognize specific genetic markers or patterns associated with various infections. While keeping a classification sensitivity of over 95%, machine learning algorithms more especially, "Extreme Gradient Boosting" performed better than a heuristic model in lowering the burden of urine sample culture. Urine samples from expecting women, children, and further patients were best classified using three separate Extreme Gradient Boosting algorithms. This approach reduced effort by 41% and had a 95% sensitivity for each grouping (Nahar & Kachnowski, 2023).

AI is used in many forms in healthcare for example, they use ML, Deep Learning, and NLP in machine learning of microbial diseases to identify diseases. On oncology radiography and hospital labs, it already performs quite well at analysis structured data. Natural language processing pursues an analysis of the speech and the text. It is easier to create and manage Electronic Medical Records (EMRs) and detects several ailments (Rabaan et al., 2022).

Some examples of artificial intelligence applications include the development of complex algorithms for culture by specifically identifying the culture and improving culture analysis effectiveness. Automated detection of Methicillin Resistant *Staphylococcus aureus* (MRSA) and culture analysis of culture in urine sample has been made possible due to automated methods like PhenoMATRIX and the automated plate assessment system (APAS) Independence. Artificial intelligence (AI) can be used to predict the patterns of anti-bacterial susceptibility that can be used to detect and treat early drug resistant disease. Two great instances of large laboratory processes converted to include artificial intelligence (AI) are Kiestra Total Laboratory Automation (TLA) and WASP Lab, where ML algorithms use standard test results, such as urine, in order to identify positive from negative instances to identify sexually transmitted illnesses, for example trichomoniasis. The usefulness of this method primarily is in environments with constrained resources (Ghorashi et al., 2023).

The Molecular Detection or Diagnosis

AI improves the clarification of molecular diagnostic procedures like Next-Generation Sequencing (NGS) and Polymerase Chain Reaction (PCR). The intricate data produced by these methods may be processed by machine learning algorithms, resulting in more rapid and precise pathogen identification and resistance reporting. In clinical microbiology, the advent of MALDI-TOF mass spectrometry has greatly increased the speed and specificity of pathogen detection. The time required to identify infections and find important resistance determinants can be further decreased by using rapid molecular assays. Interaction between the microbiology lab and antimicrobial stewardship teams is crucial since the advantages of these technological advancements can only help patients if the results are quickly shared and evaluated by doctors (Li et al., 2024).

Antimicrobial resistance (AMR) prediction and medication discovery by analyzing microbial genomes, proteomes, and metabolic pathways, artificial intelligence makes it easier to identify potential treatment targets. By predicting the empathies for compound fastening to microbial targets, this improves the drug development process and expedites the selection of potential drugs for experimental validation. Predicting the pharmacokinetic and pharmacodynamics characteristics of medications is significantly impacted by AI. AI-powered modeling ensures the safety, effectiveness, and compatibility of clinical development while minimizing adverse responses and optimizing dosage levels. Artificial intelligence finds licensed medicines that can be used to treat microbiological disorders by using data on approved medications and their mechanisms of action. By avoiding drawn-out drug development processes, this tactic can save time (Lorkowski et al., 2024).

The problem of antibiotic resistance can be forecasted using AI by examining the genetic sequences of pathogens. By working on terabytes of genomic data and then identifying changes associated with resistance, machine learning algorithms can be useful in choosing which treatments to use and clipping the spread of resistant bacteria. With increased capacity to see, i.e. vast volumes of data, artificial intelligence (AI) in the form of deep learning and its machine learning subfield is being used to tackle the problems in the field of AMR. More recently, AI has enabled new developments in AMR such as the discovery of new AMR genes and mutations as well as made the diagnostic time scale down from days to hours. A further study focused on how segmentation of machine learning models is being utilized to predict antibiotic conflicts in basis of genome sequencing document records in the sequence primarily based diagnostic.

Learning and other AI procedures have been used to speed up the process by quickly creating and assessing lots of novel antibiotic molecule.

1. Get rid of the drug expansion in the initial stages.
2. U employ any pressured medical drugs such as discovering new improvement of propranolol
3. DL variations and combining with other methods to find new antibacterial peptides.
4. Increase the precision of distinguishing between bacteria that are resistant to antibiotics and those that are susceptible to them, which can help with clinical decision making. Predicting outbreaks and epidemiology. In order to forecast outbreaks and monitor the spread of infectious diseases, AI systems are able to analyze epidemiological data. In order to predict disease hotspots and guide public health actions, machine acquiring models can use records from multiple sources, such as social media, climate trends, and tourism logs (Aldea et al., 2024).

Measures to prevent and control infections Artificial intelligence (AI) is revolutionizing infection prevention and control (IPC) and healthcare-associated infection (HAI) surveillance. Monitoring infection patterns and assessing therapeutic choices require the use of complex dataset analysis from electronic health records (EHRs). Using deep learning on chest radiography to diagnose tuberculosis is an example of how artificial intelligence (AI) can be used to diagnose diseases with consequences for infection prevention and control (IPC). Labs use ML algorithms and AI-enhanced microscopy to provide accurate antibiotic therapy and quick diagnosis. Even though AI has the ability to significantly alter the world, there are still challenges in locating high-quality datasets for model development (Bhinder et al., 2021).

AI, however, has the ability to significantly impact the implementation of patient care and public health policy as well as improve the efficacy of infection monitoring. Management of patients Models that predict the emergence of sepsis in advance, outperforming traditional scoring techniques, highlight the important significance of AI in early indication systems for sepsis. Regular clinical parameters have been added to the algorithms, making sepsis prediction more feasible in a variety of settings. By using screening techniques that depend on big data and device learning, artificial intelligence has improved the identification of sepsis. To increase accuracy, these methods use unstructured textual data (Visan & Negut, 2024).

Conclusion

The effectiveness of artificial intelligence in treating sepsis is confirmed by empirical research, which also shows a link between early warning systems and lower death rates and shorter hospital stays. Sepsis subtyping, which entails classifying several phenotypes with various clinical traits, is another procedure that artificial intelligence (AI) helps with. AI models are used to swiftly identify common bacteria and fungi in pathogen detection and antibiotic sensitivity testing. This aids in the optimization of empirical antibiotic treatment. During the treatment of sepsis, the administration of fluids and management are guided by AI models. Urine production and fluid response during resuscitation may be predicted by these models. Individualized medical care is facilitated by the evaluation of therapy results using causal inference frameworks.

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