Ethical Challenges Arising from the Integration of Artificial Intelligence (AI) in Oncological Management

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Abstract

The emergence of Artificial Intelligence (AI) in oncology has given rise to a broad spectrum of ethical issues that demand thorough examination and careful deliberation. This research examines the ethical challenges posed by the integration of Artificial Intelligence (AI), specifically Deep Learning (DL) in various aspects of oncological management, namely, cancer screening, diagnosis, classification, grading, prognosis, therapy response, precision medicine, and radiotherapy. In the screening of cancers such as cervical, colorectal, lung, and breast, AI methodologies like Convolutional Neural Networks (CNNs) and DL algorithms have significantly enhanced the detection and analysis processes. However, this advancement is accompanied by ethical concerns regarding the accuracy and reliability of AI systems, the equitable access to AI-enhanced screening technologies, and the handling of privacy and consent issues. The use of DL in cancer diagnosis, classification, and grading, notably through the analysis of histopathology slides and various imaging techniques, presents its own set of ethical dilemmas. These include potential biases in the training datasets, the challenge of maintaining model reliability across diverse patient populations, and the imperative to balance the efficiency of AI tools with the indispensable role of human expertise in medical decision-making. AI-driven models are significantly aiding in customizing treatment in areas like patient prognosis, therapy response, and precision medicine. Ethical concerns in these areas include ensuring data privacy and patient consent, tackling biases in AI to avoid unequal treatment, and maintaining clear communication with patients about AI's role in their treatment decisions. In radiotherapy, AI and deep learning (DL) are improving the accuracy of treatment planning and delivery. This progress prompts ethical considerations about the reliability of AI in crucial functions like outlining target volumes and identifying organs at risk, blending AI tools with the clinical judgment of healthcare professionals, and guaranteeing fair access to these advanced technologies across various healthcare environments. This study also highlights the necessity for data governance protocols, the development of transparent and interpretable AI systems, and the continuous collaboration among technology developers, healthcare professionals, and ethicists.

Indexing terms: Artificial Intelligence, Cancer Management, Deep Learning, Ethical Challenges, Precision Medicine, Radiotherapy, Screening

Introduction

The United Nations Secretary-General's assertion regarding the role of Artificial Intelligence (AI) in realizing the Sustainable Development Goals (SDGs) [1], [2], specially those included within SDG 3, which focuses on health, is a reflection of the growing acknowledgment of AI's potential in addressing complex global challenges. AI, by virtue of its advanced analytical and predictive capabilities, holds the promise of significantly enhancing healthcare delivery and medical research. It has the opportunity to transform healthcare systems by improving diagnostic accuracy, optimizing treatment pathways, and enabling more personalized medicine approaches. Moreover, AI can play a role in resource allocation and management, ensuring that healthcare services are rendered more efficient and accessible. This aligns with the broader objectives of the SDGs, which strive to foster a more equitable, inclusive, and sustainable world.

The utilization of Artificial Intelligence (AI) in healthcare concurrently precipitates a myriad of ethical, legal, commercial, and social dilemmas that transcend national boundaries. These concerns, while partly mirroring the challenges traditionally associated with software and computing in healthcare, are compounded by the unique attributes of AI. The evolution of AI technologies over the past decades has outpaced the development of corresponding regulatory frameworks, leading to a gap in oversight and ethical governance. AI's ability to analyze vast datasets and make autonomous decisions raises critical questions about accountability, transparency, and the potential for unintended consequences in clinical decision-making.

Table 1. Ethical, legal, commercial, and social challenges of AI in general healthcare.

Challenge	Details
Evolution and Regulatory Gap	AI technologies in healthcare have evolved rapidly, outstripping the development of corresponding regulatory frameworks. This creates a gap in oversight and ethical governance, especially considering AI's capacity for analyzing vast datasets and making autonomous decisions.
Human Autonomy	AI's delegation of decision-making processes could undermine both patient autonomy and clinician discretion. Ensuring a balance between AI's capabilities and human oversight in critical healthcare decisions is paramount.
Algorithmic Bias and Disparities	AI algorithms can perpetuate or exacerbate existing biases if not properly designed and audited. This can lead to healthcare disparities, particularly affecting marginalized or underrepresented groups, due to skewed datasets or algorithmic design.
Access Inequality	The availability of advanced AI systems might be disproportionately higher in affluent areas, potentially widening the healthcare access gap between high-income and low-income regions and exacerbating global health inequities.
Commercial Interests and Commodification	The drive of commercial interests in AI development in healthcare could prioritize profit over patient welfare, raising concerns about the commodification of health.
Techno-optimism and Health Disparities	An unmoderated enthusiasm for AI in healthcare ("techno-optimism") can intensify existing disparities in healthcare access and establish a default reliance on technological solutions, disregarding the broader social and economic context.
Digital Divide	Disparities in access to healthcare technologies are influenced not only by financial resources but also by the digital divide, which manifests across geography, gender, age, and technology availability.
Data Quality and Representativeness	Biases in AI due to limited, low-quality, or non-representative datasets can reinforce prejudices in healthcare delivery. Predictive algorithms based on inadequate data are prone to racial or ethnic biases, leading to discriminatory practices.

One of the principal ethical challenges posed by AI in healthcare is the preservation of human autonomy. The delegation of decision-making processes to AI systems could potentially undermine the patient's autonomy and the clinician's discretion. This scenario necessitates a balance between leveraging AI's capabilities and maintaining human oversight in critical healthcare decisions. AI algorithms, if not designed and regularly audited, can perpetuate or even exacerbate existing biases, leading to disparities in healthcare delivery and outcomes. Such biases can stem from skewed datasets or algorithmic design and can significantly impact marginalized or underrepresented groups.

There exists a risk of widening the healthcare access gap between high-income and low-income regions, as advanced AI systems might be disproportionately available in more affluent areas, exacerbating global health inequities. Additionally, the commercial interests driving AI development in healthcare could lead to prioritization of profit over patient welfare, raising concerns about the commodification of health.

The unrestrained enthusiasm for the potential advantages of Artificial Intelligence (AI) in healthcare, often termed as "*techno-optimism*", warrants cautious examination, in the context of its propensity to intensify existing disparities in healthcare access. This optimism, if not moderated, risks establishing a default reliance on technological solutions for health issues. One of the critical concerns is the exacerbation of unequal access to healthcare technologies, both within affluent nations and between high-income and low-income countries. Such disparities are not merely a matter of financial resource distribution but are also influenced by the digital divide, which can manifest along the lines of geography, gender, age, or the availability of technological devices.

The incautious application of AI in healthcare could perpetuate or even amplify existing biases, particularly if the AI systems are trained on limited, low-quality, or non-representative data sets. These shortcomings in data can lead to AI models that reinforce and deepen existing prejudices and disparities in healthcare delivery. Biased inferences and misleading data analyses resulting from such flawed AI applications can have detrimental impacts. Additionally, predictive algorithms that rely on inadequate or inappropriate data sets are susceptible to racial or ethnic biases, leading to discriminatory practices in healthcare.

As AI and DL become increasingly prevalent in areas such as cancer screening, diagnosis, classification [3], grading, prognosis, therapy response, precision medicine, and radiotherapy, they bring with them an array of ethical dilemmas. These challenges include concerns over the accuracy and reliability of AI systems, issues of equitable access to AI-based technologies, the management of privacy and consent, biases inherent in AI models, the balance between AI efficiency and human medical expertise, and the fair allocation of advanced AI resources in varied healthcare settings. The study aims to conduct an examination of these ethical issues, emphasizing the need for robust data governance, development of transparent and interpretable AI systems, and fostering a collaborative environment among technologists, healthcare professionals, and ethicists.

1. Ethical challenges in current AI-based Screening, Diagnosing, Classifying, and Grading of Cancer

Ethical challenges in Early Detection and Screening of Cancer

The decline in mortality rates for some common cancers is partly due to cancer screening. This involves identifying precancerous lesions, like cervical intra-epithelial neoplasia (CIN) in cervical cancer and adenomatous polyps in colorectal cancer. Treating these lesions reduces the incidence of invasive cancer. Automation, essential for high throughput and quick processing, is enhancing the efficiency of cancer screening.

A significant advancement in cervical cancer screening was made by Wentzensen et al., who created a Deep Learning (DL) classifier for p16/Ki-67 dual-stained cytology slides [4]. When compared to traditional Pap smears, this AI-based method showed equal sensitivity but higher specificity. It notably reduced unnecessary colposcopies by a third while maintaining effectiveness in identifying high-grade CIN. Similarly, for colorectal cancer, a study involving 1,058 patients demonstrated that AI-assisted colonoscopy found more adenomas per patient than standard procedures. This is crucial because a 1% rise in adenoma detection corresponds to a 3% drop in colorectal cancer incidence.

In lung and breast cancer screening, automated detection and classification using low-dose CT and mammography have gained attention. CNN-based models, with accuracy rates between 80-95%, show promise in lung cancer screening. Ardila et al. developed a DL algorithm for lung cancer risk prediction using low-dose CT scans, achieving an impressive area under the curve score [5]. For breast cancer, AI-enhanced mammography has proven effective in both preclinical and clinical settings.

Liquid biopsies, analyzing circulating tumor DNA (ctDNA) or cell-free DNA (cfDNA) from blood tests, represent a growing field in early cancer detection. These are vital for cancers lacking effective screening methods. Cohen et al.'s CancerSEEK, which detects and predicts eight cancer types using ctDNA, exemplifies this progress [6]. CancerSEEK employs logistic regression and random forest classifiers, achieving varying accuracies. While liquid biopsies currently rely on traditional machine learning algorithms, the future may see DL models taking over, eliminating the need for manual feature selection and enabling the integration of diverse data types for improved cancer detection.

The employment of artificial intelligence and machine learning in cervical, colorectal, lung, and breast cancers, presents a series of ethical challenges. A principal concern lies in the accuracy and dependability of these AI algorithms. Although AI methodologies have demonstrated enhancement in specificity and adenoma detection in cervical and colorectal cancer screenings, they simultaneously introduce ethical concerns due to the potential occurrence of false positive and negative results. Such inaccuracies may result in either unwarranted medical interventions or overlooked cancer diagnoses. The imperative of regularly validating and monitoring AI systems is paramount in order to mitigate the risk of misdiagnoses and to uphold patient confidence in the healthcare infrastructure. This ethical conundrum is centered around the challenge of harmonizing technological progress with the associated risks of diagnostic inaccuracies.

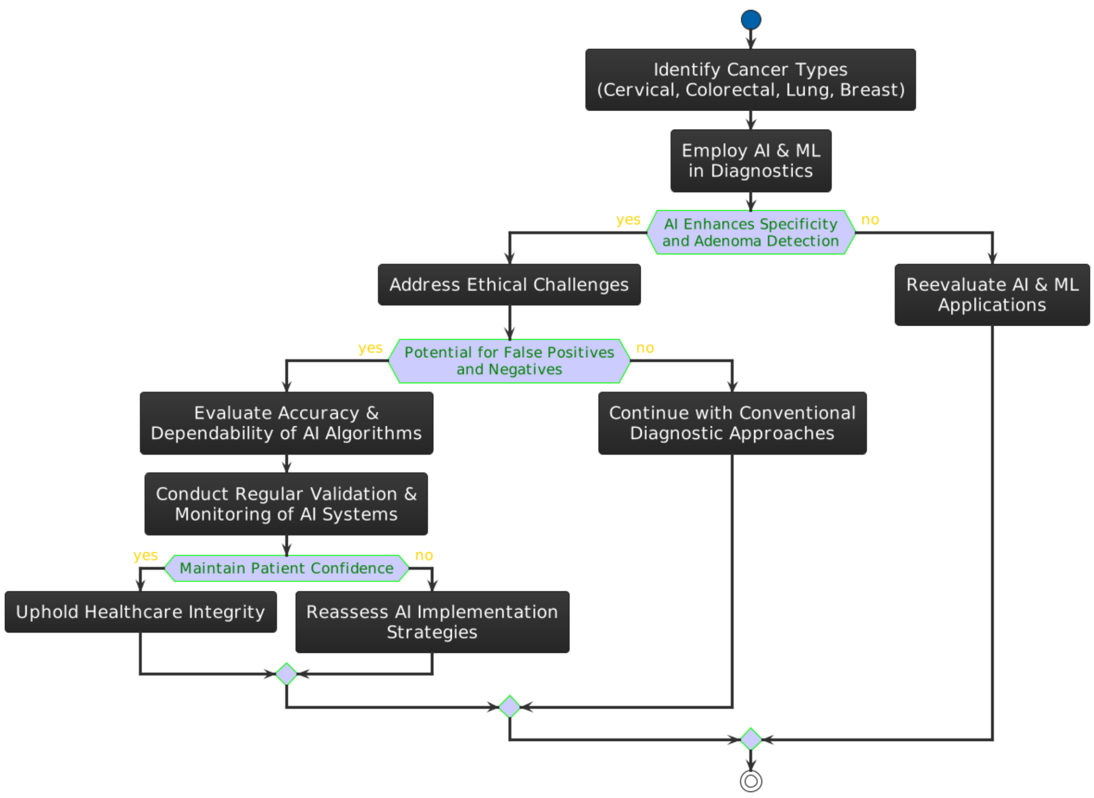

Figure 1. *There are risks of false positives and negatives, which are inherent risks in AI-driven diagnostics. These inaccuracies pose ethical issues, as they could lead to unnecessary medical interventions or, conversely, missed cancer diagnoses. Such outcomes not only affect patient health but also impact their trust in the healthcare system. This study argued that there is a need for regular validation and monitoring of AI systems. This process can ensure that the AI algorithms used in diagnostics are functioning accurately and reliably.*

Another ethical issue is the accessibility and equity of AI-enhanced cancer screening. Advanced technologies like CNN-based models for lung cancer screening and AI-enhanced mammography may not be equally accessible to all population segments. There is a risk of exacerbating health disparities, with individuals in resource-limited settings or those without access to advanced healthcare facilities being left behind. This raises ethical questions about who gets access to these technologies and how to implement them fairly in various healthcare contexts. Addressing the potential biases in AI data that could lead to unequal care is also a part of this ethical challenge. The responsibility to ensure equitable access to these potentially life-saving technologies falls on healthcare providers, policymakers, and AI developers.

The handling and storage of sensitive genetic information, and the implications of identifying genetic predispositions to various cancers, create dilemmas related to patient consent and data protection. There is also the psychological impact on patients of knowing their genetic predisposition to cancers. As the field potentially advances towards more sophisticated DL models, the need for transparent and explainable AI systems becomes crucial. Patients and healthcare providers must understand how AI-driven decisions are made, especially in cases where these decisions could significantly influence medical outcomes. The ethical responsibility in this scenario is to use advanced technologies in a manner that respects patient autonomy, ensures privacy, and supports informed decision-making in healthcare.

Ethical challenges in grading Diagnosis, Classification, and Grading of Cancer Using Deep Learning

Deep Learning (DL) models based on Convolutional Neural Networks (CNN) utilize various imaging techniques like histopathology (including whole slide imaging), radiology (CT and MRI), and endoscopy images, achieving accuracies often matching or exceeding medical professionals.

In cancer diagnosis, CNN-based DL models have shown precision with histopathology slides. For instance, in the CAMELYON16 competition focused on diagnosing breast cancer metastasis in lymph nodes using hematoxylin-eosin stained whole slide images, the top-performing CNN (using a GoogLeNet architecture) achieved an AUC of 0.994, surpassing even the best pathologist (AUC of 0.884) [7] [8]. DL models have also been used for identifying the origin of unknown primary cancers, a notably difficult aspect of cancer diagnosis.

The efficacy of DL extends to diagnosis through CT, MRI, PET-CT scans, and endoscopy. Recent studies, like Yuan et al.'s work using a 3D ResNet algorithm on CT scans to detect occult peritoneal metastasis in colorectal cancer, demonstrate higher accuracy than conventional methods. Similarly, Luo et al.'s multicenter study on gastrointestinal cancers using CNN-based GRAIDS system showed diagnostic accuracies on par with expert endoscopists and superior to non-experts [9], suggesting significant potential in community hospitals.

Beyond binary diagnosis, DL models excel in more complex cancer classifications and grading. DeepPATH, an Inception-v3 based model, effectively classifies lung tissues into adenocarcinoma, squamous cell carcinoma, or normal, with a high accuracy [10], [11]. Automated Gleason grading of prostate adenocarcinoma and using radiology images for liver cancer grading are other successful applications [12], [13]. These models often match the performance of trained experts [14].

The accuracy and efficacy of these models, as demonstrated in competitions like the CAMELYON16 and in studies utilizing various imaging techniques (histopathology, CT, MRI, PET-CT scans, endoscopy), raise questions about the reliability and consistency of these models across different patient demographics and clinical settings. While DL models have achieved high accuracy in specific instances, such as the GoogLeNet architecture surpassing pathologist performance in breast cancer metastasis diagnosis, there are concerns about their performance in diverse real-world scenarios. This includes variations in imaging quality, differences in disease presentation among patients of different ethnicities or ages, and the adaptability of these models to rare or atypical cancer cases. The ethical dilemma here revolves around ensuring equitable and accurate diagnosis for all patients, irrespective of their background or the specific nature of their disease.

A further ethical issue emerges from the potential displacement of medical professionals by deep learning (DL) models in the diagnosis and grading of cancers. The impressive efficacy of DL models in tasks such as pinpointing the origin of cancers of unknown primary origin or categorizing lung tissues into distinct cancer types (as exemplified by DeepPATH) might imply a diminished necessity for human expertise. This prospect elicits ethical concerns regarding the diminution of human discernment and experience in the realm of medical practice. Although DL models possess the capability to process and analyze data on a scale that is beyond human capacity, they are devoid of the intricate comprehension and ethical judgment that medical professionals offer. This situation engenders ethical queries concerning the equilibrium between technological expediency and the indispensable value of human insight in the field of medicine, particularly in intricate and sensitive domains such as cancer diagnosis and patient care. Additionally, the possibility of AI systems executing critical health-related decisions without human supervision entails risks associated with accountability and transparency in scenarios involving misdiagnosis or the omission of a condition's detection [15].

The accelerated adoption of deep learning (DL) models in cancer diagnosis, as evidenced by their successful application in automated Gleason grading and liver cancer grading using radiological imagery, introduces concerns regarding data privacy and security. The operational framework of these models necessitates extensive datasets comprising patient images and medical records, which inherently pose substantial risks concerning the confidentiality of patient information and the potential for data exploitation. It is of utmost importance to safeguard the privacy and security of sensitive medical data amidst the escalating digitalization and integration of artificial intelligence in healthcare.

This challenge is further intensified by the inherent biases present in the datasets employed for training these models. Such biases have the potential to engender disparate treatment outcomes across different patient demographics. Sustained collaboration amongst technologists, medical practitioners, and ethicists is critical to ensure that the advancements of DL in cancer diagnosis are harnessed in an ethical and equitable manner. This approach balances the innovative potential of DL with the ethical imperatives of patient privacy, data security, and fair treatment outcomes.

Ethical challenges in Cancer Gene Mutation Prediction

Deep Learning (DL) models have become useful in deciphering the genetic and epigenetic complexity of cancers through histopathology images. For instance, CNNs have successfully predicted various genetic mutations in lung cancer using hematoxylin and eosin-stained whole slide images (WSI), with an AUC range of 0.733 to 0.856 [16]. Similarly, these models have identified common mutations in liver cancer with AUCs exceeding 0.71. Furthermore, DL tools based on WSI are now capable of predicting a broad spectrum of genetic changes in pan-cancer analysis, including whole-genome duplications, chromosomal alterations, and specific gene variations [17].

Beyond individual gene mutations, DL models are also effective in predicting mutational patterns critical for treatment responses, like microsatellite instability (MSI) and tumor mutational burden (TMB) status. Wang et al. compared various DL models for TMB status classification, finding GoogLeNet and VGG-19 to be the best for gastric and colon cancers, respectively. These findings underscore the potential of histopathology image features in predicting genetic mutations, offering a more cost-effective alternative to direct sequencing when tumor specimens are unavailable.

DL models have also been applied to predict cancer mutations using non-invasive techniques like CT and PET/CT scans. Shboul et al. introduced a machine learning approach using radiomics for predicting various mutations in low-grade gliomas, achieving AUCs between 0.70 and 0.84 [18]. CT scans have also proved effective in predicting TMB status in NSCLC (AUC = 0.81). Although these results are promising, the specific features used by CNN models to ascertain mutation status warrant further exploration [18].

The expanding use of Deep Learning (DL) models in cancer genomics for predicting genetic and epigenetic characteristics through histopathology and radiology images, presents several ethical challenges. First and foremost, there is the issue of interpretability and transparency. While CNNs have shown promise in predicting genetic mutations in cancers like lung and liver cancer, with AUCs indicating high levels of accuracy, the decision-making processes of these models are often opaque. This "*black box*" nature raises ethical concerns about how DL models arrive at their conclusions, especially in cases where they predict complex genetic alterations or mutational patterns like microsatellite instability (MSI) and tumor mutational burden

(TMB). For example, the performance of models like MSINet in classifying MSI status in colorectal cancer or the use of GoogLeNet and VGG-19 in TMB status classification shows the need for explainability in medical decision-making. Patients and clinicians must understand the basis of these predictions to make informed treatment decisions, \ when these predictions influence crucial aspects of patient care like treatment planning and prognosis assessment [19].

Another significant ethical challenge pertains to the potential biases inherent in the datasets used to train these DL models. The success of DL in predicting genetic mutations using non-invasive techniques like CT and PET/CT scans, as seen in the prediction of EGFR mutation status in non-small cell lung cancer, depends heavily on the data on which these models are trained. If the training data lacks diversity or is skewed towards certain patient demographics, there is a risk of developing models that are less accurate for underrepresented groups. This could lead to disparities in cancer care, where certain populations might receive less accurate diagnoses or prognoses based on their genetic or epigenetic profiles.

The use of DL models in cancer genomics also raises concerns about data privacy and consent. The training of these models on histopathology and radiology images involves the use of sensitive patient information, which could be vulnerable to breaches in data security. This is critical when dealing with genetic information, which not only has implications for the individual patient but also for their family members. The ethical management of this data requires robust protocols to ensure patient consent, data anonymization, and secure data storage and handling. Moreover, as these models move closer to clinical implementation, there is a need for clear guidelines and regulations governing their use, addressing both the ethical implications of their deployment in healthcare settings and the protection of patient privacy in the era of AI-driven precision medicine.

2. Ethical challenges in Patient Prognosis, Response to Therapy, and Precision Medicine

Precision medicine customizes treatment for each patient. It segregates individuals into subgroups based on disease prognosis or treatment response. Deep Learning (DL) algorithms help in this by extracting features from medical data to create models that predict tumor relapse risks and patient treatment responses. Physicians can then offer more precise and appropriate treatments based on these predictions.

Immunotherapy has been used for treating various cancers, but the response rate varies significantly. Response prediction currently relies on biomarkers like PD-L1 expression, tumor mutational burden (TMB), microsatellite instability (MSI), and somatic copy number alterations. However, these biomarkers have limitations due to the invasive nature of biopsies and their representation of only a single tumor region. In precision medicine, DL models use radiomics and pathomics data to predict biomarkers related to immunotherapy response.

In addition to immunotherapy, predictive assays are important for selecting patients for targeted therapies and neoadjuvant chemotherapy (NAC). AI models identify imaging phenotypes correlated with specific mutations. A PET/CT-based DL model in NSCLC patients, for instance, differentiates EGFR-mutant from wild-type. DL algorithms also estimate responses to NAC in breast, rectal, and nasopharyngeal cancers. For example, Ha et al. used pre-treatment MRI data from breast cancer patients to train a CNN predicting responses to NAC, achieving an accuracy of 88% [20]. Accurate prediction of treatment response is vital to avoid unnecessary treatment toxicity and surgery delays.

The combination of Precision Medicine and Deep Learning (DL) in healthcare presents several ethical challenges. The customization of treatments using DL algorithms that segment patients based on their predicted disease prognosis or treatment response introduces concerns about data privacy and consent. The extraction and analysis of medical data for these models necessitates access to sensitive personal health information. The ethical dilemma arises in ensuring that patient data is used responsibly and with explicit consent. Furthermore, there is the issue of data representation and bias. DL models are only as good as the data they are trained on. If the data is not representative of the entire population, there's a risk of developing models that are biased towards certain demographic groups. This could lead to disparities in treatment effectiveness, potentially exacerbating existing healthcare inequalities. Physicians relying on these predictions must navigate the balance between model recommendations and individual patient care, ensuring that they do not over-rely on algorithmic suggestions at the expense of their professional judgment and patient preferences.

DL models show promise in enhancing treatment efficacy, they also present risks related to misinterpretation and over-reliance. For instance, the use of radiomics and pathomics data in DL models, as evidenced by the studies, must be approached with caution. These models might not fully capture the variability of individual tumors due to the limitations in the data used for training, such as the invasive nature of biopsies and their representation of only a single tumor region. This could lead to inaccurate predictions for some patients, raising ethical concerns about the harm caused by potential misdiagnosis or inappropriate treatment plans. Additionally, there's an ethical imperative to ensure equitable access to these advanced technologies. If only certain groups of patients have access to these predictive tools, it could widen the gap in cancer treatment outcomes across different socio-economic and racial groups.

The use of AI in predictive assays for targeted therapies and neoadjuvant chemotherapy (NAC) brings to the fore several ethical considerations. While AI models, like the PET/CT-based DL model for NSCLC and the CNN used by Ha et al. [20] for breast cancer, show high accuracy in predicting treatment responses, their implementation in clinical practice must be carefully managed. There is a risk of over-dependence on these models, potentially leading to the overlooking of clinical intuition or patient-reported symptoms. Moreover, the accuracy of these models in real-world settings, as opposed to controlled research environments, is a matter of ethical concern. Ensuring that these models are robust, transparent, and continuously validated in diverse clinical settings is critical to avoid misguiding treatment decisions. There is also an issue of communicating AI-based recommendations to patients. Patients must be adequately informed about how AI influences their treatment options, ensuring that their consent is based on a clear understanding of the technology's role in their care. This becomes even more significant in the context of dynamic AI models that adjust treatment plans over time, as it raises questions about continuous consent and patient autonomy in decision-making.

3. Ethical challenges in Deep Learning based Radiotherapy

Radiotherapy is an ideal area for AI integration due to its reliance on image and data-driven frameworks. Deep Learning (DL) is increasingly being used to enhance radiotherapy in areas like target volume delineation, organs at risk (OAR) identification, and automated treatment planning.

The process of target volume and OAR delineation is labor-intensive and its accuracy is dependent on the expertise of radiation oncologists. CNN-based semantic segmentation has emerged as a leading tool in this area, automating OAR delineation in various regions such as the head and neck, thorax, abdomen, and pelvis. Typically done on CT images, this process is quick, taking only a few seconds per patient. Segmentation accuracies are generally high for large, rigid organs like the mandible, parotid, kidney, and liver, but lower for smaller, irregular organs like the optic nerve, chiasm, intestine, and esophagus.

Automated contouring of tumor targets by DL poses challenges due to the diverse shapes and locations of tumors. However, it significantly speeds up the process and enhances consistency among radiation oncologists. Automated delineation has been explored in various cancers including nasopharyngeal, cervical, colorectal, lung, and breast cancers. For instance, Lin et al. developed a 3D CNN model for nasopharyngeal cancer contouring, showing acceptable concordance with human experts and improved accuracy and consistency among radiation oncologists [21].

Another key area is automated treatment planning. Traditional radiotherapy planning is complex and subjective, depending on the experience of clinical physicists. While knowledge-based techniques have improved consistency, they fall short in estimating patient-specific dose distributions. DL-based methods are now showing promise in individualized 3D dose prediction and optimization, as seen in Fan et al.'s work on head and neck cancers [22]. These methods can accurately predict clinical plans and optimize doses for different prescription doses within a single framework. Beyond these applications, AI is also being used in predicting radiation-induced toxicities, image reconstruction, synthetic CT generation, image registration, and monitoring intra- and inter-fraction motion.

AI's role in enhancing target volume delineation and identifying organs at risk (OAR) is critical. The use of Convolutional Neural Networks (CNN) for semantic segmentation automates the delineation of OAR, which is a labor-intensive process heavily reliant on the expertise of radiation oncologists. While this technology significantly speeds up the process and offers high accuracy for larger organs, the challenges arise with smaller, more irregular organs. The ethical concern here is the reliability of these automated processes in accurately identifying and delineating critical organs, which directly impacts patient safety. Inaccuracies in segmentation could lead to either under-treatment of the cancer or unintended radiation to healthy tissues, leading to serious complications. Furthermore, the reliance on AI technologies raises questions about the diminishing role of human expertise and judgment in treatment planning. The balance between technological efficiency and the critical oversight of experienced clinicians is a key ethical issue that needs to be addressed to ensure patient safety and optimal treatment outcomes.

Automated contouring of tumor targets by DL technologies, while enhancing speed and consistency among radiation oncologists, brings its own set of ethical challenges. Tumor delineation, being crucial in radiotherapy, requires high precision. DL models, although beneficial in standardizing contours across different practitioners, face the challenge of accurately delineating diverse tumor shapes and locations. The ethical concern here is ensuring that these automated processes do not compromise the individualized nature of cancer treatment. Each patient’s tumor is unique, and over-reliance on automated systems could lead to standardized treatment plans that may not be optimal for every patient. This raises the question of how much trust can be placed in these systems and what checks and balances are required to ensure they are used as an aid, not a replacement, for human expertise.

DL-based methods are transforming traditional, subjective planning processes into more standardized and efficient ones. However, this transition brings ethical considerations regarding the transparency and interpretability of AI systems. As these technologies become more integrated into clinical practice, understanding how they arrive at specific treatment plans becomes imperative. This is crucial not just for clinician trust in the system, but also for patient understanding and consent. Patients have the right to know how decisions about their treatment are made, and complex AI algorithms can make this transparency challenging. Moreover, there is the ethical issue of ensuring equitable access to these advanced AI tools. Disparities in access to high-quality radiotherapy services are a global concern, and the integration of expensive AI technologies could potentially widen this gap, making cutting-edge treatments available only to a subset of patients.

Conclusion

The primary objective of this study is to analyze the ethical challenges associated with the integration of Artificial Intelligence (AI) and Deep Learning (DL) technologies in oncological management. The investigation specifically focuses on various aspects of cancer care, including screening, diagnosis, classification, grading, prognosis, therapeutic response, precision medicine, and radiotherapy, where AI and DL are increasingly being employed. This research aims to identify and critically assess the ethical implications arising from the use of these technologies, such as the accuracy and reliability of AI systems, issues pertaining to data privacy and patient consent, equitable access to AI-enhanced medical technologies, potential biases in AI algorithms, the combination between AI tools and human medical judgment, and the implications of AI in treatment customization. Furthermore, the study seeks to explore the development of comprehensive data governance frameworks and the creation of AI systems that are both transparent and interpretable. This study endeavors to facilitate effective collaboration between technology developers, healthcare professionals, and ethicists to ensure that the deployment of AI in oncology is conducted in an ethically responsible manner. Through this investigation, this study aims to contribute to the formulation of guidelines and policies that address the ethical concerns related to the use of AI in cancer care.

References

[1] B. McBride, S. Hawkes, and K. Buse, "Soft power and global health: the sustainable development goals (SDGs) era health agendas of the G7, G20 and BRICS," *BMC Public Health*, vol. 19, no. 1, p. 815, Jun. 2019.
[2] C. Oluwatoyin Onabola, "Planetary health as a central context to the sustainable development goals (SDGs)," *J. Environ. Health Sustain. Dev.*, Sep. 2019.
[3] Z. Bai, R. Yang, and Y. Liang, "Mental task classification using electroencephalogram signal," *arXiv preprint arXiv:1910.03023*, 2019.
[4] N. Wentzensen *et al.*, "Accuracy and Efficiency of Deep-Learning–Based Automation of Dual Stain Cytology in Cervical Cancer Screening," *J. Natl. Cancer Inst.*, vol. 113, no. 1, pp. 72–79, Jun. 2020.
[5] D. Ardila *et al.*, "Author Correction: End-to-end lung cancer screening with three-dimensional deep learning on low-dose chest computed tomography," *Nat. Med.*, vol. 25, no. 8, p. 1319, Aug. 2019.
[6] J. D. Cohen *et al.*, "Detection and localization of surgically resectable cancers with a multi-analyte blood test," *Science*, vol. 359, no. 6378, pp. 926–930, Feb. 2018.
[7] B. Ehteshami Bejnordi *et al.*, "Diagnostic Assessment of Deep Learning Algorithms for Detection of Lymph Node Metastases in Women With Breast Cancer," *JAMA*, vol. 318, no. 22, pp. 2199–2210, Dec. 2017.
[8] P. Bandi *et al.*, "From Detection of Individual Metastases to Classification of Lymph Node Status at the Patient Level: The CAMELYON17 Challenge," *IEEE Trans. Med. Imaging*, vol. 38, no. 2, pp. 550–560, Feb. 2019.
[9] H. Luo *et al.*, "Real-time artificial intelligence for detection of upper gastrointestinal cancer by endoscopy: a multicentre, case-control, diagnostic study," *Lancet Oncol.*, vol. 20, no. 12, pp. 1645–1654, Dec. 2019.
[10] W. Xiong, T. Hoang, and W. Y. Wang, "DeepPath: A Reinforcement Learning Method for Knowledge Graph Reasoning," *arXiv [cs.CL]*, 20-Jul-2017.
[11] D. Wang, Z. Wang, C. Fang, Y. Chen, and Z. Chen, "DeepPath: Path-Driven Testing Criteria for Deep Neural Networks," in *2019 IEEE International Conference On Artificial Intelligence Testing (AITest)*, 2019, pp. 119–120.
[12] E. Arvaniti *et al.*, "Author Correction: Automated Gleason grading of prostate cancer tissue microarrays via deep learning," *Sci. Rep.*, vol. 9, no. 1, p. 7668, May 2019.
[13] W. Bulten *et al.*, "Automated deep-learning system for Gleason grading of prostate cancer using biopsies: a diagnostic study," *Lancet Oncol.*, vol. 21, no. 2, pp. 233–241, Feb. 2020.
[14] X. Wu, Z. Bai, J. Jia, and Y. Liang, "A Multi-Variate Triple-Regression Forecasting Algorithm for Long-Term Customized Allergy Season Prediction," *arXiv preprint arXiv:2005.04557*, 2020.
[15] A. Chavez, D. Koutentakis, Y. Liang, S. Tripathy, and J. Yun, "Identify statistical similarities and differences between the deadliest cancer types through gene expression," *arXiv preprint arXiv:1903.07847*, 2019.
[16] N. Coudray *et al.*, "Classification and mutation prediction from non-small cell lung cancer histopathology images using deep learning," *Nat. Med.*, vol. 24, no. 10, pp. 1559–1567, Oct. 2018.

[17] M. Chen *et al.*, “Classification and mutation prediction based on histopathology H&E images in liver cancer using deep learning,” *NPJ Precis Oncol*, vol. 4, p. 14, Jun. 2020.
[18] Z. A. Shboul, J. Chen, and K. M Iftekharuddin, “Prediction of Molecular Mutations in Diffuse Low-Grade Gliomas using MR Imaging Features,” *Sci. Rep.*, vol. 10, no. 1, p. 3711, Feb. 2020.
[19] Y. Liang, “Analysis and algorithms for parametrization, optimization and customization of sled hockey equipment and other dynamical systems.” 2020.
[20] R. Ha *et al.*, “Prior to Initiation of Chemotherapy, Can We Predict Breast Tumor Response? Deep Learning Convolutional Neural Networks Approach Using a Breast MRI Tumor Dataset,” *J. Digit. Imaging*, vol. 32, no. 5, pp. 693–701, Oct. 2019.
[21] L. Lin *et al.*, “Deep Learning for Automated Contouring of Primary Tumor Volumes by MRI for Nasopharyngeal Carcinoma,” *Radiology*, vol. 291, no. 3, pp. 677–686, Jun. 2019.
[22] J. Fan, J. Wang, Z. Chen, C. Hu, Z. Zhang, and W. Hu, “Automatic treatment planning based on three-dimensional dose distribution predicted from deep learning technique,” *Med. Phys.*, vol. 46, no. 1, pp. 370–381, Jan. 2019.