International Journal of Current Engineering and Technology
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E-ISSN 2277 – 4106, P-ISSN 2347 – 5161
Available at http://inpressco.com/category/ijcet

Review Article

A Review of Application of Artificial Intelligence in Medicine

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Received 01 Dec 2021, Accepted 05 Feb 2022, Available online 10 Feb 2022, **Vol.12, No.1 (Jan/Feb 2022)**

Abstract

Artificial intelligence (AI) in varying forms and degrees has been used to develop and advance a wide spectrum of fields, such as banking and financial markets, education, supply chains, manufacturing, retail and e-commerce, and healthcare. Artificially intelligent computer systems are used extensively in medical sciences. Common applications include diagnosing patients, end-to-end drug discovery and development, improving communication between physician and patient, transcribing medical documents, such as prescriptions, and remotely treating patients. While computer systems often execute tasks more efficiently than humans, more recently, state-of-the-art computer algorithms have achieved accuracies which are at par with human experts in the field of medical sciences. Some speculate that it is only a matter of time before humans are completely replaced in certain roles within the medical sciences. The purpose of this review is to introduce the application of AI in medicine and to provide an outlook of present and future trends.

Keywords: *Artificial Intelligence, Medical Sciences, Medicine, Application*

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1. Introduction

The concept of artificial intelligence in medicine (AIM) originated in the early 1970s [1]. It aimed to increase the efficiency of medical diagnosis and treatment with the aid of AI systems. After the 1980s, the development of AIM could be roughly divided into four stages: (1) infancy (1980s): the "decision tree" algorithm was proposed, and artificial neural networks continued to develop; (2) adolescence (1990s): "expert systems" continued to mature due to the emergence of support vector machines; (3) coming-ofage (2000s): the concept of "deep learning" was proposed, and machine learning became a prominent theme of AIM; and (4) currently, we are in the "maturation period" (2010s): as the technologies are relatively advanced. However, the ability to communicate with people still needs to be improved. Therefore, we are still in the stage of "weak" AI [2].

Artificial intelligence (AI) generally applies to computational technologies that emulate mechanisms assisted by human intelligence, such as thought, deep learning, adaptation, engagement, and sensory understanding [3, 4]. Some devices can execute a role that typically involves human interpretation and decision-making [5-6]. These techniques have an interdisciplinary approach and can be applied to different fields, such as medicine and health.

Interest and advances in medical AI applications have surged in recent years due to the substantially enhanced computing power of modern computers and the vast amount of digital data available for collection and utilization [7]. AI is gradually changing medical practice. There are several AI applications in medicine that can be used in a variety of medical fields, such as clinical, diagnostic, rehabilitative, surgical, and predictive practices. Another critical area of medicine where AI is making an impact is clinical decision-making and disease diagnosis. AI technologies can ingest, analyze, and report large volumes of data across different modalities to detect disease and guide clinical decisions [8]. AI applications can deal with the vast amount of data produced in medicine and find new information that would otherwise remain hidden in the mass of medical big data [9-11]. These technologies can also identify new drugs for health services management and patient care treatments. This article aims to present various aspects of AI as it pertains to the medicine. The article will focus on past and presents day applications in the medicine.

2. AI in Medical Diagnosis

Artificial intelligence (AI) has become synonymous with support and efficiency in the medical community. From a technology viewed with suspicion as claims touted it the replacement for the medical professional, AI has evolved to become the second pair of eyes that

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DOI: https://doi.org/10.14741/ijcet/v.12.1.1

never need to sleep. Artificial intelligence in medical diagnosis and healthcare provides overworked medical practitioners and facilities with reliable support, helping to minimize workload pressure while maximizing practitioner efficiency.

Artificial intelligence in medical diagnosis helps with medical decision making, management, automation, admin, and workflows. It can be used to diagnose cancer, triage critical findings in medical imaging, flag acute abnormalities, provide radiologists with help in prioritizing life-threatening cases, diagnose cardiac arrhythmias, predict stroke outcomes, and help with the management of chronic diseases. AI is a rich realm of data, algorithms, analytics, deep learning, neural networks and insights that's constantly growing and adapting to the needs of the healthcare industry and its patients. Over the past few years, artificial intelligence in medical diagnosis has shown immense promise in changing the standards of medical care while reducing the extreme pressures felt by the medical industry.

3. AI in Radiology

The term "use case" describes a specific clinical application of AI in radiology. Use cases can be considered as precise scenarios within the radiology service chain where automation could add significant value and establish standards. Computer-aided detection (CAD) represents the earliest clinical applications of basic AI in radiology. CAD system has been progressively implemented in radiological practice in the last two decades in the detection of lung, colon, breast, and prostate cancer, but the beginning of research in CAD, according to Kunio Doi [12], a scientist and pioneer in CAD research, can be attributed to articles published between 1963 and 1973 [13-14]. Multiple CAD applications have been reported since then, and CAD has become common in clinical practice, with the main application to the detection of lung, colon, and breast cancers [15].

The main difference between CAD and "true" AI is that CAD only makes diagnoses for which it has been specifically trained and bases its performance on a training dataset and a rigid scheme of recognition that can only be improved if more datasets are given to the CAD algorithm. True AI is characterized by the process of autonomous learning, without explicit programming of each step, based on a network of algorithms and connections, similar to what humans do.In the last decade, there has been an explosion in studies employing artificial intelligence for image interpretation that embrace disease detection and classification, organ and lesion segmentation (determining the boundaries of an organ or lesion), and assessment of response to treatment. However, it is difficult to discriminate papers related to the use of CAD and those reporting the pure application of machine or deep learning, since both terms are included in the wider term "artificial intelligence." Some of many recent applications of AI include the RSNA pediatric bone age machine learning challenge on plain radiographs breast cancer detection in mammography and MRI chest radiograph interpretation liver lesion characterization on ultrasound and CT brain tumor and prostate cancer detection [16-17].

A step beyond disease detection is disease classification into low or high risk, with good or poor prognosis. Much of the work in this field has been in brain imaging, in both benign and malignant disease. There has been considerable effort to develop AI classifiers in pediatrics, where brain mapping and functional connectivity can be linked to neurodevelopment outcome. In a study evaluating resting state-functional MRI data from 50 preterm-born infants, binary support vector machines distinguished them from term infants with 84% accuracy ($p < 0.0001$), based primarily on inter- and intra-hemispheric connections throughout the brain [18]. In multiple sclerosis, AI has been used to evaluate the performance of combinations of MRI sequences to optimize brain lesion detection. Classification of glioma grade based on MR images has been attempted with some success [19].

Automated segmentation is crucial as an AI application for reducing the burden on radiology workflow of the need to perform segmentation manually. It also provides vital information on the functional performance of tissues and organs, disease extent, and burden. Avendi et al. developed a deep learning and deformable model for left ventricular (LV) segmentation from cardiac MRI datasets, to obtain an automated calculation of clinical indices such as ventricular volume and ejection fraction [20]. Multiple studies have been published about abdominal (liver, pancreas, vessels) and pelvic (prostate) organ segmentation using a deep learning approach [21-22].

4. AI in Endoscopy

The application of AI technology in endoscopy could carry so many advantages. It can reduce inter-operator variability, enhance the accuracy of diagnosis, and help in taking on the spot rapid though accurate therapeutic decisions. Furthermore, AI would reduce the time, cost, and burden of endoscopic procedures.AI-assisted endoscopy is based on computer algorithms that perform like human brains do. They react (output) to what they receive as information (input) and what they have learned when built. The fundamental principle of this technology is "machine learning" (ML) which is a general term for teaching computer algorithms to recognize patterns in the data. It provides them the ability to automatically learn and improve from experience without being explicitly programmed. The result is AI comparable or even superior to the performance of human brains. One of the fastest-growing machine-learning methods is deep learning (DL). This approach inspired by the biological neural network of the human brain uses a layered structure of algorithms called multi-layered artificial neural networks. In addition, just like our brains do, DL models can analyze data with logic, identify patterns, draw conclusions, and make decisions. This makes DL AI far more capable than that of standard ML [23].

Gulat and Emmanuel have pointed out that endoscopy is an attractive technology for AI augmentation with immense potential; after deep learning, the AI system can significantly enhance the diagnosis of stomach and intestinal diseases, including Barrett's esophagus, squamous carcinoma, and gastric cancer, by shortening the detection time and improving the diagnostic accuracy [24]. In addition, some scholars have collected 7556 clinical images by endoscopy and then analyzed them by AI technology to provide a practical neural network algorithm to automatically detect bowel lesions; the results showed that endoscopy combined with the new AI algorithm had a higher sensitivity and more accurate localization of the bowel lesions than with the traditional model [25]. With more and more research confirming the feasibility of AI plus endoscopy in the diagnosis and classification of various diseases [26–28], there is obviously a future for this new technology.

Similar to above, the application of AI technology also raises the level of diagnosis using ultrasonography and biochemical tests. Although image-based computer aided diagnosis (CAD) systems have already been applied by doctors to diagnosis through ultrasound, the performance is largely dependent on the detection and classification methods. Combined with AI technology, methods have changed a lot. For example, Nguyen has proposed a new ultrasonographic image analysis method based on AI that successfully enhanced the consequence of thyroid nodule classification [29]. Other scholars have also confirmed that the use of AI can promote the traditional ultrasonographic detection of tumors in the thyroid, breast, bronchia, puborectalis muscle, and urogenital hiatus as well as other obstetric and gynecological lesions, with a high efficiency and accuracy [30–34].

5. AI in Pathology

As in other domains, artificial intelligence is becoming increasingly important in medicine. In particular, deep learning-based pattern recognition methods can advance the field of pathology by incorporating clinical, radiologic, and genomic data to accurately diagnose diseases and predict patient prognoses.Microscopic morphology remains the gold standard in diagnostic pathology, but the main limitation to morphologic diagnosis is diagnostic variability in bearing error among pathologists.

Table 1. List of research works in applications of artificial intelligence to image analysis based pathology

Garud et al. (2017) [38]	Breast cancer	FNA cytology/175 (images)	Decision Benign/cancer	CNN	None	Image level decision acc. 89.7%
Li and Ping (2018) [39]	Lymph node metastasis	CAMELYON16/400 (WSIs)	Decision Yes/no	CNN + CRF	Color jitter, rotation, etc.	Patch level decision acc. 93.8%
RannenTriki et al. (2018) [40]	Breast cancer	Frozen section OCT/4,921 (frames)	Decision Benign/cancer	CNN	None	Patch level decision acc. 94.96%
EhteshamiBejnordi et al. (2018) [41]	Breast cancer	BREAST Stamp/2,387 (WSIs)	Decision Benign/cancer	CNN + CNN	None	WSI level decision AUC 0.962
Litjens et al. (2016) [42]	Lymph node metastasis	Lymph node specimen/271 (samples)	Decision Yes/no	CNN	None	Sample level decision AUC 0.90
Cires¸ an et al. (2013) [43]	Breast cancer	MITOS/300 mitosis in 50 images	Mitosis detection	CNN	Rotation, flip, etc.	Detection F1-score 0.782
Teramoto et al. (2017) [44]	Lung cancer	FNA cytology/298 (images)	Classification	CNN	Rotation, flip, etc.	Overall classification acc. 71.1%

The Gleason grading system is one of the most important prognostic factors in prostate cancer. However, significant interobserver variability has been reported when pathologists have used the Gleason grading system [35-36]. In order to get a consistent and possibly more accurate diagnosis, it is natural to introduce algorithmic intelligence in the pathology domain, at least in the morphological analysis of tissues and cells. With the help of digital pathology equipment varying from microscopic cameras to whole slide imaging scanners, morphology-based automated pathologic diagnosis has become a reality. In this review, we focus on morphology-based pathology: diagnosis and prognosis based on the qualitative and quantitative assessment of pathology images. Typical digital image analysis tasks in diagnostic pathology involve segmentation, detection, and classification, as well as quantification and grading [37]. We briefly introduce typical techniques used for AI in digital pathology and a few notable research studies per disease. The list of studies reviewed in this paper is given in Table 1.

6. AI in Drug Production

Artificial intelligence in Pharma refers to the use of automated algorithms to perform tasks which traditionally rely on human intelligence. Over the last five years, the use of artificial intelligence in the pharma and biotech industry has redefined how scientists develop new drugs, tackle disease, and more.

The MLP network has applications including pattern recognition, optimization aids, process identification, and controls, are usually trained by supervised training procedures operating in a single direction only, and can be used as universal pattern classifiers [45]. RNNs are networks with a closed-loop, having the capability to memorize and store information, such as Boltzmann constants and Hopfield networks [45-46]. CNNs are a series of dynamic systems with local connections, characterized by its topology, and have use in image and video processing, biological system modeling, processing complex brain functions, pattern recognition, and sophisticated signal processing [47]. The more complex forms include Kohonen networks, RBF networks, LVQ networks, counter-propagation networks, and ADALINE networks [45]. Examples of method domains of AI are summarized in Figure 1.Several tools have been developed based on the networks that form the core architecture of AI systems.

One such tool developed using AI technology is the International Business Machine (IBM) Watson supercomputer (IBM, New York, USA). It was designed to assist in the analysis of a patient's medical information and its correlation with a vast database, resulting in suggesting treatment strategies for cancer. This system can also be used for the rapid detection of diseases. This was demonstrated by its ability to detect breast cancer in only 60 s [48-49].The vast chemical space, comprising >1060 molecules, fosters the development of a large number of drug molecules [50]. However, the lack of advanced technologies limits the drug development process, making it a time-consuming and expensive task, which can be addressed by using AI [49]. AI can recognize hit and lead compounds, and provide a quicker validation of the drug target and optimization of the drug structure design [50-51].

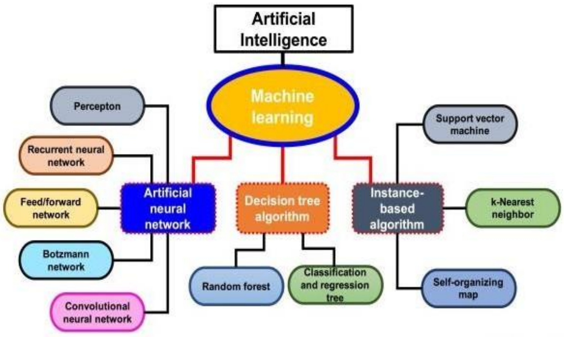

Figure 1 Method domains of artificial intelligence (AI). This figure shows different AI method domains along with their subfields that can be implemented in different fields drug discovery and development.

Table 2. Examples of AI tools used in drug discovery

Tools	Details	Website URL	Refs
DeepChem	MLP model that uses a python-based AI system to find a suitable candidate in drug discovery	https://github.com/deepchem/deepchem	[52]
DeepTox	Software that predicts the toxicity of total of 12 000 drugs	www.bioinf.jku.at/research/DeepTox	[53]
DeepNeuralNetQSAR	Python-based system driven by computational tools that aid detection of the molecular activity of compounds	https://github.com/Merck/DeepNeuralNet-QSAR	[54]
ORGANIC	A molecular generation tool that helps to create molecules with desired properties	https://github.com/aspuru-guzik-group/ORGANIC	[55]
PotentialNet	Uses NNs to predict binding affinity of ligands	https://pubs.acs.org/doi/full/10.1021/acscentsci.8b00507	[56]

7. AI in Medical Education

AI could help physicians by amalgamating large amounts of data and complementing their decision-making process to identify diagnosis and recommend treatments. Physicians in turn need the ability to interpret the results and communicate a recommendation to the patient.Physicians go through extensive periods of training before they can eventually register as specialists. Although medicine has seen major changes over the last decades, medical education is still largely based on traditional curricula [57]. The specific length of training differs between countries, but the core competencies of these curricula are globally similar [58]. After a core phase of preclinical didactics, training is mostly centered around practice-based learning [54]. Medical education is often based on 6 domains: patient care, medical knowledge, interpersonal and communication skills, practice-based learning and improvement, professionalism, and systems-based practice [59]. These fields were introduced by the Accreditation Council for Graduating Medical Education (ACGME). A large part of medical training focuses on consuming as much information as possible and learning how to apply this knowledge to patient care. This process is still largely memorization based [49]. Less time is spent on familiarizing medical students or residents with new technologies such as AI, mobile health care applications, and telemedicine [59-60]. In the United States, USMLE does not test on these subjects [61]. However, change seems inevitable since the 2018 annual meeting of the American Medical Association (AMA) saw the adoption of AMA's first policy on augmented intelligence, encouraging research into how AI should be addressed in medical education [62]. In Table 1, several initiatives for incorporating AI in medical education are shown, as presented by the AMA [62].

Table 3. Initiatives for artificial intelligence in medical education

Institution	Project
Duke Institute for Health Innovation	Medical students work together with data experts to develop care-enhanced technologies made for physicians
University of Florida	Radiology residents work with a technology-based company to develop computer-aided detection for mammography
Carle Illinois College of Medicine	Offers a course by a scientist, clinical scientist, and engineer to learn about new technologies
Sharon Lund Medical Intelligence and Innovation Institute	Organizes a summer course on all new technologies in health care, open to medical students
Stanford University Center for Artificial Intelligence in Medicine and Imaging	Involves graduate and postgraduate students in solving heath care problems with the use of machine learning
University of Virginia Center for Engineering in Medicine	Involves medical students in the engineering labs to create innovative ideas in health care

8. AI in Coronavirus Research

During the current global public health emergency caused by novel corona virus disease 19 (COVID-19), researchers and medical experts started working day and night to search for new technologies to mitigate the COVID-19 pandemic. Recent studies have shown that artificial intelligence (AI) has been successfully employed in the health sector for various healthcare procedures. In the race to control the spread of COVID-19, AI was used to work as human intelligence in order to address the following: early detection and diagnosis, treatment monitoring, contact tracing, prediction of cases and mortality, development of drugs and vaccines, medical workload reduction, and disease prevention [63]. During the fight against COVID-19, due to the fact that the quantification and localization of pulmonary lung CT data cannot be accurately and efficiently evaluated, Zhang developed a new system based on deep learning to analyze the CT data of patients and concluded that the right lower lobe of the lung is the high occurrence area of COVID-19 pneumonia [64]. In addition, Aikateriniapplied an AI machine learning algorithm in the analysis of COVID-19 CT scans, and their findings indicated that the algorithm could promote earlier detection and medical care [65]. Moreover, Tivani proposed pointof-care diagnostic services that blended radiology pathology, and artificial intelligence all together, further assisting the diagnosis of COVID-19 [66]. Additionally, Sweta performed a quick intelligent screening for potential drugs to treat COVID-19 with a drugrepositioning method; this group was able to quickly detect drugs that may be useful by using both AI- and pharmacology-based methods, thus demonstrating that this method could be helpful for COVID-19 drug design and research [67]. This method also has been confirmed by other scholars, who established a platform based on AI learning and prediction models to identify the drugs on the market with a possibility for treating COVID-19; as a result, they found more than 80 drugs with great potential [68]. Furthermore, there has been much research on AI algorithm assistance, which pushed the quick development of COVID-19 vaccines [69–71].

9. Future of AI

Artificial intelligence is impacting the future of virtually every industry and every human being. Artificial intelligence has acted as the main driver of patient diagnosis using radiological, pathological, endoscopic, ultrasonographic, and biochemical examinations, and it will continue to act as a technological innovator for the foreseeable future. In addition, AI technology also has played a crucial role in medical drug production, medical management, and medical education, taking them into a new direction. Artificial intelligence (AI) is transforming the way we interact, consume information, and obtain goods and services across industries. In health care, AI is already changing the patient experience, how clinicians practice medicine, and how the pharmaceutical industry operates. The journey has just begun. The future of AI in health care could include tasks that range from simple to complex—everything from answering the phone to medical record review, population health trending and analytics, therapeutic drug and device design, reading radiology images, making clinical diagnoses and treatment plans, and even talking with patients.

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