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The role of artificial intelligence in cancer diagnostics - a review

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Abstract
Introduction and purpose

Artificial intelligence (AI) is more advanced than ever and finds more and more new applications. Attempts are being made to use computer data analysis in medicine. The aim of this study is to summarize the knowledge on the use of AI in the diagnosis of breast, prostate, skin and colorectal cancer with particular emphasis on the applications and effectiveness of AI in making diagnoses.

A brief description of the state of knowledge

The most frequently used form of artificial intelligence in diagnostics are algorithms that analyze databases and recognize patterns. They can capture the features of samples characteristic of tumors, such as abnormal cells in the biopsy material or the alarming size and color of the skin lesion. Additionally, AI is capable of analyzing magnetic resonance images, radiographs, and other standardized test results. In most cases, AI is more effective than clinicians, sometimes as effective as they are, and almost never less effective. As a rule, the most accurate and adequate diagnosis can be obtained by joining the forces of AI and medical specialists. Working with learning algorithms requires the use of very extensive data sets. Every effort should be made to protect sensitive information from patients' medical history.

Conclusions

The results of research on the effectiveness of AI in cancer diagnostics are very promising. Further research and development of information technology systems may positively affect the quality and effectiveness of tumor diagnostics.

Key words: artificial intelligence; breast cancer; prostate cancer; skin cancer; melanoma; colorectal cancer

Introduction and purpose

Computers play an increasingly important role not only in our everyday life, but also in medicine and related fields. Their appearance allowed for a significant improvement in the functioning of hospitals and the implementation of better methods of diagnosis and treatment. We are currently on the doorstep of another revolution. Artificial intelligence (AI) is defined as the ability of a system to correctly interpret data from external sources, learn from them and use this knowledge to perform specific tasks and achieve goals through flexible adaptation [1]. This type of action, very similar to how the human mind works, can find a wide range of applications in diagnostics.

Cancer is a heterogeneous group of diseases with an often aggressive course and a low cure rate. They affect most parts of the body, especially those with clusters of intensely dividing cells (glands, skin). The key to effective therapy is early diagnosis of the lesion, which is often hampered by the presence of non-specific symptoms [2].

The aim of this study is to describe the applications of artificial intelligence in the diagnosis of cancer, in particular breast, prostate, skin and colorectal cancer. Attention is paid to the ways of using AI in cancer diagnostics and its effectiveness compared to classical clinical diagnostics.

Description of the state of knowledge

Methods, effectiveness and moral objections

Progressive technological development has contributed to the creation of more accurate methods of imaging and laboratory diagnostics. Currently, there are attempts to use artificial intelligence and machine learning in the diagnosis of various diseases, including COVID-19 [3-5], Alzheimer's disease [6,7] and cancer [8-10]. For this to be possible, the algorithms must be properly adapted to the analysis of epidemiological data, the patient's medical history or the results of ones tests. This enables AI to look for patterns and point to the most likely diagnosis. An example is the diagnosis of Alzhiemer's disease. Its diagnosis is based on clinical evaluation, brain radiation imaging, analysis of the patient's medical history and family history [11]. One of the studies showed that the use of the algorithm of this language analysis used by patients enables the diagnosis to be made with 74% efficiency, even several years before the onset of symptoms [12].

Artificial intelligence can also be used to analyze radiographs. To make it possible, the program must be provided with a certain number of radiological images compiled with the results of patient examinations. Over time, the algorithm "learns" and begins to notice certain features of radiographs that are characteristic of people with a given disease. After some time, it is able to analyze the photos and recognize if there are any disturbing changes that may suggest a disease [4, 13].

Research on the effectiveness of artificial intelligence shows that when properly used, it achieves similar or better effects than experienced specialists [14]. Additionally, AI requires much less time for data analysis than a human [15], which shortens the diagnostic process.

In any discussion about the use of artificial intelligence, ethical questions and doubts also arise. Even when it is outperformed by clinicians, AI will continue to make mistakes and misdiagnose. This raises the question of who will be responsible for these mistakes - the person responsible for creating the algorithm, the person supervising its operation or the one who approved the AI in the diagnostic process [16]. Attention is drawn to the need to protect patients' personal data and their medical history - sensitive data necessary for the proper functioning of AI - and to respect the patient's privacy and will, including the right to refuse to diagnose with the help of an algorithm [17].

Breast cancer

Breast cancer is second most frequent cancer and ranks the second as cause of death among women around the world [18]. The earliest signs of breast cancer are usually invisible and easily overlooked, so the screening methods like mammography and ultrasound must be performed regularly. There is no doubt that image-based diagnosis has some restrictions like the presence of noise in images, inadequate clarity, poor contrast and radiologist’s competencies like visual perception ability or experience [19] Maybe, the AI could help in breast cancer diagnosis and make it more accurate and quicker.

Comparing an ability to diagnose lesions by radiologists and AI, it was observed, that AI system showed better diagnostic results than human readers. In this study, the lesions of maximum intensity projection (MIP) in dynamic contrast-enhanced (DCE) breast magnetic resonance imaging (MRI) were evaluated. The AI system calculated the possibilities of malignancy using RetinaNet, while radiologist’s task was to classified the lesions as benign or malignant. 13 normal, 20 benign and 52 malignant cases were classified. The AI achieved the highest scores in terms of sensitivity, specificity, and area under the receiver operating characteristic curve (AUC) and they were 0.926, 0.828 and 0.925, respectively. In comparison, human readers without AI – 0.847, 0.841 and 0.884 and human readers with AI using – 0.889, 0.823 and 0.899 [20].

AI system may be useful not only in MRI evaluation, but also in ultrasound images classification. In the Quan Xia research, they compared breast lesions classification in the system recommended by the American Society of Radiology (BI-RADS) for each breast mass evaluated by doctor and AI. AI had high sensitivity – 95.8%, specificity – 93.8%, and accuracy – 89.6%, while senior doctors reached lower scores – 79.2%, 81.3% and 60.5%, respectively (Junior doctor: 75.0%, 68.8%, 43.8%). The highest effectiveness was achieved due to the help of AI in senior doctor’s work, because sensitivity was 100% and others, specificity – 93.8% and accuracy – 93.8%. The AI, in this research, diagnosed lesions better than doctors and improved the quality of breast cancer ultrasound diagnosis by physicians [21].

Prostate cancer

Prostate cancer (PCa) as one of the most frequent cancers in male population [22] poses a number of diagnostic difficulties, in managing of which AI may constitute a great contribution. Even though the 2020 EAU-EANM-ESTRO-ESUR-SIOG Guidelines on Prostate Cancer [23] recommend the use of multiparametric magnetic resonance imaging (mpMRI) – guided biopsies, which are superior to previously used transrectal ultrasonography-guided biopsies in both sensitivity and specificity, especially the specificity of up to 81% is thought to be possible to further increase [24]. The rise in detectability of clinically insignificant, indolent lesions is considered crucial to decrease the amount of unnecessarily performed biopsies. In the use of MRI-based diagnosis, AI is currently utilised for the lesion detection, localisation and the assessment of its aggressiveness. AI systems are sustainable to process biopsy images as well, including differentiation between PCa and benign prostatic hyperplasia (BPH), Gleason grading, local staging, or even the prediction of recurrence. Important problem possible to solve with the implementation of AI is the lack of the diagnosis reproducibility, common due to differing level of pathologists’ experience [25].

Syer et al. in their 2021 systematic review included data from 27 studies that met the following criteria: PCa detection/classification evaluation of AI system, comparison of its efficacy with radiologist's against histopathological diagnosis reference, patients were not treated for PCa before, and the full text was available. The studies with cohorts of less than 30 patients were not included, as well as the ones with incomplete information given to the radiologists (eg. only one sequence). A number of studies reported superiority of AI diagnostic capabilities comparing to radiologist, although majority of them were performed on the data small, internal patient groups. Evaluation of the studies on larger, external datasets didn't show that supremacy. Data synthesis of the review resulted in a report of insufficient evidence for the AI efficacy in that matter and lack of justification for its clinical deployment at present [26]. The use of AI for histopathological diagnosis although less tested, have had far more promising results. First, promising attempts of cancer detection was started by Litjens et al. in 2016 on small datasets [27], but in 2019 Campanella et al. evaluated the possible utility of deep learning system in cancer detection of 15178 patients, basing on 44732 slide images of core needle biopsies [28]. As calculated by Perincheri et al. in their validation study, the algorithm developed by Campanella et al. had sensitivity of 97,7% and specificity of 99,3% [29]. Further research showed the AI efficacy in distinguishing between benign and malignant cores, or Gleason grading – the results achieved by the system in Strom et al. study were comparable to ones assessed by international expert pathologists [30]. The AI-based algorithm of Pantanowitz et al. was tested in similar conditions, which resulted in it's high efficacy and successful validation and clinical deployment [31]. The AI-based analysis of biopsy slides in case of PCa seem to have far more potential than radio imaging-based algorithms, although further advances are sought to be made, for example frozen section analysis, or intraoperative histological examination.

Skin cancer

Developing artificial intelligence based diagnostic methods has become a trend in diagnostics of melanoma and skin cancer. According to Skin Cancer Foundation data, the global incidence of skin cancer is increasing annually [32]. There is significant variation in incidence around the world, with the highest rates in Australia (37 cases per 100,000) and the lowest in South-Central Asia (0.2 per 100,000) [33]. The gold standard for melanoma and skin cancer diagnosis is histopathological assessment.

Convolutional neural networks (CNN) are an example of using AI in melanoma and skin cancer diagnostics. CNN are supervised and trained to analyze visual aspects of skin lesions, such as diameter, shapes, colors, patterns etc. CNN during their training phase need guidance with verified diagnosis of every image they learn. Therefore, the main issue of effectively using them is to create a reliable dataset of images of the highest quality. First study comparing CNN and dermatologists performance was published by Esteva et al. in 2017 [34]. Dermatologists mean sensitivity was 86.6%. At this sensitivity, doctors specifity (71.3%) was significantly lower than CNN' specifity (82.5%). Other comparison studies made by Haenssle [35], Tschandl [36] and Fujisawa [37] showed that CNN specifity in results is equal or not inferior to those made by dermatologists. Tschandl proved that CNN are as precise as dermatologists in classifying both pigmented and unpigemented skin lesions. In lesions of basal skin carcinoma or Bowen's disease, the doctors were outperformed by CNN (diagnoses made by doctors of basal skin carcinoma were accurate in 51% while diagnoses made by CNN were accurate in 85% of cases) [36].

Population diversity may be the biggest barrier in using CNN on a greater scale. Sensitivity of CNN drops from 91% to 85.5% when results from one hospital are used to compare with results from another hospital with different population [38]. Skin lesions in melanoma may look unalike in different populations, what complicates training process of CNN. Results with satisfactory sensitivity gathered from images of skin lesions from one group of patients may not be easily transferable to a different group [39]. Rajpara study showed that traditional dermatoscopy and artificial intelligence performed equally well for diagnosis of melanoma lesions. Sensitivity of artificial intelligence outperformed dermatoscopy (91% for AI compared to 88% for dermatoscopy) [40]. Unsuprisingly, the best outcome is achieved when human and artificial intelligence are combined [41]. In Hekler's study mean accuracy of physicians was 42.94%, mean accuracy of CNN was 81.59% and mean accuracy of physician-computer fusion was 82.95%.

Colorectal cancer

Colorectal cancer (CRC) is the most common type of cancer that develops in the digestive system and is the fourth most common cause of cancer death in the world [42]. In 2012, approximately 1.36 million new cases of CRC were detected and approximately 690,000 deaths were recorded as a result of it. Currently, endoscopic examinations, especially colonoscopy, are considered to be the most frequently used and the most sensitive and specific methods in the early detection of CRC [43,44]. Nevertheless, the use of this method entails certain difficulties, among which we can distinguish the lack of cooperation on the part of the patient, the lack of information about the family history, which is very important when it comes to the genetic basis of CRC, difficulties in performing the test, its cost and risk of complications [45]. Hence, much effort is currently spent on developing effective strategies for early diagnosis, monitoring of disease progression and relapse.

Recent studies indicate the importance of the use of artificial intelligence systems in the diagnosis and treatment planning of CRC, which not only translates into high efficiency of screening programs but also significantly affects the five-year survival rate of patients who received appropriate treatment. The rapid development of AI meant that colonoscopy became an appropriately sensitive examination, thanks to the implementation of methods of automatic detection of colon polyps using energy maps (Fernandez-Esparrach et al., 2016) or the classification of polyps as hyperplastic or adenomatous (Zhang et al., 2017) [46,47]. Additionally, the 2015 Infocus-Breakpoint system can measure the area of neoplasia with millimeter accuracy in the case of non-polypomatous CRC [48].

Histopathological examination of endoscopic specimens is essential for the diagnosis and evaluation of colon cancer. The results, however, depend on the experience and knowledge of the pathologist. Hence, the use of AI can automatically classify and diagnose biopsy samples, greatly improving the accuracy of diagnosis while reducing time and cost [49–51].

Blood tests are a non-invasive, sensitive, and relatively cheap diagnostic method. Hence, the continuous improvement of the sensitivity of this type of test method may contribute to the improvement of early detection of CRC. Soares et al. developed a classification method based on blood fluorescence spectroscopy [52]. Artificial intelligence has also been found to play an important role in genetic testing for CRC. For this reason, Hu et al. designed an experiment comparing the accuracy of three different neural networks (S-Kohonen, BP, and SVM) to the classification of cancer-based on gene expression. 15 genetic markers have been identified as predictors of recurrence risk and prognosis for colon cancer patients through a series of screening and validation tests [53].

Conclusions

Artificial intelligence plays an increasingly important role in medical diagnostics. Year by year, the algorithms are improved and the range of AI applications becomes wider. One of the most important applications of this technology is cancer diagnostics. Algorithms are most often used to detect cancerous changes on radiographs or other standardized samples. This process is preceded by an algorithm training, during which, under the supervision of a specialist, large amounts of data are presented to AI and alarming patients results are indicated.

This article analyzed the diagnostic efficacy of artificial intelligence in several of the most common cancers. The research results are very promising and indicate the high effectiveness of AI. In the case of breast cancer diagnostics, high accuracy of AI has been demonstrated in both MRI and ultrasound analysis of lesions, especially when the analysis was supported by the opinion of clinicians. In prostate cancer diagnosis, AI is used in lesion detection, localization and the assessment of its aggressiveness. The use of AI to differentiate PCa from BPH may prove particularly important, which may help to reduce the number of unnecessary prostate biopsies. Additionally, significant effectiveness (sensitivity: 97.7%; specificity: 99.3%) of the algorithms analyzing prostate biopsy materials in search of PCa was demonstrated. AI in prostate cancer can also compensate for the lack of reproducibility of diagnoses caused by differences in the experience of pathologists. It should also be noted that the diagnoses made by the same algorithm differ significantly in the case of different patients diagnosed for skin cancer. Contrary to changes at the cellular level, macroscopic skin lesions can differ significantly between populations, which significantly limits the possibility of using one algorithm on different patient groups. Nevertheless, CNN is able to analyze various aspects of skin lesions (diameter, shape, color, patterns) and does not differ from the accuracy presented by specialist doctors, and even obtains better results than them. Also in this case, the greatest effectiveness is obtained when AI and doctors join forces. Successful diagnosis of colorectal cancer by AI contributed both to an increase in the effectiveness of screening programs and to a better five-year survival rate of patients who received more adequate treatment. The studies indicate the high accuracy of AI in the examination of samples for CRC and the potential of AI in detecting prognostic markers for this cancer.

For medical diagnostics with the use of artificial intelligence to develop, further research is needed, including the improvement of existing algorithms and the creation of new ones. It will also be necessary to resolve many ethical issues related to the use of AI in the diagnosis and treatment of patients, as well as the social standardization of the use of computer data analysis in therapy. However, this effort has the potential to significantly improve the diagnosis and therapy of cancer patients.

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