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TRANSFORMING ONCOLOGY WITH ARTIFICIAL INTELLIGENCE. CURRENT APPLICATIONS AND PROSPECTIVE ADVANCES, MODERN NOVEL INSIGHTS

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Abstract

Background: *It is evidenced that cancer is among the major causes of death in the world and requires enhanced applications such as AI machine learning and deep learning approaches to enhance diagnosis, treatment endorsement, and better results among patients of cancer. Objective: This systematic review investigates role of artificial intelligence in oncology with a special focus on machine learning, deep learning, and the use of predictive modelling. They are discussed here concerning their utilization in cancer diagnosis, treatment recommendation, and prediction.* ***Methodology:*** *A systematic electronic search was conducted based on PRISMA guidelines in PubMed, Science Direct, and Google Scholar from year 2018 to 2024. Thus, the included studies explored various AI interventions in oncology that included machine learning algorithms, deep learning models, diagnostic tools powered by Artificial Intelligence, etc. Two key areas were evaluated: analyses of AI in considering diagnostics in comparison with the more commonly used imaging and pathology and in determining treatment outcomes and patients' survival rates. Data from Asia Pacific, Europe, and Americas was obtained to get broad view on incorporation of AI within oncology. Initially 80 studies were taken but 20 were put in the systematic review table.* ***Results:*** *The systematic review highlighted improved performances of AI in early diagnosis of cancer, in cancer treatment planning and in prognosis. The previous studies revealed that the AI models offered better diagnostic performance compared with traditional diagnostic technologies, mainly in medical imaging and molecular pathology. Moreover, a new perception of AI for targeted therapies revealed a higher survival rate and quality of life in patients. As the AI technologies advance, impediments like data privacy and big data required for AI were described but considered as conquerable.* ***Conclusion:*** *Artificial intelligence especially machine learning and deep learning algorithms are gradually becoming an innovative solution in the field of disease treatment and diagnosis by improving the course of treatment, and therefore the prognosis for the patient's condition are significantly more accurate. Its incorporation in the clinical setting can reasonably improve the future landscape of cancer treatment, making it work more effectively as well as outcome more predictable.*

Keywords: *Artificial intelligence, Cancer diagnostics, Deep learning, Machine learning, Oncology, Personalized treatment, Predictive analysis, Predictive modeling*

INTRODUCTION

Cancer remains one of the main causes of morbidity and mortality in the world, with more than 19 million new cases diagnosed annually, and about 9.6 million deaths every year. Previous cancer diagnosis and therapies in the clinical methodology have posed a problem in detection and treatment since they lack

accuracy in detection of particulars of genetics of the patients (1). The revolutionary idea of adding artificial intelligence (AI) particularly machine learning and deep learning algorithms in oncology has the largest potential in today's medicine as the number of possibilities it provides in cancer diagnosis, treatment and patients' control is almost limitless (2). It's in this capacity that the capabilities of AI can be applied to solve these difficulties by supporting higher diagnostic insights and individual treatment plans while also increasing the efficiency of patient outcomes.

AI engages with oncology across multiple levels, including in imaging analysis, genetic data analysis, treatment decision and prognosis. Diagnostics is another area where AI is able to detect problems including malignancies on mammograms, lung cancer on CT scans and MRIs more accurately than human radiologists (3). The application of AI such as machine learning performs an interpretative and analytical capability that can uncover little images or signs that the normal human being eye cannot see, and thus, early detection of cancer is enhanced. also, de novo biomarkers are emerging though artificial intelligence in analysing large data set of molecular pathology genetic data for enabling treatment of cancer. Especially, the ability of NEKO to input the large amount of data into the system and to apply all the necessary data-mining algorithms for the outcome analysis in a short time preventing the multiple iterations of the input of wrong data is crucial when it comes to the process of precision oncology that calls for the treatment of cancer based on the genetic characteristics of a patient.

In addition, it is also growing the possibility to design individual treatment programs (4). Doctors and scientists have been using the machine learning approach in an attempt to anticipate the response of the individual patient to a given treatment (5). Applying a particular patient's clinical information such as mutations, characteristics of the tumour, and previous efficiency of treatments, AI allows oncologists to choose which treatment would be most effective avoiding several unsuccessful attempts and side effects. AI solution also contributes as the key solution in enhancing the clinical decision support system and improving the clinical work flow and efficiency of the oncology departments.

There are numerous studies on AI solutions in oncology, but significant gaps prevent the utilization of AI in oncology from being ideal. A significant gap is in data diversity most of the AI models are built from homogeneous datasets that don't represent the diversity of the population by age, ethnicity, and socioeconomic status. A common issue arising from this can be the generation of biased outcomes and low applicability for other patients (6). Another issue that arises in the course of work with an artificial intelligence system is its explainability. Clinicians use models as "black boxes," a problem that is inherent to the deep learning networks making the implementation of these models in clinical practice challenging (7). Lastly, while there are numerous qualitative enhancements in utilizing AI for diagnostic and therapeutic purposes, there are very few research findings that provide quantitative evaluation of the effectiveness of AI in the treatment of diseases the rates of error reduction or, even better, the increase in survival rates when AI is applied (6, 7).

Much work has taken place in exploring AI in oncology but considerable limitations remain in data diversity, model interpretability, ethical challenge, and quantitative validation. The objectives of this work were to provide an overview of the current and potential use of AI (machine learning, deep learning and predictive modelling) in oncology by evaluating the role of AI technologies in diagnostics, individual treatment, and, prognosis concerning patients with cancer. This review summarizes findings of numerous global studies and increases the generalizability of AI by synthesizing AI models such as machine learning and deep learning to clarify these specific models' clinical understanding. Additionally, data privacy and implementation barriers are discussed as well as the need for responsible integration of its application. By including quantitative metrics on diagnostic and treatment improvements, this review aims to support the empirical validation of AI with respect to oncology applications and guide future research in directions amenable to being inclusive and providing effective oncology applications.

METHODOLOGY

Following the guidelines of PRISMA, we performed a review between March 2024 and July 2024 using a systematic approach to guarantee transparency and rigor during the selection process. A literature search was conducted successively using two independent reviewers on the databases: Includes IEEE Xplore, PubMed, Scopus, Science Direct and Google Scholar. The chosen databases were picked up because of their relevancy to both technological and medical research, and were used to cover all types of studies related to AI applications in oncology. Studies that were chosen were cross checked between reviewers to ensure relevancy and quality of studies and to reduce possible bias happening during the process of selecting studies. The first result presented 80 articles published within 2018 to 2023 discussing how Artificial intelligence and its applications like machine learning and deep learning algorithms can assist in the field of oncology. Systemic screening of the articles was done according to predetermined inclusion criteria, which includes peer review, relevance to application of AI in oncology and publication date. Specific AI technologies of oncology were observed, namely imaging, genomics and diagnostics and we used inclusion criteria of study type, sample size and their use of specific AI technologies such as machine learning and deep learning models. Search keywords used are "artificial intelligence in oncology", "machine learning in cancer treatment", "AI diagnostics in oncology", and "deep learning models in oncology". Studies that did not meet the inclusion criteria or studies that contained irrelevant, outdated information were eliminated. After removal of 10 duplicates, 70 studies were left for initial screening. Of these, 33 were excluded because their title and abstract did not meet the predefined criteria, for example was irrelevant to AI application in oncology, did not offer first hand demonstration, or was about non-oncological topics. As a result, 37 full text articles were assessed in more detail and were added in this study. In each of these inclusion predeterminants, the approach taken was to be structured and consensus driven to reduce bias and ensure consistency among reviewers. A method of inclusion criteria based on peer reviewed studies within the range selected years and on AI techniques in cancer diagnosis, treatment and prognosis, was applied and this led to the selection of 20 articles which were put in the review table. Further data was drawn from selected studies by examining key details within these studies including; author, year published, geographical region, research design, AI methodologies, and outcomes recorded in oncology. Studies from Asia, Europe and the Americas on multiple types of cancers such as breast, lung, prostate, colorectal and ovarian cancer, showed that variety of forms of AI techniques were employed.

RESULTS

The present review encompasses the majority of examined studies, which were carried out utilizing experimental data from AI applications in oncology - diagnostics, treatment planning, and prognosis prediction. The 20 studies were retrospective correlational based on patient data from cancer registries in 18 studies and prospective clinical in 2. Instead, all studies utilized AI techniques (such as machine learning, deep learning, and AI-driven imaging) on all cancer's types like breast, lung, prostate and ovarian.

Representative studies were performed across the Asian Pacific region (45%), Europe (35%) and America (20%). They were all published from 2020 to 2023, such that they mirror AI developments in oncology to date. Results of the review show significant improvements in diagnostic accuracy up to 15% and treatment planning up to 10–20% reduction in treatment errors. Moreover, AI applications in prognosis prediction were able to surpass 5-year survival rates an additional 5-8% in some cancers, including breast and lung cancers.

In total, 70% of the studies were sourced from Google Scholar, 20% from Pub Med, 10% from Science Direct and Scopus. Only studies that were relevant to AI in oncology applications and with empirical support were selected. In Table I, we summarized key outcomes (error reduction percentages and survival rate improvements) of application of each of the AI technologies by cancer type. Baseline comparisons also were made, where feasible, with standard diagnostic and treatments to assess the effect of the specific AI enhancements.

DISCUSSION

Artificial intelligence application in oncological practice is quickly becoming the new standard and approach to cancer management. The findings of the 20 studies stated that AI technologies especially machine learning algorithms and deep learning models, have improved the cancer diagnosis, treating plan, and prognosis prediction (28). This discussion will synthesize the results of the identified studies, discuss strengths and challenges of applying AI to oncology, and suggest future avenues of research and practicing.

Table I. Summary of AI techniques applied to various cancer types: Techniques, outcomes, and insights from 20 studies

Year (location)	Cancer Type	AI Technique	Sample size	Outcome (reference)
2021 (Austria)	Breast	Deep Learning	500	Diagnostic accuracy improved by 15% (8)
2020 (India)	Lung	Machine Learning	1000	20% error reduction in treatment planning (9)
2021 (Turkey)	Prostate	Neural Networks	750	8% improvement in 5-year survival prediction (10)
2022 (China)	Colorectal	AI Imaging	600	Early detection improved by 12% (11)
2022 (USA)	Ovarian	AI Biomarkers	300	Personalized treatment yielded a 7% survival rate increase (12)
2020 (China)	Liver	Machine Learning	1200	Mortality rates reduced by 10% (13)
2023 (Spain)	Skin	AI Pathology	850	Diagnostic accuracy enhanced by 14% (14)
2020 (US)	Leukemia	AI Genomics	900	Improved therapy response prediction by 12% (15)
2022 (China)	Pancreatic	AI Radiology	950	Enhanced treatment planning accuracy by 15% (16)
2023 (India)	Bladder	AI Molecular Data	1100	10% improvement in survival prediction (17)
2020 (India)	Breast	Machine Learning	1300	Higher diagnostic accuracy by 15% (18)
2022 (Malaysia)	Lung	Neural Networks	400	Early detection accuracy improved by 10% (19)
2021 (China)	Colorectal	AI Imaging	500	Diagnostic error reduced by 12% (20)
2022 (Mexico)	Prostate	AI Biomarkers	700	Treatment outcome enhanced by 11% (21)
2022 (China)	Liver	Machine Learning	1000	Prognosis accuracy improved by 8% (22)
2022 (China)	Ovarian	AI Pathology	600	Survival rates increased by 5% (23)
2021 (Japan)	Pancreatic	AI Genomics	800	Diagnostic accuracy increased by 13% (24)
2021 (Italy)	Bladder	AI Imaging	1100	Optimized treatment planning, accuracy improved by 10% (25)
2022 (India)	Skin	Neural Networks	1200	Reduced recurrence rates by 9% (26)
2024 (Iran)	Leukemia	AI Molecular Data	900	12% improvement in survival prediction (27)

One of the main findings that emerged from the review was the increased diagnostic accuracy provided by imaging techniques that utilizes artificial intelligence. The conventional ways of cancer diagnosis like mammography, CT scans and MRI scans are predominantly interpreted by personnel and as such, they involve imprecision. On the other hand AI models are able to find quite nuanced patterns in the imaging data that sometimes might be overlooked by the radiology specialists and therefore are able to diagnose cancer at an earlier stage as well as more accurately (29). This is especially for cancers of which early stages are often asymptomatic for a long period; like pancreatic or ovarian cancer. Machine learning-

based imaging products have the potential of reducing diagnostic errors, and subsequent timely interventions that could greatly enhance the survival of such patients.

Apart from making diagnosis better, utilization of artificial intelligence has proven appropriate in personalizing medical care. In the analyzed studies, the authors showed that AI algorithms mainly ML and DL can successfully handle molecular data, such as genomics and proteomics to predict biomarkers for management of patients (30). This kind of specific treatments that are adapted to the patient's cancer type and other features of their individual case have become accepted as standard practice in the management of many malignancies. The value of AI includes the possibility to process a large amount of genetic information within a short time frame, thus enabling oncologists to make better decisions regarding potential treatment options that will likely be most effective for certain patients. This helped to reduce the empiric traffic characteristic for the methods of cancer treatment and decreases the probabilities of side effects connected with the mistake in the choice of the cancer treatments.

Further, the review also discusses AI's role in trying to forecast outcomes for the patients as another area of development that has occurred. Through clinical information, features of the tumour, type of mutation the patient has or earlier response to a certain treatment, AI algorithms (ML , DL, predictive analysis etc) can identify how the patient will react to a particular form of treatment or recurrence risk (31). It has been stated that such a predictive function can improve the overall treatment plan of oncologists which enhances patient outcomes over the long run. For example, other AI models can be used to predict patient's relapse risk and thus, additional intensive treatment is applied.

Despite all the benefits that AI can bring to oncology, there are many important issues and limitations which are still to be addressed before AI can fully be integrated into clinical practice. One big emerging challenge comes from the quality and variability of data used for training AI models most datasets are not diverse in age, ethnicity and socioeconomic backgrounds which can result in biased models that perform less than optimal for some populations. Due to data homogeneity, AI models can then not generalize well to all demographic groups (32). In order to combat this, future models must indeed be trained on a variety of datasets which are diverse and highly typical of the broader populace. As a result, AI based interventions in oncology can become more generally applicable and equitable, and be more widely used amongst different patient demographics.

A key limitation, however, is the requirement for significant change to existing clinical workflows and infrastructure to integrate AI tools into them. For example, application of AI in healthcare systems would require extended training courses for all kinds of healthcare professionals to be able to effectively utilize AI-based decision supporting systems. In addition, the establishment of a robust infrastructure to support continuous use and updating of these tools will almost certainly require investments in both technology and training (33).

Furthermore, handling patient information is an issue of great ethical concern and which involves data privacy and security. To ensure patient confidentiality, there is need to ensure data storage and transfer security, to keep patient's trust and to comply to legal terms. To minimize risks from a data breach it is important to maintain strong data protection by using encryption and access controls.

Turning the attention to the future, the prospective of the AI application in oncology is rather great (34, 35). This means that we may see even more sophisticated tools for cancer control as further advancements are made in the design of machine learning algorithms and more high-quality data becomes available. Future research must aim at the creation of high performing but at the same time interpretable AI models to allow the clinician to understand why a particular prediction is made (36, 37). In summary, AI has enormous potential to change the way cancer is diagnosed, treated as well as the outcome achieved. Finally there is a probability of increase of using AI in cancer care using new methodologies to enhance the early diagnosis and appropriate treatment which will consequently increase the patient survival rate.

CONCLUSION

Finally, the application of artificial intelligence (AI) in the localization of oncology can be described as the new direction in combat against cancer. The 20 reviewed studies represent a transformative advancement in the battle against cancer by application of artificial intelligence (AI) in oncology with great progress in diagnostics, personalized therapies and prognostic accuracy. An analysis of large datasets using machine learning and deep learning techniques generates novel insights that result in more beneficial results than traditional methods. While there are challenges related to data diversity and privacy, as well as seamless integration with healthcare workflows necessary for realizing AI's clinically impactful potential, it is clear that those who utilize deep learning in clinical practice have found a way around these challenges. Even in future research, it is important that we develop datasets which are diverse and representative so that when AI models are built, we can be sure that those models will work as intended across populations, minimizing bias and improving fairness. And of course, we must build robust data privacy protocols such as encryption and anonymization to protect patient information and build trust. However, in order to enable effective use of AI for clinical integration, more studies are needed to discover appropriate approaches to training healthcare professionals and adapting workflows, as well as the appropriate infrastructure, to make AI a collaborative tool that strengthens, rather than replaces, the role of human expertise in oncology.

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