Review of AI Applications in Oncology: Current Tools, Challenges, and Opportunities for Clinical Decision Support

Elda Xhumari[1], Enrik Dollaj[1]

[1]University of Tirana, Tirana, 1001, Albania

Abstract

AI is a game-changer in the competitive field of modern healthcare, especially in oncology. Given this burden of disease, it could be used in a timely fashion only if this information is accurate and can lead to patient management change. Artificial intelligence - incl. machine learning, deep learning and natural languages processing - will have a considerable potential to increase the level of automation, pattern recognition and predicting information, so that also the CDSS could be improved [1][2]. They apply across the spectrum of cancer management -from early detection through use of medical imaging to planning treatment as well as prognostication -and they even have potential for drug discovery [3]. A review of published evidence on the state-of-art technologies for AI cancer applications in oncology is reported, including plethoric cited sources of the most important hardware/software tools and systems adopted in experimental or clinical settings. It highlights the value of improved accuracy in diagnostics, the ability to personalize treatment, and to make healthcare systems more efficient. At the same time, it does a deep dive into the particular barriers to wider adoption, like data quality, model transparency, interpretability, algorithmic bias and regulatory hurdles. This paper also talks about ethical implications, and why clinicians, data scientists and policy-makers should come together and work collaboratively. This critical review discusses the state of the art and prospects of current research in the development of oncological CDS systems and describes novel fields of innovation such as explainable AI (XAI), federated learning and real-time clinical integration which could pave the way for the provision of oncological care. These results suggest that AI is neither a substitute for human perspective nor a parallel practice to human decision-making in the clinical setting, but a powerful assistant, that, if used responsibly, could significantly enhance patient care.

Keywords

Artificial Intelligence in Oncology, Precision Medicine, Explainable AI, Federated Learning

1. Introduction

Cancer is one of the most complex and worldwide common diseases in the human species and the cause of almost 1 in 6 deaths in the world as indicated by WHO PfizerApollo [4]. With cancer rates increasing while fresh clinical data grows larger and more diverse, oncologists need smarter, more efficient systems to help them make life-and-death decisions. Cancer is usually treated by multi-disciplinary teams and there are various diagnostic tools ranging from radiological imaging, tissue pathologic classification, genomic profiling to electronic health records (EHR). Although medical technology has evolved in recent years, the individual differences between cancer patients are so great that it can be impossible for clinicians to effectively consider and use all the available information in a timely manner.

The fields of AI have recently drawn a lot of attention with potential benefits to expand the reach to provide new clinical workflows and care delivery. AI systems can sift through large data sets and apply advanced algorithms to discern the patterns within medical data that the human eye cannot perceive. AI is being utilized in oncology for various purposes including tumor detection in radiological images, patient survival prognostication & risk stratification; and, more recently,

[1]6th International Conference Recent Trends and Applications in Computer Science and Information Technology, May 22-24, 2025, Tirana, Albania

* Corresponding author.
elda.xhumari@fshn.edu.al (E. Xhumari); enrik.dollaj@fshnstudent.info (E. Dollaj)
0000-0002-1206-6424 (E. Xhumari)

discovery of new drug candidates. Further, such technologies not only have the potential to improve the speed and accuracy of diagnosing the condition, they can also be employed to customize a therapeutic regimen to an individual patient profile, resulting in a higher therapeutic score and reduced incidence of side effects.

But applying AI in clinical practice is not without its challenges [4]. Many of the most powerful ML models require high-quality labeled data to be put into production, and data labeling itself has resource (human, time, & financial) costs and difficulties. Moreover, utilization of AI tools requires a culture-change in the clinician-technology interface, where transparency and trust is more important than black-box sophisticated AI. Herein, we aimed to review how AI is being used to support treatment of cancer patients, and to discuss with oncologists, some of the potential advantages, limitations and real-world concerns related to the use of such technologies. It also suggests crucial avenues for future research and development aiming to help AI's production along an ethical, inclusive, and clinically relevant path.

By reviewing examples of the creativity of newly innovated concepts and website-based tools, as well as challenges associated with the system-level application of AI in different oncology clinic settings, we intend to lead oncologists to a clearer comprehension of how AI applications could be informatically implemented to quickly ease clinical workflow.

2. AI Applications in Oncology

AI is increasingly being adopted in various oncologic domains, is generating tools that enhance clinical decision-making using the power of automation, pattern recognition and predictive modeling. These applications span all aspects of cancer care, including diagnosis and screening, treatment selection, prognostic prediction, and patient monitoring. The next section proceed to the top AI impacted domains and currently available tools and systems.

2.1. Diagnosis and Imaging

Medical imaging is one of the most mature domains in oncology in the field of AI adoption. However, machine learning methods, in particular deep convolutional neural networks (CNNs), have demonstrated at least comparable, and in some cases superior, performance than specialists in tumor classification and detection.

High-resolution radiological images from CT, MRI, PET and mammography scans can then be processed by AI systems to uncover lesions that might indicate early-stage cancer. For example, Google Health has developed the LYNA (lymph node assistant) to detect metastatic breast cancer in lymph nodes from pathology slides and achieved high sensitivity [5]. Close by, Aidoc and Zebra Medical Vision supply radiology tools that use AI to send alerts if there could be an abnormality on head and chest scans.

Beyond detection, AI tools can assist in segmentation of tumors and in the calculation of the volume of a tumor; it can also predict the molecular subtypes using radiologic findings—an essential task for proper diagnosis and planning of treatment).

2.2. Treatment planning

Oncology According to AI for life sciences report, medical imaging is one of the most mature AI applications for adoption in oncology. However, machine learning methods, particularly deep convolutional neural networks (CNNs), have demonstrated nearly equal or superior performance to specialists in tumor detection and classification.

AI models can process high-resolution images taken from CT, MRI, PET and mammography scans to identify lesions that could indicate an early-stage cancer. For instance, Google Health has built the LYNA (lymph node assistant) to detect metastatic breast cancer in lymph nodes from path slides achieving high sensitivity [5]. AIdoc and Zebra Medical Vision work to provide AI-assisted radiology tools, also in that neighborhood, warning when head and chest scans might indicate something abnormal.

Beyond detection, AI tools have the potential to assist in the segmentation of tumors and the measurement of tumor volume, as well as making a prediction of molecular subtypes from imaging characteristics—processes that are essential for diagnosis and treatment planning.

2.3. Prognostic prediction and analytics

Another area where AI can make a significant positive impact is in the prediction of patient outcomes, such as rates of survival, chances of recurrence and response to treatments. Modeling approaches, such as random forests, support vector machines (SVM) and deep learning based on patient level clinical, demographic, and genomic data, can be trained to stratify patients into risk strata. Yet, machine learning prediction models trained in EHR data can accurately predict 5-year survival rates for breast, lung and colorectal cancers [6]. These resources help clinicians counsel patients, allocate resources and make decisions about follow-up care. Furthermore, AI has the artificial intelligence potential to identify patterns that indicate the early stages of disease, which can empower proactive intervention, reinforce the specific details of intervention, and potentially enhance long-term outcomes.

2.4. Drug Discovery and Personalized Medicine

AI is being used in drug discovery more than ever before to expedite the process of finding new compounds and perfecting the way drugs interact with targets. For instance, AI algorithms can look for and predict how multiple molecules interact with cancer cells by mining intricate biological datasets allowing multi-target drugs to be developed. AI-powered platforms are being used to enhace drug discovery pipelines, and develop personalized treatment recommendations for individual patients' genetic makeup in the companies such as Deep Genomics, BenevolentAI and Insilico Medicine [7]. This is particularly important for precision oncology, where patients are treated based on the molecular make-up of their individual tumor.

2.5. Clinical workflow optimization

Beyond the clinical front lines, AI is helping to improve administrative burden and operational efficiency through the optimization of clinical workflows. NLP applications could support documentation and availability of data, by automatically extracting relevant information from unstructured clinical notes. Appointments can be "intelligently" scheduled by artificial intelligence (AI)-based solutions improve resource utilization, shorten the wait for appointments, and speed up patient flow. Others have utilized AI chatbots, and virtual assistants to support patients through the process of diagnosis and treatment, enhancing communication and alleviating anxiety [8]. This enables clinicians to personalize, create and support patient-centered care through the automation of mundane, routine work and the optimization of the big data flow with such specialized algorithms.

3. Challenges and limitations

Although AI in oncology shows immense potential, there are considerable challenges in its widespread adoption [9]. These hurdles are not merely technical, but ethical, regulatory, and operational. Addressing these limitations in depth is critical to safe, effective, and equitable deployment of AI-driven systems in clinical settings.

3.1. Data Privacy and Security

Oncology just can defy the overwhelming reliance on big data, as is the case for genomic data, radiological images, and EHR-based data for AI in oncology models. These data often include very sensitive personal and medical data, and there may be significant concerns around privacy and security. Tight regulations, such as HIPAA in the United States and GDPR in Europe, hold legal binds over how medical data can be obtained, stored or distributed. Compliance with these laws may entail substantial costs around data anonymization, data encryption and secure access protocols. Further, the increasing trend to use central-cloud-based (or third-party) platforms for AI training brings in more risk of data leaks/crack etc.

3.2. Data Quality and Bias

A further significant challenge to AI effectiveness is the quality and variedness of the training data. AI models is only as good as the data it's trained on. In oncology, the accessible datasets are often small or not representative of diverse populations and are imbalanced across stages of disease and types of disease. Bias in the learning algorithm can cause the algorithm to work well on some subgroups but less well on others, resulting in compromised fairness and accuracy. For example, an AI model that is predominantly trained on imaging data from white patients may perform less well when applied to patients of other racial groups. In the same way, AI models are less capable to predict the response of rare diseases or rare presentations, what limits their application in a clinical scenario.

3.3. Interpretability and Trust

Despite their ability to predict things — not just whether patients are likely to survive, but also what television show they are most likely to watch or who they will marry — many AI models, especially those of deep learning, are known as "black boxes" because their decision logic may be incomprehensible to human experts. This lack of transparency is a major inhibition to clinician trust and to regulatory approval, particularly in high stakes fields such as oncology.

Understandably, clinicians are reluctant to accept recommendations and predictions generated by AI that cannot be explained or validated. This has initiated an increasing interest in Explainable AI (XAI) methodologies that were designed to increase the interpretability and transparency of models [10]. Nevertheless, constructing XAI approaches that are informative in a clinical sense, has been a problem in ongoing research agenda.

3.4. Regulatory and Clinical Validation

Legal standards for the use of AI in medicine are high, as we require a lot of evidence to show that AI is safe and works well when it is used in medicine. For example, in the United States, medical devices that are based on AI need approval from the Food and Drug Administration (FDA). This typically includes clinical trials, peer reviewed evidence, and proof of reproducing across multiple healthcare settings. One challenge is that AI tools often get better over time, as new data is added to the system — a phenomenon known as adaptive algorithms. This is problematic for existing regulatory structures, which are commonly tailored for static systems. Regulators and developers will need to work together to produce new protocols that take into consideration the changing nature of AI. Furthermore, a lot of the AI tools are not tested beyond experimental or retrospective scenarios. Their clinical benefit in practice has yet to be determined because of lack of prospective clinical validation.

3.5. Ethical and Legal Implications

There are many ethical considerations for the use of AI in oncology. So, what if an AI gets the wrong diagnosis, or prescribes the wrong drug — who's responsible? How do we get informed consent when patients don't understand how A.I. is affecting their care? These problems are made worse by concerns over algorithmic autonomy—machines gaining ever more agency. And there's the risk of overreliance in AI, where there may be an erasure of clinicians who will depend too much on automated shortcuts rather than on clinical judgment. Mechanisms are required to preserve the clinician at the core of decision making and guaranteeing that AI is an additive rather than a disruptive force. Lastly, within this context, the gap of AI technology deployment between well-endowed institutions and resource-limited health-care systems might widen the existing gap in oncology care delivery [4].

4. Opportunities and future directions

Though not without its hurdles, the potential and promise of AI in oncology is clear. Data science, computational power and clinical informatics are evolving at breakneck speed to enable stronger, more interpretable and more universally applicable AI solutions. This section discusses salient opportunities that may shape the future of AI-based decision support in oncology, and how these developments have the potential to overcome historical shortcomings and deepen clinical relevance.

4.1. Explainable AI (XAI)

Recently, attention is being paid to the trend toward explainable and interpretable models. Explainable AI (XAI) is an emerging field that seeks to build a bridge between complex model outputs and human cognition, so that clinicians can understand how and why predictions or recommendations are made. For example, heatmaps in radiology can show visually where in the volume affected a model's diagnosis, while decision trees and attention-based models can reveal which variables drove prognosis predictions [10]. These methods don't just create better explainability and trust, but can also help when auditing a model's performance, or looking for biases. Explainable AI may also have a critical part to play in regulatory approval, by offering concrete proof of model reliability and aiding the clinical adoption process.

4.2. Federated Learning and Privacy-Preserving AI

Privacy and facilitating multi-institutional collaborations make federated learning a more novel solution. It enables AI models to be trained on a variety of distributed datasets without sharing sensitive patient data. Each participant keep data on its local place, only send model parameters, which can greatly reduce the privacy risks. This model is particularly useful in oncology, where rare subtypes and heterogeneous data across the population can be spread across multiple hospitals and research institutions [8]. Federated learning has the potential to enhance the generalization and the performance of AI systems by offering secure large-scale model training opportunities.

4.3. Integration with Real-Time Clinical Systems

For AI to have an impact it will need to be embedded into Electronic Health Records [EHRs] and daily clinical practice with minimal friction. That means going beyond the stand-alone decision support tools versus embedded systems that interact with clinicians in their everyday work. This type of integration can allow for real-time risk warnings, automatic diagnostic recommendations, and responsive therapy adjustments in accordance with patient status. Integrating AI within the clinical workflow allows for quicker decision-making, lower cognitive burden and personalized care paths for clinicians. Down the line, AI could serve as a "second opinion" available at the point of care, constantly learning, adjusting, and improving as more data comes so that the technology takes less and less time to arrive at the same conclusion [8].

4.4. Personalized and Precision Oncology

AI will remain a force behind the growth of precision oncology, in which treatments are customized using a person's genetic, lifestyle and clinical information. Applying AI to omics data—including genomics, proteomics, and metabolomics—can reveal intricate relationships among genetic mutations and cancer phenotypes. With data from next-generation sequencing more available, AI can be used to identify actionable biomarkers, predict treatment response, and guide clinicians to choose the most effective targeted therapies. AI might also enable n-of-1 trials, in which treatment is fine-tuned on the basis of real-time feedback to a single patient [11].

4.5. Collaboration Across Disciplines

Realizing the promise of AI in oncology: Options, requirements, and then Some Clinicians, data scientists, bioinformaticians, engineers, ethicists, and regulators must work more closely and more effectively together if AI is to achieve its full potential in oncology. Interdisciplinary teams are of the essence to develop user-friendly AI systems serving real clinical needs that are ethical and legally compliant. In addition, collaborations between universities, hospitals and technology companies can promote innovation and improve the translation into clinical use of AI tools. The creation of common data repositories, open-source platforms, and common benchmarking will also foster research and promote reproducibility [12].

4.6. Empowering Patients with AI

Artificial intelligence can be applied in the age of digital health beyond hospitals to help patients directly. Mobile apps, wearables and AI-driven chatbots can enable symptom tracking, ensure adherence to medication and enable education—improving patient engagement and early identification of complications. Tools such as these provide a new level of personalization and accessibility, especially in remote or underserved regions. Patient-facing AI, with proper checks in place, has the potential to democratize access to good cancer care and put more people at the center of their own health [12].

5. Conclusion

The addition of AI as a new tool in the oncologist's toolbox is one of the most exciting and likely transformative developments in contemporary medicine. AI tools play a critical role in the era of cancer care such that they help to enhance clinical judgment, increase diagnostic precision, and optimize therapeutic strategies. From deep image analysis and automated pathology, to genomics-guided drug discovery and real-time risk prediction, AI has already transformed the oncology landscape.

The present review provides an overview of the current use of AI in various aspects of cancer care, where the widely used tools and innovative new developments are job highlighted. It has also touched the major hurdles in the adoption of AI such as data privacy concerns, lack of algorithmic interpretability, and regulatory barriers. Addressing these challenges suggests a multi-tendrilled solution, including technical innovations like explainable AI and federated learning, policy innovation and development, interdisciplinary collaboration, and ethical fore vision.

The future is wide open for AI in oncology. As computational models become increasingly transparent, comprehensive, and clinically interfaced, the role of computational models to assist oncologists and empower patients will increase. The future of cancer care is not about replacing clinicians but is a story of augmenting them by equipping them with intelligent, adaptive tools that improve decision making and in turn result in better outcomes.

For this vision to fully come to life, the field will need to keep investing in equitable access to AI tools, strong clinical evidence and collaborative ecosystems that bridge the worlds of technologists and healthcare professionals. With responsible development and deployment, AI will be instrumental in accelerating progress in precision oncology and changing cancer care for the good.

Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

References

[1] Esteva, A., Kuprel, B., Novoa, R. A., Ko, J., Swetter, S. M., Blau, H. M., & Thrun, S. (2017). Dermatologist-level classification of skin cancer with deep neural networks. *Nature*, 542(7639), 115–118. https://doi.org/10.1038/nature21056

[2] Ardila, D., Kiraly, A. P., Bharadwaj, S., Choi, B., Reicher, J. J., Peng, L., & Corrado, G. S. (2019). End-to-end lung cancer screening with three-dimensional deep learning on low-dose chest computed tomography. *Nature Medicine*, 25(6), 954–961. https://doi.org/10.1038/s41591-019-0447-x

[3] Rajpurkar, P., Irvin, J., Zhu, K., Yang, B., Mehta, H., Duan, T., ... & Ng, A. Y. (2017). CheXNet: Radiologist-Level Pneumonia Detection on Chest X-Rays with Deep Learning. *arXiv preprint arXiv:1711.05225*. https://arxiv.org/abs/1711.05225

[4] World Health Organization. (2021). Ethics and governance of artificial intelligence for health. https://www.who.int/publications/i/item/9789240029200

[5] Google Health. LYNA: Lymph Node Assistant. https://health.google/technologies/ai/lymph-node-assistant/

[6] Topol, E. J. (2019). High-performance medicine: the convergence of human and artificial intelligence. *Nature Medicine*, 25(1), 44–56. https://doi.org/10.1038/s41591-018-0300-7

[7] Hosny, A., Parmar, C., Quackenbush, J., Schwartz, L. H., & Aerts, H. J. W. L. (2018). Artificial intelligence in radiology. *Nature Reviews Cancer*, 18(8), 500–510. https://doi.org/10.1038/s41568-018-0016-5

[8] Obermeyer, Z., & Emanuel, E. J. (2016). Predicting the Future — Big Data, Machine Learning, and Clinical Medicine. *New England Journal of Medicine*, 375, 1216–1219. https://doi.org/10.1056/NEJMp1606181

[9] Yang, G., Zhang, J., Liu, J., Sun, M., Li, M., & Pan, Z. (2021). AI-enabled cancer diagnosis and prognosis prediction: Opportunities and challenges. *Cancer Letters*, 522, 234–246. https://doi.org/10.1016/j.canlet.2021.07.007

[10] London, A. J. (2019). Artificial intelligence and black-box medical decisions: accuracy versus explainability. *Hastings Center Report*, 49(1), 15–21. https://doi.org/10.1002/hast.973

[11] Tempus. Precision oncology solutions. https://www.tempus.com/

[12] IBM Watson for Oncology. IBM Corporation. https://www.ibm.com/watson-health/solutions/oncology