
Role of AI in Biomedical Research and Pharmaceutical Development

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ABSTRACT

Artificial Intelligence (AI) is rapidly transforming modern healthcare, biomedical research, and pharmaceutical development by enabling the analysis of large and complex datasets. AI technologies, including machine learning (ML), natural language processing (NLP), and generative AI, are increasingly used to accelerate drug discovery, optimize clinical trials, and support pharmaceutical innovation. These technologies assist researchers in identifying therapeutic targets, predicting drug–target interactions, performing virtual drug screening, and repurposing existing medications. AI has also played a significant role in vaccine development, particularly during the COVID-19 pandemic, by facilitating genetic sequence analysis and accelerating vaccine design. In addition, AI-driven applications improve patient engagement and treatment adherence through personalized health monitoring, automated reminders, and digital health platforms. In rehabilitation, AI-supported robotics, wearable technologies, and smart systems enhance patient recovery by monitoring movement, providing feedback, and enabling remote therapy. Furthermore, AI tools such as chatbots and digital assistants support mental health communication and patient education. Administrative healthcare processes also benefit from AI through automated data extraction, clinical documentation, and robotic process automation, which reduce workload for healthcare professionals. Despite these advantages, challenges such as data privacy, ethical concerns, technological limitations, and patient acceptance remain critical considerations. Overall, AI holds significant potential to improve healthcare outcomes, increase efficiency, and support innovation in medical research and clinical practice.

Keywords: Artificial Intelligence in Healthcare; Drug Discovery and Pharmaceutical Development; Patient Engagement and Rehabilitation

Introduction

Biomedical Research and Pharmaceutical Development

Artificial intelligence is optimally equipped to examine the extensive and intricate datasets used in medical research [1]. Furthermore, it may be used to further scientific research endeavours, amalgamates diverse data sorts, and facilitates pharmaceutical innovation. Pharmaceutical companies are concentrating on artificial intelligence to optimise medication development processes. Researchers may use predictive analytics to identify suitable candidates for clinical trials and create precise models of biological processes [2]. Machine learning enhances clinical trials during the pre-trial phase by selecting the cohort, organising participants, and collecting and analysing data. It may enhance the patient-centered perspective, generalisability, effectiveness, and success of clinical studies. Nonetheless, machine learning requires more focus on its functional and philosophical challenges in clinical trials. Alongside machine learning, natural language processing (NLP) has shown promise in improving participant management in clinical trials; nevertheless, the impact of these technologies on clinical trial quality and participant experience remains uncertain. Additional study may be undertaken to compare various techniques for enhancing participant management [4]. In clinical research, generative AI may be used to produce synthetic data, hence augmenting datasets and enhancing variety [5]. Moreover, researchers may conduct

experiments in an immersive and regulated environment using metaverse technologies. The advantage of using the metaverse is facilitating research cooperation among geographically dispersed scholars. The metaverse enables collaborative study in a virtual environment akin to that of researchers in a shared laboratory. ChatGPT, another AI-based technology, may be used in clinical trials to assist with data gathering and disseminate information on clinical studies [1]. It may assist in summarising relevant papers and identifying key findings, enabling medical researchers to effectively explore extensive online information [6]. Furthermore, a chatbot using ChatGPT assists in interpreting medical terminology for researchers in the field. However, additional ethical concerns may emerge when using chatbots in medical research [6].

Furthermore, AI tools in drug development have evolved from machine learning, bioinformatics, and cheminformatics models [7]. These technologies may significantly reduce the substantial costs and duration associated with novel medication research [98]. A prior research indicated that an AI-driven robotic scientist (Eve) executed the drug development procedure swiftly and cost-effectively [9]. In drug development, AI is mostly used to identify candidate compounds; nevertheless, it is likely that its application will evolve dynamically in the future. Numerous successful medication discoveries facilitated by AI demonstrate the capabilities of AI-driven companies to swiftly investigate drug possibilities. Toronto-based Deep Genomics used an AI workbench platform to develop a novel genetic target and the corresponding oligonucleotide therapeutic candidate DG12P1 for the treatment of a rare, hereditary variant of Wilson's illness. Moreover, identifying novel therapeutic targets is essential during drug discovery research to develop new first-in-class clinical medications [7]. AI can identify hit and lead compounds, facilitate the fast validation of therapeutic targets, and enhance the strategic design of drug structures. The capacity of AI to predict the interaction between medicines and targets was used to facilitate the repurposing of existing medications and to circumvent polypharmacology. Repurposing an existing medicine advances it to later rounds of clinical trials. Prior study indicated that ChatGPT may be used to evaluate an extensive corpus of scientific material, including patents and research articles, therefore identifying novel therapeutic targets and generating unique concepts. In drug development, it aids in training the model on an extensive corpus of scientific knowledge prior to its use in generating hypotheses or recommendations for future investigation. Additionally, AI is used for drug screening. Prior research indicated that multiple algorithms, including extreme learning machines, deep neural networks (DNNs), random forests (RF), support vector machines (SVMs), and nearest-neighbor classifiers, are utilised for virtual screening (VS) based on synthesis feasibility and for predicting *in vivo* toxicity and activity. The purpose of evaluating the proteins that comprise a virus, namely the spike protein, is Artificial Intelligence in vaccine development. An AI system can effectively categorise several components inside a complex structure to identify the one most likely to provoke a strong immune response. Moreover, the advancement of AI systems in healthcare facilitates the invention of the genetic sequences of the COVID-19 virus and its variations. It additionally, it facilitates the development of vaccines and pharmaceuticals, including medication repurposing, to acquire effective preventative and therapeutic medicines for mitigating the COVID-19 pandemic.

Patient Involvement and Adherence

Patient involvement and compliance are the last barrier in healthcare, distinguishing between favourable and unfavourable health outcomes. Non-compliance refers to a patient's failure to adhere to a prescribed treatment regimen or to take the required drugs. Patients who are significantly involved in healthcare likely have improved health outcomes, including healthcare utilisation, costs, and patient satisfaction. A poll of healthcare leaders and executives indicated that less than 50% of their patients were significantly engaged in treatment programs. Healthcare providers use clinical specialists to formulate treatment regimens aimed at enhancing patients' acute or chronic health conditions. Nonetheless, it is often inconsequential when a patient neglects to implement the necessary behavioural modifications, such as managing weight, arranging a follow-up appointment, and adhering to a treatment regimen. Such settings facilitated the adoption of AI to effectively improve patient involvement. Machine learning and workflow engines are being used to facilitate composite interventions and the continuum of care. Messaging warnings and tailored content that promote behaviour at critical periods represent a promising area of study.

Furthermore, a research indicates that using applications and online platforms that enable patient connection with healthcare professionals may enhance engagement rates by 60% or more. Healthcare applications aggregate, store, and disseminate patient data on the cloud. These applications let users to access data at any time and place, and have the potential to improve patient health outcomes. These are AI-driven applications for medical consultation that enable patients to get information (non-emergency). Some applications have been endowed with the capability to monitor patients and provide alerts for medication adherence. Moreover, ChatGPT is employed in numerous healthcare applications to automate extensive tasks such as summarisation, note-taking, and report generation, thereby enhancing efficiency and saving time. It aids patients in symptom assessment, appointment scheduling, and medication management, hence enhancing patient adherence, education, and self-management of chronic conditions.

Restoration

Artificial intelligence has groundbreaking applications in the domain of rehabilitation. It encompasses both physical (robotics) and virtual (informatics) domains. Moreover, a branch of AI termed ML pertains to specific techniques for developing algorithms that inherently improve via experience. In rehabilitation, machine learning is used for perioperative medicine, brain-computer interface technology, myoelectric control, and symbiotic neuroprosthetics, among other applications. Machine learning techniques have been used in the domain of the musculoskeletal system, such as in the assessment of patient data, clinical decision support, and diagnostic imaging. An artificial cognitive application was used in treatment to evaluate rehabilitation activities based on signals from the machine.

Technological advancements are revolutionising methodologies and skills in rehabilitation research and practice via AI and robots. Smart homes can facilitate everyday activities for inhabitants and notify careers when help is required. Moreover, intelligent mobile and wearable technologies are accessible for data collection and provide consumers insights to

evaluate health enhancement and monitor advancement towards individualised rehabilitation objectives [4]. Furthermore, inertial sensors in wearable technology may be used to ascertain if people are correctly executing and complying with training routines [1]. workout adherence was evaluated in healthy adults participating in a rotator-cuff workout program while using an Apple iWatch. Multiple supervised learning techniques were used to precisely classify workout accuracy across all algorithms [6]. A neural network achieved 99.4 percent detection accuracy, illustrating the prospective value of wearable gadgets and machine learning in exercise monitoring. Nonetheless, evaluating performance just via wearable devices may be inadequate for improving adherence due to the many challenges associated with exercise effectiveness. Supplementation- Supportive robots, both physically and socially, may assist persons in their recovery from accident or disease. These robots facilitate the bridging of gaps caused by cognitive, motor, or sensory impairments. These technologies significantly enhance individuals' functional capacity, autonomy, and overall health. Patients with musculoskeletal problems received treatment by basic mobilisation with dexterous or soft robotic hands. Nonetheless, the long-term effectiveness of this therapy remains unproven. A recent research indicates that AI-enabled robots may oversee patient movement accuracy and assist patients in executing motions effectively in the future. Healthcare professionals may bridge the disparity between the demand for rehabilitation services and the availability of qualified therapists by including an AI-driven application, ChatGPT, into rehabilitation sessions. These may provide patients an AI-enhanced approach that supplements traditional treatment. ChatGPT offers patients customised and cooperative support, therefore maintaining their engagement and interest throughout the healing process. ChatGPT may be configured to provide workout suggestions, monitor progress, and provide feedback to persons rehabilitating from physical injuries. Additionally, it may aid stroke or brain injury patients in exercising their speech and language abilities via conversational engagement. This tool is readily available via digital devices, whether at home or outside. A recent research indicated that a language model like ChatGPT was taught to revise text with a high degree of empathy. It facilitates seamless communication inside a peer-to-peer mental health support system and enhances non-expert conversational abilities. It underscores the potential of human–AI collaborations to enhance diverse community-oriented activities dependent on self- or peer-administered treatment, including cognitive behavioural therapy.

Furthermore, metaverse neurorehabilitation includes an AI-driven gross motor function classification system (GMFCS), rehabilitation materials used as rewards during therapy, virtual character mobility via weight shifting, and deep learning-based movement evaluation. The objective is to augment engagement and amusement, provide rehabilitative activities using AI, and reduce the chance of Covid-19 transmission. A recent research indicated that metaverse physiotherapy (MPT) decreased perceived COVID-19 infection and improved cardiac and gross motor performance in children with cerebral palsy compared to conventional physiotherapy. Furthermore, artificial intelligence has been used in gait analysis, whereby machine learning-based video analysis has shown that computers can automate the identification of gait abnormalities and associated pathologies in individuals with osteoarthritis and Parkinson's disease. Home-based physiotherapy may be effectively administered via counselling, real-time observation, and remote monitoring by digital therapists. A method for providing remote neurorehabilitation using digital treatments,

including minimally supervised aided therapy, to facilitate stroke patients' continuity of care from hospital to home. AI-integrated systems for remote neurorehabilitation must fulfil technical requirements, namely usefulness, safety, and robustness, since patients utilise these devices at home to address their demands. These technologies must be scalable, and their use in neurorehabilitation necessitates a clinically driven and transparent strategy for patients, their families, and healthcare professionals. This condition may bolster trust in technology-enhanced therapy inside a home setting. Moreover, these attributes are essential for securing informed consent from patients with neurological illnesses regarding technology-enhanced rehabilitation and for fostering their active participation in treatment. This technology-assisted home rehabilitation significantly influenced neurorehabilitation during and after the COVID-19 pandemic by offering extensive access to high-quality, continuous, and intensive therapy, which improved long-term functional outcomes and fostered independence and quality of life in stroke patients.

A recent review regarding sports medicine indicates that AI presents a promising opportunity for incorporation into wearable technologies. AI methodologies analysing data from sensors might track trends in physiological metrics, alongside positional and kinematic data, to suggest enhancements in athletic performance. Artificial intelligence can enhance the efficacy of injury prediction models and augment the diagnostic accuracy of risk stratification systems.

Implement a dependable method for the continuous surveillance of patient health data, hence enhancing the quality of the patient experience. Despite the advantageous uses of AI in sports medicine, certain hurdles may impede its integration into wearable devices. The issues include absent data, socioeconomic bias, data security, outliers, signal noise, and the difficulty in acquiring high-quality data using wearable technologies. Sensors that measure heart rate identify artefacts caused by arm movements during physical activities; this issue might be addressed by sophisticated sensors capable of collecting and transmitting accurate data. A significant obstacle to their implementation is patient acceptance. Prior research indicated that fifty percent of users having a wearable device ceased its usage, with one-third of them discontinuing after six months. A prior research indicated that 50% of patients saw the integration of AI in wearable technology as a substantial opportunity, while 11% regarded it as detrimental. Patients expressed concerns that the technology would abuse and misuse personal data, therefore compromising the human element of treatment. Consequently, educating patients about the role of AI in assisting doctors, as well as its capabilities and constraints, is essential to enhance the acceptance and adoption of AI.

Administrative Applications

Artificial intelligence may alleviate administrative responsibilities by autonomously filling structured data fields from therapy notes, extracting essential information from historical medical records, and aggregating recorded patient interactions. For instance, the typical nurse in the United States allocates one-fourth of their working hours to regulatory and administrative responsibilities. The time of physicians and nurses might be conserved by voice-to-text transcription. Despite the widespread use of rule-based systems linked with electronic health record (EHR) systems, they do not possess the accuracy of supplementary

algorithmic solutions grounded in machine learning (ML). Amazon is developing an advanced machine learning solution to get important insights from unstructured electronic health record data and scientific annotations. Additionally, bidirectional encoder representations from a transformer for electronic health records (BEHRT), a deep neural sequence transduction model for EHRs. The BEHRT demonstrated the capability to use diverse embeddings, including age, position, visit, and event, to delineate the patient's clinical history. It can simultaneously predict the likelihood of 301 conditions in an individual's future visits. It considerably improves the average accuracy scores across several tests in comparison to current deep EHR models. Its flexible structure allows for the integration of many ideas, including evaluation, diagnosis, and pharmaceuticals, so improving the precision of its forecasts. A recent research introduced a hierarchical BEHRT (Hi-BEHRT) model, a transformer-based architecture, for risk prediction. The research noted the superior performance of Hi-BEHRT relative to current deep-learning models in risk prediction tasks for patients with extensive clinical histories of diabetes, heart failure, stroke, and chronic kidney disease [5].

Robotic Process Automation (RPA) may be used for several healthcare purposes. These responsibilities include clinical records, revenue cycle management, claims processing, and medical record administration [6]. Moreover, healthcare organisations (HCOs) have used chatbots for telemedicine, mental health services, and patient interactions. NLP-based systems may facilitate straightforward transactions, like appointment scheduling and medication refills. In the realm of payment administration and claims, another artificial intelligence technique, machine learning, may be used to reconcile data across many websites. Insurance organisations are tasked with validating the accuracy of many claims. Inaccurate claims that go unnoticed reveal substantial financial opportunities that may be addressed by data reconciliation and claim analysis.

A hybrid machine learning-based decision support system (ML rule-based expert system) exhibited much greater accuracy in identifying prescribing mistakes within a clinical environment. A recent analysis assessed the evolution of AI tools for clinical pharmaceutical services and found that machine learning methods, particularly natural language processing and deep learning, were extensively used. The expansion of AI-driven apps and solutions for clinical pharmaceutical services is in its nascent stages. Substantial action is required.

Conclusion

Collaborated with data experts to evaluate the efficacy of these AI technologies for clinical pharmaceutical services in practical environments. Pharmacists must acknowledge these advancements to effectively use them while preserving their interpersonal ties with patients and healthcare teams.

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