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New Opportunities and Challenges for Health Professionals in the era of Artificial Intelligence – Review

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Summary

Introduction and purpose: Modern medical knowledge has grown to a vastness incomprehensible for a single health professional to learn and accommodate. The usage of modern information technologies comes to help, one of them being artificial intelligence, a branch of computer science aimed at developing solutions to perform tasks similar to the human brain, but more efficient and complex, without actual human intervention. The goal of this review is to provide reader with the knowledge how artificial intelligence is applied in various branches of medicine.

Brief description of the state of knowledge: In the fields of infectious diseases, including COVID-19 diagnostics, radiology, dermatology and surgery, works lean toward the statement, which suspect application of AI is beneficial for medical practitioners. Programs help to develop statistical models for virus spreading and the creation of antiviral solutions. The radiological application involves the analysis of images to aid radiologists in diagnosing certain features, similarly to dermatology, where eg. AI can identify malignancy of skin nevi. In the department of surgery, predictive algorithms can help in choosing operation methods and improve outcomes.

Conclusions: Usage of AI assistance in the medical field has proven to be successful, but it is yet to be commonly encountered in everyday work. Programs need to be further developed and made more approachable to users without expertise in the IT field. AI may also prove useful in the process of education of health professionals.

Keywords: artificial intelligence; infectious diseases; radiology; dermatology; surgery; health

Introduction

The term artificial intelligence (AI) first appeared in 1955 and was described as a machine trying to mimic human cognitive capabilities [1], but in modern terms, scientists define it as "thinking humanly and acting rationally". Programs are able to perform similar tasks to a human brain without human intervention, but most of the time more efficient if built correctly and fed an appropriate amount of data [2]. Since its introduction, AI has made significant progress, allowing programs to automatically analyze, explain and represent complicated data, and using the computational power of modern personal computers it can be applied locally, without a need to rent or buy expensive workstations and server clusters [3]. Algorithms process the amount of data, beyond scope of human capabilities, can discover important information from data and assist in making clinical decisions, reducing the chance of potential man-made errors. [4].

The purpose of this review is to familiarize the reader with the application of artificial intelligence technology in chosen fields of medicine.

Infectious Diseases

Artificial intelligence is used in the field of infectious diseases. It can be applied for early detection and diagnosis of the infection, projection of morbidity and mortality rates, contact tracing and modeling vaccine and drug response [5].

Modeling the antigenic variation of viruses can improve the prediction adequacy of immune efficacy of vaccines as well as increase vaccine screening efficiency. A deep learning approach containing bidirectional long-short-term memory neural network and a convolutional neural network has been applied to model an antigenic variation in the influenza A virus, which has shown 99.20% of efficacy in predicting the strains in the forthcoming year [6].

In the case of norovirus infection, the management measures most of which rely more on prevention than treatment, data mining technology based on the wavelet transform AI algorithm was used to identify the at-risk group. Such findings can be implemented to protect patients prone to infection and as a result, reduce the clinical infection rate of the virus [7].

Moreover, machine learning (ML) methods may have the ability to help improve the development and optimize viral clearance unit operations for new therapeutic antibodies [8]. The application of artificial intelligence-based algorithms in drug repositioning may be crucial for predicting drug-target interactions, allowing to eliminate the need of extensive, resource-consuming in-vitro research [9]. Furthermore, another vital application of AI is creating a disease transmission model. A divide-and-conquer algorithm has been used to predict associations between known viruses and potential mammalian species. The results showed that there is a significant underestimation in the number of associations in wild and domesticated mammals by a factor of 4.3, and the average potential mammalian host-range of viruses by a factor of 3.2. This indicates the existence of a knowledge gap regarding reservoirs and the potential for transmission of zoonotic and domesticated mammals' viruses [10].

The identification of factors conducive to spreading the pathogen has proved to be useful in the case of the COVID-19 pandemic crisis as well. A deep learning method has been used for forecasting the risk of COVID-19 infection and has shown relatively high efficacy in predicting future COVID-19 cases [11]. Moreover, the use of machine learning algorithms has enabled to develop HealthMap and BlueDot, both of which can predict the outbreak of the virus with great efficiency [12]. The diagnosis of COVID-19 relies mostly on real-time reverse-transcription polymerase chain reaction (RT-PCR), however this technique has shown to have much lower sensitivity (71%-80%) than the 3D deep-learning framework developed specifically for the detection of COVID-19 (known as COVNet) by examination of the chest x-ray and computed tomography (CT) scan images of patients, accurately distinguishing patients with COVID-19 from patients with non-COVID-19 community-acquired pneumonia. COVNet is able to process each CT scan in under 5 seconds with 90% sensitivity and 96% specificity for COVID-19 identification [12], [13]. Moreover, another deep learning diagnostic system is used to identify features of COVID-19 infection in CT scans of individuals with false-negative RT-PCR results. [13] Although artificial intelligence is still in its initial stages when it comes to the discovery of new therapies, in silico screening with AI can allow the identification of potentially effective therapeutic agents among already existing drugs. Molecule transformer-drug target interaction (MT-DTI) is a type of natural language processing (NLP) tool. It has been used to predict binding affinity values between available antiviral drugs and target proteins on SARS-CoV-2. This allowed the identification of atazanavir, an antiretroviral medication, which may be effective in the treatment of SARS-CoV-2. [13] Artificial intelligence and machine learning are able to identify viral proteins of SARS-CoV-2 for drug development, hence supporting the development of vaccines and medications [14].

Radiology

AI solutions are emerging in radiology as well. The constant need for automatization and misdiagnosis reduction is growing, inducing engineers and scientists to develop more and more complex and reliable applications. Though the primary function of AI is to support radiologists during image evaluation and making a diagnosis, future solutions may be advanced enough to work independently [15]. Presently AI is used mainly in three major domains, including diagnostic AI, predictive AI, and operational AI [16].

Diagnostic AI is the most common feature used in AI solutions implemented in radiology, being offered in 79% of studied applications [17]. A major impact of AI can be majorly seen in the automated detection of findings. Machine learning solutions enable displaying or highlighting relevant findings and supporting radiologists in image evaluation [18]. They can produce automatically generated reports with natural language processing as well [19]. Moreover, AI can be used to boost an imaging process, decreasing the imaging time and improving the positioning and the quality of images. Furthermore, automated solutions can help with the interpretation of images, suggesting a diagnosis based on the predictive models [18]. Such tools can improve interpretation reliability, decreasing incorrectly detected findings (false positives) [15]. However, maintaining a high level of the machine learning interpretation is crucial, especially for static models, which have been shown to deteriorate after ca. 8 months. Static AI models are not designed to correctly reply to real-time changes in the imaging environment, becoming significantly inaccurate over time. This phenomenon is induced by picked data-sets used for machine learning and a lack of scientists' knowledge of image processing and scanning protocols. To overcome this problem, a continuous data stream in real-time should be used, replacing static models with continuous learning AI [16].

Predictive AI can be also implemented to predict disease outcome and response to the treatment using radiology AI-enabled biomarkers. Such solutions are the most addressed to oncological patients, as determining the risk profile based on the tumor characteristic can be beneficial for their treatment [20]. Machine learning models can be taught in order to develop radiomics-derived prognostic scales for numerous tumors [21]. These AI solutions can be based on various radiological factors, including intensity-based measures, subvisual heterogeneity and texture, shape and volumetric features as well as tumor microenvironment and vascularity radiomics [20].

Operational AI focuses on optimizing patient scheduling, reducing delays, and therefore contributing to enhanced patient satisfaction. Though only 3% of AI solutions address the operational and administrative tasks, studies have shown that predicting waiting times and proper scheduling is an important factor in patients' contentment [17]. An analysis of ultrasound, radiography, CT and MRI delays has proved that machine learning solutions such as elastic nets, which are simple regularization algorithms based on an ordinary linear regression model, are the best in delay prediction [22].

Dermatology

Artificial intelligence is gaining increasing importance in dermatology, and the latest research shows that accuracy matches or even exceeds dermatologists' ability to diagnose skin lesions from clinical and dermoscopic images. Several artificial intelligence studies are already focusing on differentiating benign and malignant pigmented lesions, improving the diagnosis of psoriasis and other inflammatory skin diseases.

Previous studies illustrated that AI can distinguish between benign nevi vs. melanoma using individual pixels from dermatoscopic and non-dermatoscopic images [23], [24], [33], [34], [25]–[32].

A further study by Jutzi et al. [35] assessed patients' attitudes toward AI. It demonstrated that most respondents supported using AI, mainly to help detect melanoma early at home. Nevertheless, potential errors, poor quality of analyzed photos, and insufficient protection of AI data still stand as significant barriers. Lately, machine learning and convolutional neural network (CNN) models have been found to classify melanoma on histopathological or clinical images with exceedingly high diagnostic accuracies and sensitivities [36]–[38]. ML models using factual data, including more racially diverse datasets, are being trained, increasing the availability of artificial intelligence in remote health care facilities with limited resources [36], [39]. Some authors noted the usefulness and accuracy of smartphone applications that classify the risk of photographed lesions or detect malignant / pre-neoplastic changes on histopathological images [39], [40].

One investigation examined the correlation between dermatoscopic and reflectance confocal microscopy (RCM) observations and the histologic classification of melanocytic lesions with peripheral globules [41]. They discovered that dermoscopy and RCM correctly identified 84.21% of dysplastic nevi and 100% of melanomas. The size and shape of peripheral globules and cancerous RCM features like pagetoid cells, non-edged papillae, atypical junctional thickenings, and atypical cells at the dermal-epidermal junction, dysplastic nevi, and melanocytic lesions differ significantly from one another. Additionally, it has been demonstrated that a top-ranked computer algorithm has greater specificity than dermatologists in classifying photos of melanomas, nevi, and seborrheic keratoses (85.0 vs. 72.6%) [42]. As a result, AI can accurately distinguish skin pictures of melanoma and its benign imitators. Despite all of this promising research, an oncologic transformation of nevi cannot be predicted by doctors or AI, despite the increasing accuracy of diagnosing melanomas [43]. This is because some melanocytic nevi, such as dysplastic or spitzoid nevi, are static on clinical presentation and there isn't enough data to train AI on their progression. Understanding how AI may follow the progression of dysplastic nevi requires more research.

According to a review by Du et al. [44], ML can predict the clinical results and prognosis of several dermatoses such as non-melanoma skin cancer, psoriasis, and chronic venous ulcers. Larger sample sizes of data would allow ML algorithms to give reliable results; nevertheless, this may be a limitation as they must acquire substantial dermatologic data sets through national and international cooperation between registries. The authors emphasize the necessity for prospective clinical studies to verify the use of ML models to predict outcomes.

Recently, an ML model accurately predicted the Dermatology Quality of Life Index for psoriasis patients stopping risankizumab [45], a similar ML technology was used to build a highly effective biomarker for predicting the progression of alopecia areata to alopecia totalis or alopecia universalis [46]. Furthermore, a multicenter prospective open-label pilot study was lately conducted referring to treating psoriatic patients with secukinumab. A prediction model was created using the clinical characteristics of patients, reaching a 91.88% success rate in correctly forecasting respondents and nonresponders [47].

Although AI has several uses in dermatology, certain obstacles limit its widespread use, including generalizability, standardization, and interpretability [23], [35], [44]. Most original research studies in AI have not studied the applications in large-scale clinical trials. Further, high-quality clinical trials are required to support the application of AI in the dermatological field.

Surgery

There is no doubt that artificial intelligence opens up many new possibilities in the field of surgery. There are many indications that in a few years AI will be able to revolutionize the science and practice of surgery, leading to a colossal improvement in the quality of patient care.

In their daily work, surgeons make many risky decisions, and they report that the most common causes of serious errors are diagnostic mistakes. Traditional clinical decision-making tools exist, but they are inaccurate and the retrieval of data is tedious and time-consuming [48]. For this reason, there is a high degree of likelihood that the commonly used artificial intelligence will initially focus on significantly improving the performance of doctors, by assisting in making the right clinical decisions. In the future, the surgeon will be able to perform a comprehensive operational risk assessment based on data collected from the patient in a mobile application. The patient will complete data such as glucose level, consumed meals, physical activity and weight, which will be sent to the electronic medical record (EMR). With the participation of artificial intelligence, it will allow for automated analysis of population data and specific patients. As a result, it will be possible to precisely determine the degree of risk when planning an operation, detect comorbidities as well as provide relevant information in the field of postoperative care. Additionally, it will be helpful in making decisions during surgery, due to the analysis of intraoperative progress integrated with EMR data, symptoms and electrosurgical energy consumption. This can be significant in avoiding adverse events and faster anticipation of processes taking place during operations. The combination of data from before, after, and during the procedure will improve the recovery process as well as predict and prevent complications. This enables care that is individually tailored to the needs of the patient [49], [50].

It should be emphasized that one of the domains of AI - machine learning algorithms in bariatric surgery have shown particularly promising possibilities. Most of the ML algorithms used were able to predict weight loss along with surgical complications with an accuracy of 98% [51]. Machine learning has also found application in the preoperative assessment of lymph node metastases in patients with colorectal cancer, which is of key importance in the treatment of this cancer. The clinical model had a diagnostic accuracy of 64.87%. Importantly, the diagnostic efficiency of the radiometric model was significantly higher than that of the clinical models [52].

In addition to the key role of artificial intelligence in planning and decision-making, its application in the field of surgical techniques should be mentioned. It has been shown that remote control robotic surgery not only increases the safety of the procedure but also allows operations to be performed in places anatomically inaccessible to the doctor's hands. It is very likely that in the future, doctors will only supervise robots in surgical operations [53].

Conclusion

We can share the optimism that AI technology will find application in various fields of medicine. Difficulties that need to be overcome are in sociological and applicative aspects. Many medical professionals are still afraid that software is going to replace them, while most currently developed commercial solutions are aimed to ease and increase the effectiveness of work. From the user point of view, having an approachable and simple interface, that could be used without or with a minimal amount of training is one of the most important things.

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