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Review Article

Clinical Applications of Artificial Intelligence in Healthcare: A Brief Review

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Introduction

The healthcare industry is experiencing a technological revolution, thanks to the widespread adoption of computer information systems. These systems have significantly enhanced hospital operations, patient care, and medical research. Over the years, hospitals have increasingly relied on computers for efficient management of both administrative tasks and clinical processes. Computer information systems have greatly contributed to several essential hospital functions such as human resource management, medical care administration, and electronic patient record systems. These advancements have also facilitated the storage, retrieval, and sharing of medical data, making the entire healthcare process more streamlined, efficient, and accessible. (1,2)

One of the most significant advancements has been the use of electronic health records (EHR), which have replaced traditional paper-based records. EHRs have revolutionized how patient data is collected, organized, and shared across healthcare providers, improving not only the accuracy of records but also the quality of care. With the integration of AI and machine learning, EHRs are being optimized further to predict patient risks and outcomes, as well as guide clinical decision-making.(3)

Additionally, the role of computer systems in medical imaging has become indispensable. The application of AI and deep learning in medical imaging has enabled doctors to analyze complex images with speed and accuracy. This includes tasks such as preprocessing, pattern recognition, and image compression, which help in managing large volumes of imaging data and improving diagnostic precision. As AI continues to evolve, its applications in healthcare are expanding to encompass areas like disease prediction, treatment planning, and even the development of new drugs.

The emergence of E-health is another critical factor in the transformation of modern healthcare. By utilizing digital technologies, such as smartphones and telemedicine, E-health aims to enhance patient care and overall healthcare system efficiency. Telemedicine, which involves the remote diagnosis and treatment of patients, plays a central role in this paradigm. The combination of E-health tools, telemedicine, and Mobile Health Applications (MAS) has been a game-changer, especially in managing chronic conditions, offering healthcare services to underserved populations, and improving the accessibility of medical expertise.

Five Key Medical Applications of AI

1. Expert Systems in Medicine

Expert systems have been one of the earliest applications of AI in healthcare, designed to simulate the decision-making abilities of medical professionals. These systems leverage a knowledge base of medical expertise and inference mechanisms to diagnose diseases, recommend treatments, and provide decision support. Essentially, expert systems attempt to replicate the cognitive functions of human experts in specific domains, such as radiology, oncology, or infectious diseases.

At the heart of an expert system lies the domain knowledge base, which is a repository of structured information about a particular field of medicine. The second critical component is the inference engine, which processes the knowledge base and applies logical reasoning to make decisions based on the input data. Expert systems can be incredibly effective in providing diagnostic suggestions, identifying potential causes for medical symptoms, or determining the best course of treatment for a patient.

Several successful expert systems have been developed over the years. MYCIN(4) was one of the earliest and most influential expert systems, specifically designed for diagnosing and treating infectious blood diseases, such as bacterial infections. ONCOCIN (5)was developed for the treatment of cancer patients, and CASNET (6)was created to assist in diagnosing glaucoma. In addition, DXplain (7) is a well-known expert system that suggests a list of possible diagnoses based on a set of clinical findings, helping medical students and practitioners in their diagnostic processes. CADUCEUS (8), developed at the University of Pittsburgh, is a more advanced expert system that encompasses knowledge of over 700 diseases and provides diagnostic support for a wide range of medical conditions.(9)

Today, expert systems have evolved beyond simple diagnostic tools to become integral parts of healthcare delivery. In the UK, Babylon Health is an AI-powered online healthcare platform that allows patients to consult with doctors remotely, check their symptoms, receive medical advice, and even order test kits. Furthermore, innovative systems like Germwatcher—developed by the University of Washington—track hospital-acquired infections, enhancing infection control and improving patient safety.(10)

2. AI in Electronic Health Record (EHR) Analysis

EHRs have become a cornerstone of modern healthcare, enabling hospitals to store and manage patient information digitally. EHRs consist of structured data (such as patient demographics, diagnosis, medications, and lab results) and unstructured data (such as physician notes, radiology reports, and discharge summaries). Analyzing and processing this vast amount of data is a complex task, but AI and machine learning are making it more efficient and effective.

Recurrent Neural Networks (RNNs) are particularly effective in processing structured data within EHRs. RNNs are a type of deep learning model that excels at analyzing sequential data, such as patient health records over time. By examining these patterns, AI can predict outcomes like hypertension, heart failure, and cardiac arrest, providing valuable early warning signs and improving the proactive management of patients at risk.

For unstructured data, AI technologies such as Natural Language Processing (NLP) can be used to analyze and derive meaning from free-text entries, such as physician notes or radiology reports. NLP techniques like text summarization, sentiment analysis, and topic extraction allow for the extraction of useful insights from large volumes of unstructured medical data. This AI-driven analysis aids healthcare professionals by highlighting relevant information in patient histories, which can help guide decision-making and improve patient care.

Furthermore, AI algorithms can be employed to identify patterns in EHR data that may not be immediately visible to clinicians. For example, predictive models can analyze large datasets to identify potential risks for chronic conditions such as diabetes, heart disease, or cancer. These insights enable healthcare providers to intervene earlier and prevent the progression of these conditions.(11,12)

Despite its promise, the application of AI to EHR data is not without challenges. The data contained in EHR systems is often noisy, incomplete, and inconsistent, which can affect the accuracy of AI predictions. Additionally, ensuring interoperability across various EHR platforms is a significant challenge, as many healthcare organizations use different software systems. Overcoming these obstacles will be critical in fully realizing the potential of AI in EHR analysis.

3. AI in Drug Discovery and Development

AI is revolutionizing the drug discovery and development process, which traditionally involves multiple stages such as drug design, clinical trials, quality control, and market release. The drug development process is notoriously slow, expensive, and fraught with high failure rates. However, AI is speeding up these processes by improving the accuracy and efficiency of various stages of drug discovery.(13,14)

AI technologies, including Machine Learning (ML) and Deep Learning (DL), are used to analyze vast datasets and predict the efficacy and safety of drug candidates.(15,16) In the early stages of drug discovery, AI models can sift through large chemical databases to identify potential drug candidates. DeepChem (17), for instance, is an AI-powered tool that assists in finding promising drug molecules. By leveraging big data and predictive models, AI can uncover novel drug candidates that may have been overlooked by traditional methods.

Moreover, AI is also being used to predict the toxicity of drug molecules and assess their safety profiles. DeepTox,(18) for example, is an AI tool that predicts the toxicity of thousands of drug molecules, which can help researchers identify potential safety issues early on. This ability to predict toxicity significantly reduces the risk of failure during clinical trials, saving time and resources.

Another area where AI is making a major impact is in personalized medicine. Traditional drug development often involves creating a one-size-fits-all treatment, but with AI, healthcare providers can tailor treatments to individual patients based on their genetic makeup. By analyzing a patient's genetic data, AI can help determine the most effective therapies for that specific individual, ensuring that treatments are not only effective but also safe.

Additionally, AI can optimize the design of clinical trials, ensuring that they are more efficient and cost-effective. AI-powered simulations can predict how a drug will behave in the body and assess the likely outcomes of a clinical trial, leading to better trial designs and faster approvals.

4. AI in Medical Imaging

Medical imaging has long been a cornerstone of healthcare, helping doctors diagnose diseases by providing detailed images of the internal organs and tissues. Traditional medical imaging technologies, such as X-rays, CT scans, MRI, and PET scans, provide valuable insights into a patient's condition, but analyzing these images can be time-consuming and prone to human error. AI, particularly Deep Learning, has revolutionized the way medical images are analyzed, leading to faster and more accurate diagnoses.(19)

Deep learning models can automatically analyze medical images and identify patterns that might not be visible to the naked eye. For example, AI-powered systems have shown great success in detecting breast cancer, lung cancer, and even Alzheimer's disease from medical images. Deep learning models can also be used to identify tumors, classify lesions, and determine their severity, all of which contribute to more accurate diagnoses.

In addition to detecting diseases, AI is also used to stage diseases, such as cancer, based on imaging data. For example, AI can analyze the size and shape of a tumor from an MRI or CT scan and classify it into different stages of cancer. This staging process is crucial for determining the most appropriate treatment options and predicting the likely course of the disease.

One of the key advantages of AI in medical imaging is speed. AI can analyze images in a fraction of the time it takes a human to do so. This is especially important in emergency situations, where time is critical, and early intervention can save lives.

While AI has made tremendous strides in medical imaging, challenges remain. High-quality, annotated datasets are required to train deep learning models, and the variability of medical images across

5. Intelligent Robot Applications

Robotics is a branch of artificial intelligence. Robotic systems can be used inside the body, on the body or outside the body. Those applied inside the body include microrobots, surgical robots or interventional robots. Microrobots are very small devices that can move unimpeded through the body. They can be used for tasks such as targeted therapy or localized delivery of drugs, to assist in physical surgery by drilling through a blood clot and directed local tissue heating to destroy cancer cells. Robotic prostheses, and orthoses are examples of robotic systems worn on the body. Robotic systems applied outside the body can help to avoid direct contact when treating patients with infectious diseases and assist in remote surgical procedures [20].

Robotic Surgery: Robotic surgery (RS) or robot-assisted surgery involves minimally invasive surgery using robots. With developments of new techniques and availability of required facilities, RS enables doctors to perform complex procedures with greater precision and accuracy in many specialties like urology, gynecology, general surgery and neurosurgery. RS is becoming popular because of many benefits like smaller scar, less pain, three-dimensional view of the surgical site, quicker recovery and reduced post operative complications etc. Machine learning techniques learn from surgeon's experience and aid decision-making in real time. A clinical robotic surgical system includes a camera arm and mechanical arms with surgical instruments attached to them. The systems currently in use are not designed to act independently.

Conclusion

Artificial Intelligence has the potential to automate many tasks that require human intervention. AI with Machine Learning and Deep Learning algorithms plays important role in medical image analysis. It changed the way people process the enormous number of images. Availability of the set of medical images depends on clinical practices. Robot-assisted surgery allows doctors to perform many types of complex procedures with more precision, flexibility and control. It may be concluded that AI has great hopes and further studies are warranted to better explore the role of AI.

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