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Artificial Intelligence for Cancer Diagnosis and Treatment in Africa

Wasswa Shafik

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This book provides a comprehensive exploration of how artificial intelligence and digital health innovations are reshaping cancer care across Africa. Beginning with the foundational epidemiological and health system realities of the continent, it examines Africa's readiness for oncology transformation and the ethical, legal, and social considerations of adopting AI in cancer diagnosis and treatment.

The book presents advanced applications, from deep learning-driven imaging and precision oncology to telepathology, mobile health platforms, and digital tools for survivorship, relapse prediction, and palliative care. It further highlights strategies for scaling AI systems, strengthening rural health infrastructure, fostering public–private partnerships, and building a skilled workforce equipped for the next era of oncology.

Designed as a timely resource for clinicians, cancer researchers, AI scientists, digital health innovators, public health professionals, policymakers, medical educators, and postgraduate students, this work bridges cutting-edge technology with urgent public health needs. It offers actionable frameworks, contextual adaptations for low-resource settings, and a forward-looking vision for equitable, AI-enabled cancer care in Africa. This book serves as both a guide and a catalyst for sustainable, inclusive, and technologically empowered oncology systems across the continent.

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This book is dedicated to my family, whose unconditional love, sacrifices, and unwavering belief in my potential have been the foundation of all my achievements. Their tireless support and encouragement throughout this book-writing journey have inspired me to strive for excellence and persevere in the face of every challenge.

I also dedicate this work to my friends, members of Dig Connectivity Research Laboratory (DCLab) and the School of Digital Science (SDS) at Universiti Brunei Darussalam, whose patience, understanding, and constant motivation have been my anchor through the highs and lows of this book journey. Your presence gave me strength during the most difficult times, and your faith in me kept me going when I doubted myself.

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Preface

Africa has over 1.3 billion people with a risk of developing cancer during their lives of beyond 30%. There were 1.12 million cancer deaths in Africa in 2020, with 9 million worldwide. In males, prostate and lung have the highest incidence, while in females, breast and cervical have the highest incidence. Prostate, liver, and lung are the most frequent causes of cancer deaths in males, while breast, cervical, and liver in females. Nevertheless, kidney cancer, eye cancer, melanoma, vulvar cancer, corpus uteri cancer, oropharynx cancer, and thyroid cancer have a higher estimated incidence in Africa compared to the world. Seventy percent of cancer deaths occur in the poorest regions of Africa, where there is a higher rate of infectious causes of cancer, and significant shortages in clinical and palliative care, prevention, early detection, treatment, and reconstruction. The special characteristics that inflation has had in Africa because of COVID-19 worsen all areas of cancer control. For these and other reasons, Africa needs to implement cancer control urgently. Here are the many databases available, which would make it possible to improve not only the care of cancer patients but also prevention, early diagnosis, and palliative care. Cancer is a major public health problem in Africa, and the incidence and related mortality rates of this disease are gradually increasing. In males, prostate cancer is the most frequent, and in females, breast cancer surpasses cervical cancer, both worldwide and in Africa. However, infections producing chronic inflammation and immunosuppression are responsible for a higher percentage of cancer cases and deaths in Africa. Colon cancer incidence and mortality rates are rising sharply in several parts of Africa due to urbanization and changes to a Western lifestyle, and this trend will accelerate in the coming years. Culturally modified dietary habits, together with actions to prevent infectious diseases that cause cancer, may slow the uptake of the Western lifestyle.

The burden of cancer is predicted to increase to 21.7 million new cases and 13 million cancer deaths per year globally by 2030. In Africa, 1.2 million new cancer cases are expected in 2030. Globally, delays in diagnosis and treatment pave the way for poor cancer survival rates. These disparities are pronounced in low-resource countries due to late presentation, late diagnosis, and late initiation of treatment or none at all. The five-year relative survival of many cancers is significantly worse in African countries compared to high-income countries. In addition, data on the burden and patterns of cancer incidence in Africa are grossly incomplete. We review some of the challenges associated with obtaining a cancer diagnosis. The decline in cancer-related deaths in high-income countries has been attributed to early detection and treatment of cancer. In recent years, cancer-associated deaths in Africa have also started to decline. However, these statistics may be grossly inaccurate and also alarming, given that many low- and middle-income countries are unable to generate civil registration and vital statistics data. Furthermore, treating cancer in Africa is hampered by poor access to diagnostic equipment, including computed tomography and magnetic resonance imaging scanners. Africa has only 30% of the number of hospitals providing cancer treatment that high-income countries have, and only three sub-Saharan countries report a distributive ratio of one for having both a pathology laboratory and a chemotherapeutic center. Scans of the thorax or abdomen are used to help arrive at a diagnosis in approximately one-third of cancer patients in high-income countries but are rarely used for this purpose in Africa due to cost. In addition, histopathological confirmation of the cancer type before initiation of treatment is often impractical because of limitations in population-level resources for pathology diagnosis.

Recent publications revealed that artificial intelligence (AI) applications were most frequently used in the diagnosis phase of the cancer care continuum, particularly in medical image interpretation. Steps toward standardization of lung cancer imaging and improved technology have made rapid radiology diagnosis of lung cancer more feasible. Many AI-based computer-aided diagnosis tools harness currently available clinical imaging datasets to assist radiologists in cancer detection as well as risk stratification. Certainly, radiologists may benefit from the advances associated with such tools and innovative techniques. It is with these developments and technology pushes that researchers worldwide are advocating for more rapid development, initiation of clinical trials, and regulatory guidance surrounding the approval of such AI-based adjunct tools to oncologists. The speed at which AI-based tools evolve and mature for clinical readiness is increasing and likely to continue to do so as massive amounts of annotated imaging data are used to train ML algorithms. Certainly, increased efforts to develop such algorithms, with close collaborations between radiologists, oncologists, and data scientists, are highly encouraged. Breast cancer is the most common type of cancer in the world, with over 2 million cases expected each year, and it represents the second-leading cause of cancer-related deaths among women. Several screening strategies have been implemented in national policies, and mammography is the most widespread test. However, it still presents several limitations, including a low sensitivity for specific groups and a high false-positive rate, particularly in premenopausal women. Artificial intelligence has demonstrated substantial promise in assisting radiologists in breast cancer detection and risk stratification. Recent developments have integrated deep learning algorithms with digital mammography for tasks such as breast region localization and segmentation, tumor detection, and diagnosis prediction. AI models are beginning to show the capability to provide CAD-like assistance for radiologists. However, these models are still in the development stage and require further improvement and standardization before prospective clinical evaluation.

Advancement of Information and Communication Technologies (ICTs) has disrupted traditional health systems globally. The introduction of digital health solutions aims to bridge the gap between an individual's health status and the need to drive wellness. Digital health strives to leverage available resources to optimize healthcare service delivery, tackle health disparities, and drive toward universal health coverage. Digital health expands on the usage of technology and digital communications to enhance the processes of the health system in the delivery of services to individuals and the community at large at all levels. Digital health assists in the innovation of cancer management to improve on the limitations of the outdated conventional processes of healthcare. Digital health innovation primarily encompasses a variety of technology-based solutions, including telemedicine, artificial intelligence, big data, virtual and augmented reality, robotics, and mobile devices such as smartphones and wearables. There has been an explosion of global startups harnessing new technologies to tackle health sector challenges. These newly emerging digital health innovations, among other benefits, can increase access to cancer education, early detection, action, and treatment. Africa has been increasingly adopting digital health innovations. However, more work still needs to be done, especially in the cancer space, to begin realizing the potential benefits outlined. Globally, telemedicine has been touted as a solution to the challenge of increasing access to healthcare services, especially specialized health services and education, to remote areas in Africa and other low- and middle-income countries. Increased access to healthcare services has been associated with reduced mortality and morbidity rates. In general, the use of mobile devices and applications has been proposed to reduce the burden of chronic diseases, infectious diseases, re-admissions, and overflow of health facilities through the provision of education, diagnostic and treatment services, and emotional support. In Africa, telemedicine in the form of mobile applications is being increasingly applied to disseminate information, educate, and increase access to services, early detection, and support to others with cancer. Other forms of digital health being integrated into traditional cancer systems include electronic health records. The implementation of EHRs strives to streamline the outpatient and inpatient processes for healthcare service delivery. EHRs are proposed to eliminate recall bias, reduce paperwork errors, and enhance the monitoring of patients diagnosed with cancer and other chronic diseases.

While most evidence cited in support of the use of AI in oncology concerns cancer diagnosis, less support exists for its use in areas of cancer treatment. Nevertheless, as our understanding of the unique biological properties of human cancers improves, an increasing role for computerization in individualized patient therapy is emerging. It is now widely recognized that there is no single treatment that works for all cancers; each patient, and even the same type of tumor in different patients, is unique. Thus, the concept of personalized medicine has come to the fore, and AI can help oncologists determine the most appropriate treatment for patients depending on their unique genes and their cancer. Enabling factors to guide AI implementation in oncology treatment involve validating platforms for rapidly assessing drug response, analyzing drug interactions according to the genetic dependencies of specific clinical malignancies, and predicting clinical outcomes according to drug knowledge. Prominent examples include AI tools that have been validated to be able to assist oncologists in specifying personalized treatment plans for patients based on their unique genes, predicting which patients are at risk for chemotherapy response, and determining the optimal chemotherapy via analysis of paired biopsies pre- and post-treatment. In a further advance, robotic surgical techniques, which have gained popularity among surgeons in most countries, can now be improved with AI accessories, including cameras with computer vision, depth imagery, and sensors, which have also become commercially available. These developments include the use of AI in motion tracking when using robotic-assisted surgery and possibly the future application of AI in tumor resection with robotic assistance. Radiation therapy continues to be one of the standards of treatment for most solid tumors, relying on the accurate positioning of the tumor as well as precise mapping of the dose distribution around the target volume.

The application of AI in digital health, especially in cancer diagnosis and management, has been transformative, notably due to the intricate nature of cancer's form and function, and the extensive volume of data produced. Data in healthcare is often reflective of society at large, and therefore prone to bias, albeit not necessarily through directly related effects. Hence, health data are fraught with ethical pitfalls. AI evaluations are not independent. They are made based on algorithms that themselves may be biased toward specific outcomes. Thus, bias detection and mitigation in digital health AI algorithms are essential in addressing prejudice. The issue of accounting for bias and variation is twofold in research. First, it is important to ensure that there is variability across the entire cohort of patients involved in the training, testing, and validation pipelines. Second, it is important to consider that irrespective of the training cohorts, any implementation of an AI model in a newly different population may require a careful examination of bias, even if a less biased training set is used. We consider three substantive areas of medicine and clinical care in which ethical factors must be considered when applying AI: informed consent, privacy and data governance, and bias. Ethics in AI is a field of interest in and of itself, with numerous guidelines and frameworks that are proposed beyond the essential examination of the social hot topics of AI: job replacement and displacement, bias, privacy, and security. Given dignity is respected, the healthcare goals of eating, living, and dying well can be enabled with and without AI, as well as the implicit greater good argument in global health. The development of an AI tool requires successive engagement with stakeholders throughout its development and may benefit from co-designed engagements with stakeholders, such as members of the patient advocacy group(s).

Developing a strategy for the implementation of AI and digital health relies on strong foundations. Policy frameworks for AI implementation in general healthcare governance are generally lacking in Africa, and the acceptance and adoption of AI in health have important dependencies on pre-existing trust in conventional models. Further, the optimization and best practice use of AI in health are based on existing large-scale infrastructure in the form of digitalization of primary and secondary health data and data systems management, plus policy support for local product development, adaptation, and deployment. A robust clinical and epidemiological research environment incorporating innovative methods of data analysis, data mining, deep learning, and modeling at both primary and secondary healthcare levels will strengthen the readiness for the validation of AI technology and its application in real-world settings to augment clinical decision support systems and outcome prediction, among others. Fundamental to AI implementation in a general health governance context will be (i) the policy context for the wider integration of technology in areas such as telemedicine and mobile health, (ii) the regulatory framework for the approval and inclusion of AI products along the continuum of care, and (iii) the development of training programs to strengthen the capacity of the health workforce to adapt and utilize AI technology as part of their duties. These elements must remain dynamic and adaptable to changes as lessons are learned from the iterative introduction of AI technology into Africa's healthcare systems. The creation of robust local health AI ecosystems combining health systems research, product development, and technology corroboration, utilizing the continent's world-renowned research institutions for statistical analysis, epidemiological modeling, and deep learning algorithm and software development, will facilitate the expedited implementation alongside dynamic regulatory support.

The application of AI in cancer care continues to advance and holds great promise to achieve improved outcomes for patients across domains. AI's capacity to analyze and distill massive amounts of complex data can be leveraged with exciting emerging technologies, such as digital holographic, acoustic, and electromagnetic sensing, advanced imaging techniques, molecular profiling of tumor microenvironment and circulating tumor cells, miniaturized lab-on-chip devices for point-of-care testing, gut microbiome profiling, digital pathology, radiomics, genomics/epigenomics-based patient stratification, multi-omics-enabled virtual biopsy, clinical data syndication, and blockchain for health data sharing and patient privacy. These combined technologies have tremendous potential to enable scaling in low-resource settings with respect to early diagnosis, re-stratification of therapeutic options, and routine monitoring of treatment response. These approaches may also help in grappling with the issues of high pricing and unequal access to advanced diagnostic and therapeutic technologies. In addition, advanced interactive, personalized decision-support applications for empowering patient involvement are being increasingly developed. Innovative models for integrating AI into collaborative problem-solving safety nets involving socially active stakeholders can also be devised. By alleviating the cognitive load of the patient community, such initiatives can redirect their focus on taking responsibility for their health in coordination with the other stakeholders. If harnessed sensibly, AI could prove to be an incredible companion to humans in tackling the cancer menace in Africa.

This book begins by grounding the reader in Africa's oncology landscape. Chapter 1 analyzes cancer's epidemiological profile on the continent, identifying systemic barriers and emerging opportunities. Chapter 2 evaluates the readiness of African digital health ecosystems for AI integration in oncology, focusing on infrastructure, policy, and digital maturity. Chapter 3 discusses the global evolution of AI in oncology and how these tools can be contextualized for Africa's unique needs. Chapter 4 explores the ethical, legal, and social implications of AI in cancer care, while Chapter 5 highlights the importance of data governance, interoperability, and equity in building inclusive digital health systems. The second half of the book delves into applied AI solutions and implementation strategies. Chapter 6 presents AI-driven imaging and diagnostic systems using deep learning for early cancer detection. Chapter 7 discusses NLP-based tools that enhance clinical decision support, and Chapter 8 explores remote diagnostics, telepathology, and teleradiology in low-resource African settings. Chapter 9 examines the integration of genomics and AI for precision oncology tailored to African populations, while Chapter 10 focuses on aligning AI tools with national cancer guidelines. Chapters 11–15 explore AI's role in treatment monitoring, survivorship, relapse prediction, palliative care, and rural infrastructure. The final section (Chapters 16–20) addresses scale-up strategies, public–private partnerships, impact evaluation, workforce development, and future innovations, offering a strategic vision for AI-enabled, equitable cancer care across Africa.

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The completion of this book is the outcome of a collective intellectual journey, and I owe a profound debt of gratitude to many individuals and institutions whose contributions, both direct and indirect, have shaped its direction and substance. I wish to begin by acknowledging the School of Digital Science (SDS), Universiti Brunei Darussalam, whose intellectual rigor, methodological clarity, and persistent encouragement provided not only critical guidance but also the academic discipline that underpins this work. Their mentorship cultivated the balance between theoretical depth and practical relevance that I sought to achieve throughout this book. In particular, the academic community at the Dig Connectivity Research Laboratory (DCRLab) provided a vibrant platform for interdisciplinary discourse at the nexus of artificial intelligence, sustainability, and societal transformation. Their critical reflections, collaborative spirit, and shared pursuit of impactful research profoundly shaped several chapters of this book. I am grateful to the broader network of scholars and practitioners working at the intersections of academia, technology, sustainability, and governance. Their pioneering work laid a solid foundation upon which this book builds. Likewise, I acknowledge the editors, peer reviewers, and publishing professionals who invested their time and expertise in refining the manuscript and ensuring its scholarly relevance. On a more personal note, I extend heartfelt thanks to my family and close friends, whose patience, resilience, and unwavering encouragement sustained me throughout the long hours of research and writing. Their understanding provided the emotional stability necessary to undertake such a demanding intellectual endeavor. Finally, I wish to recognize the global community of students, researchers, and policymakers whose engagement with the themes of artificial intelligence, healthcare, digital health sustainability, and inclusive development continues to push the boundaries of knowledge. This textbook is written with the hope that it will serve as a scholarly textbook, a reference, and a catalyst for critical debates, informed decisions, and transformative practices in the years ahead. We can make a sustainable difference, no matter how small it is, because it will be of merit to the next generation.

Introduction

In recent decades, numerous studies have reported strong predictive capabilities for machine learning and deep learning models across a wide range of tasks in the fields of radiology, digital pathology, histology, and genomics. However, these studies have been conducted primarily in Europe, North America, and parts of Asia, where the distribution of patients and disease phenotypes is sufficiently well known, and where the data on the causes, patterns, and dynamics of disease continue to be generated and recorded. Less effort has been directed to the question of harnessing AI technology for the benefit of the African continent and other parts of the Global South, where the need is more urgent than in the Global North and where the potential return on investment is likely to be far greater. Nevertheless, the share of AI-based applications of radiomics, genomics, and digital pathology in oncology has increased at an impressive rate.

Cancer incidence and mortality rates are on the rise in Africa. Despite constituting only 17% of the global population, the African continent is home to approximately 9% of cancer cases and deaths. These statistics, however, mask a great deal of variability: cancer incidence and mortality are increasing at a much higher rate in regions of Africa, such as North Africa, than in Western countries; indeed, some countries have experienced a decline in cancer incidence. Furthermore, the majority of published data on cancer epidemiology in sub-Saharan Africa originates from only 5% of the continent's countries. The International Agency for Research on Cancer has reported that among men in North Africa, the three leading cancers in 2020 were prostate, lung, and colorectal cancer, while breast, cervix uteri, and colorectal cancer were the top three among women. In sub-Saharan Africa, cervical cancer remains the most common type among women, but breast cancer is not far behind; among men, Kaposi sarcoma constitutes the most common form. Age-standardized incidence and mortality rates are on average lower than in the more developed regions of the world, but the burden of cancer-related disease and death increases sharply with age.

A consistent pattern of increasing incidence and mortality punctuates a historical record of cancer diagnosis and treatment in Africa. With data sourced predominantly from the African Cancer Registry database (ACRD), the region presently accounts for approximately 7% of worldwide reporting and 17% of global cancer deaths. Cancer is the third most common cause of mortality in Africa, following communicable diseases and non-communicable diseases, and evidence from recent studies suggests that cancer has now surpassed tuberculosis as the most lethal infectious disease in several countries. According to the World Health Organization 2020 report, the following ten form the most diagnosed cancers on the continent (in ascending order of incidence): head and neck, cervical, kidney, liver, colorectal, breast, prostate, nonmelanoma skin cancers, Kaposi sarcoma, and Hodgkin lymphoma. Notable disparities are found in incidence and mortality rates for these and other cancers across different African regions, attributable in large part to the lack of organized screening programs and insufficient access to treatment in some areas.

Despite affecting a relatively small number of individuals in younger age groups, cancer is now among the most prevalent diseases in Africa from 50 years onward and poses a significant challenge for the continent's growing elderly population. Extrapolated data, which predict a 133% increase in cancer mortality by 2040, highlight the urgent need to alleviate emerging capacity issues. Furthermore, risk factors for the disease (both communicable, such as viral infections, and non-communicable, such as tobacco use) vary geographically and influence the range of cancer types diagnosed in each region. Since nearly all African nations are characterized by resource constraints, public health focus should remain on the prevention of communicable diseases. Unfortunately, data quality and availability remain poor, with a limited number of cancer registries actively processing new information. Radiation therapy and more sophisticated treatment methods are not yet available

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in all countries, and there is insufficient funding to support these developments. It was within this context that the ACRD was initiated in March 1996. Hosted by the International Agency for Research on Cancer, the ACRD now serves to collate epidemiological data on cancer from the continent and provide training for cancer registration. Recent WHO projections predict a rapid increase in cases for Africa by 2030 and beyond, which are yet unrecorded due to incomplete data capture.

Artificial intelligence encompasses techniques that enable computers to mimic human-like behaviors. Machine learning, a subfield of artificial intelligence, entails exposing computers to vast troves of historical data, enabling them to identify complex patterns, make predictions, and refine performance. Deep learning is an advanced form of machine learning that applies convolutional neural networks to images and radiomics for high-dimensional feature extraction from images, pathology scans, and omics data. Machine learning methods may be categorized as supervised or unsupervised. Supervised methods require a training set of labeled data (input data and the corresponding desired result) for model training, followed by model evaluation using an independent test set. The model is deemed useful if it can generate outputs with acceptable accuracy when supplied with unlabeled input. A variety of machine learning tasks, such as segmentation, classification, regression, adversarial generation, and synthesis, have been undertaken successfully using either supervised or unsupervised methodologies. Deep learning tends to shine when the volume of labeled data is vast, whereas classical machine learning or domain-specific heuristics can excel when the volume of labeled data is moderate; subject-matter experts have devoted significant knowledge in feature engineering, or the use case is not image-based. A significant requirement for successful deployment of machine learning methods is the availability of a sufficiently large, high-quality, diverse, and well-annotated dataset. Infrastructure supporting data governance, quality, availability, and ease – or difficulty – of access dramatically influences the success and generalization of a model. Performance metrics need to be selected according to the specific task being solved, and validation must also be tailored accordingly, especially for rare-event predictions.

For cancer diagnosis to be effective, an enduring partnership between the health system and AI tools is essential. The various speakers at Diffusion, the SONAP Annual Conference 2023 in Accra, highlighted the applicability of AI in three aspects of radiology, pathological diagnosis, and genomics. Radiographs, CT and MR scans, and other images are crucial supplementary data that are acquired for a significant percentage of patients with cancer. There are neural networks capable of performing digital screening and diagnosis for these specimens. Nevertheless, the burden of diagnosis is exceedingly high, especially in the poorer regions, where radiologists and pathologists are lacking. A win–win yet cautious role for AI in these areas includes pre-screening, triaging, and assisting the expert before reporting. AI in these areas is capital- and labor-intensive compared with the rest of medicine. A data pipeline for data quality and annotation solutions, along with integration to enable direct workflow implementation into existing reporting systems of hospitals, is pertinent. NDMLs' ability to perform spatial mini-maps together with Albright-Kossor-by-quotient and clinical data also supports modality-sharing/multimodal-complementary AI. Remote lack of infrastructure and expertise marks an opportunity for AI-assisted reported analysis. AI is still noisier than nurses and non-expert clinicians, and it is inappropriate to unquestioningly trust it. Cloud or local deployment is a design consideration, local being preferable to those with complete borderline cases that cannot be submitted for a clinical report.

AI tools for imaging, pathology, and genomics represent the most mature areas for high-resolution cancer diagnostic platform development. In radiology (primarily chest imaging), major vendors have either integrated fully automated AIs into their products or provided an additional layer of AI-powered diagnosis alongside the human report. Similarly, in digital pathology, commercial solutions able to provide a primary diagnosis by using multiple stains and covering whole-slide images have been developed and validated. For genomics, several companies have enabled the deployment of AI algorithms that reveal signatures outside the report generated by the manufacturer. Multiple pathologies, from all types of hematological cancers to solid tumors (breast, skin), now have AIs able to report in a standalone fashion, but the requirement of human annotation for training and performance evaluation hampers the speed of development and validation.

Radiological and pathology images, as well as genomic sequencing data, are in extensible formats supported by interoperability standards. Disparate clinical information (clinical history, physical examination, laboratory reports, and computed data, including cancer stage, score enumeration, and type of therapy imposition) is in semistructured and unstructured formats. Radiological and pathology reports in a readable form are normally accepted for algorithm evaluation after careful reading and binarization by primary pathologists. Speedy incorporation of all cancer-relevant information in a single AI pipeline will boost diagnostic precision. For AI diagnosis, these widely accepted data structures allow the development of high-resolution solutions without complex, costly, and time-consuming center- and pathology-wise integration protocols. AI-assisted cancer genomics analysis has entered a phase similar to digital pathology, with several established AIs reporting signatures beyond the human-generation product and the full spectrum of hematological cancers being supported by available AIs. Eventually, large winning-acquisition data structures and an increasing knowledge platform will allow the deep-learning teams to develop public-domain solutions for the remaining cancer types.

Artificial intelligence (AI) systems can aid clinicians during treatment planning by supporting:

(i) disease staging;
(ii) early prognosis;
(iii) therapy selection;
(iv) external beam radiotherapy dose optimization; and
(v) adaptive treatment of recurrence or treatment failure.

The objective of these AI systems is to improve clinical decision-making and, ultimately, patient outcomes. Uncertainty should be transparently communicated to clinicians, who remain responsible for therapeutic decisions. Severe treatment planning and therapy-receipt-related uncertainty are best handled in a multidisciplinary environment, where experts with different but complementary training jointly define a treatment plan. While research datasets have generally been collected retrospectively from single institutions, prospective multi-center clinical trials are the gold standard to investigate the efficacy of a novel therapeutic approach, including pre-prepared AI support. AI systems can also help stage a patient's cancer, provide early prognostic stratification for patients presenting with a particular disease stage, and suggest therapy selection. In other words, during the often-ambiguous decision-making processes surrounding treatment planning, AI systems can assist but should always remain secondary to the oncologist.

The present study of AI-driven cancer diagnosis and treatment is predicated on the availability of high-quality data and a conducive healthcare infrastructure. Consequently, special emphasis is placed on the development and continuous upkeep of these data ecosystems. The following sections address the necessary conditions for the success of various AI applications along the cancer diagnostic and treatment pathways. Important considerations include data governance, interoperability, storage, computing resources, and the deployment of AI at local facilities versus in cloud environments. Potential sources of health-related data are identified along with relevant regulatory frameworks, standards, and policies. The successful implementation of AI systems requires well-functioning health infrastructure and extensive data ecosystems that serve as repositories of high-quality data, in terms of both quantity (volume) and data quality (completeness, utility). Data from health information systems, hospitals, clinics, and registries can improve the performance of AI applications by helping to overcome the limitations of isolated laboratories. AI applications built on local datasets, models, and ecosystems that can operate without internet connectivity, or where connectivity is sporadic, are clearly desirable. Pilot studies offer opportunities to develop such data ecosystems, along with the supporting infrastructure (computing resources, cloud versus local storage). Key decisions include whether the AI application is hosted in the cloud or at local facilities, and the degree of data governance required to ensure interoperability, storage, and access. The current state of data ecosystems is described in order to identify the main sources of health-related data as well as gaps and needs related to data stewardship, regulation, and quality assessments.

Implementation of AI in cancer diagnosis and therapy in Africa faces several technical, operational, infrastructural, financial, and sociocultural hurdles; viable, evidence-based solutions exist for each major category. The technical challenges arise from the typically limited volumes of specialized data and accompanying long-tailed performance characteristics. AI, especially supervised deep learning, thrives on large datasets. However, corresponding image or genomic data needed to train multi-centric, high-quality real-world applications are scarce, particularly in less economically developed or resource-constrained regions. Health infrastructures in Africa often cannot generate domain-specific data, hindering the development of AI-based diagnostics for local use or to ensure populations can benefit from these devices. In addition, trained models can be valid only for patients similar to those represented in the training data distribution. The feasibility of data sourcing and annotation can often be addressed by careful project design or collaboration. Strategies exist to overcome hospitals' de facto restrictions on using patient consents to generate secondary data without disclosure, remote data haplotyping has been shown possible with even very small numbers of samples, and multinational research entities can specially sample patients for device validation.

AI models for healthcare decision support must consider ethical, legal, and social implications at every stage of their development. Research in data governance and data sharing for Africa highlights key issues. Addressing these issues requires deliberate attention to consent, patient privacy, medical bias in AI systems, accountability, patient trust, and considerations of equity. These principles should shape policy development and oversight structures for AI systems in health and society more broadly. Adequate public norms, legal frameworks, and regulations must underpin the sustainable, socially beneficial deployment of AI technology in healthcare. Strong frameworks will clarify the boundaries within which AI technologies can be expected to be developed, made available, and used. Regulatory frameworks matter for AI, particularly in areas of significance for human well-being, since the complexity of AI systems and the fact that their behavior cannot always be predicted a priori mean that risks may not always be obvious or manageable through conventional approaches to accountability. Integrating regulatory insights with ethical considerations specific to AI technology can clarify the scope and purpose of AI–ML regulation.

The adoption of AI in cancer diagnostics and treatment in Africa requires close attention to personnel training, governance, and certification. An implementation roadmap must specify competence needs across stakeholder types (healthcare professionals, data scientists, engineers), educational programs (undergraduate and graduate degrees, continuing education, mentoring), assessment frameworks, and stewardship organizational structures with explicit mandates and responsibilities. The establishment of appropriate career paths for domains critical for successful AI deployment will enhance retention. Regimes ensuring ethically sound treatment of health data should be put in place. Given that AI technologies are intended to supplement rather than replace health professionals, it is essential to develop roadmaps for cost-effective implementation. The deployment of AI within complex socio-technical systems ultimately requires the formation of proper multidisciplinary teams aimed at solving precise clinical problems, encompassing the expertise necessary to ensure both the successful specification and use of AI solutions. These teams must include members with the training necessary to oversee the ethical and legal implications of any deployment. To this effect, it is recommended that the training of such individuals follow a structured curriculum covering ethics, law, sociology, and risk assessment, with an emphasis on the interactions between these domains.

African initiatives applying AI to cancer diagnosis and treatment range from single-project or small-group endeavors to continent-wide partnerships tackling many pathways simultaneously. Selected representative projects illustrate the diversity of pursuits and common themes. A pathology-based pilot in Madagascar uses regional institutions to reach accessible patients, focusing on deep learning for disease detection and identifying key distinguishing features. Breast cancer is the initial pathology focus, with cervical lesions next. The Trinidad and Tobago initiative uses limited regional data from multiple institutions to generate an AI-based pathology triage tool, developing an annotation guideline for neural-network training on diagnosed cases. A regionally balanced, public–private partnership spanning different media employs foundational and supervised AI for radiological image classification, archiving, generation, and interpretation, as well as colposcopic image reporting.

The Ghana-based Data Science Initiative for Global Health at the University of Ghana uses harmonized regional clinical data to predict obstetric and cardiovascular outcomes, stratifying cases to prioritize and share resources. A pyrotechnic-based Cervixcan project applies transfer learning on a private–public UK–Ghana partnership pickle, with ongoing work on testing readouts. The Disease Insight for Arise Asia partnership estimates breast cancer patterns and employs machine learning and deep learning for histology and liquid biopsy-supported models. Integriprod in Côte d'Ivoire focuses on histology – bold shapes and deep learning analysis of digital slides to model population patterns, comparing sample structure and variable margins at different exploratory levels. The sub-Saharan African skin cancer project employs skin-type categorization metadata with a machine learning classification breast group, among others. The African AI training for the early digital pathology project focuses on specific AI bottlenecks by honing training and inference of validated models.

Increased machine learning capabilities should facilitate the development of tools capable of replicating human behavior across many domains of daily life. For AI applications to be successfully deployed across all sectors, however, and, in particular, for the health sector in Africa, these innovations must be accompanied by systems of support and regulatory governance. Recommendations for policy interventions that can provide the needed support to AI in health applications, particularly in cancer diagnosis and treatment, are provided alongside potential funding sources to help these technologies develop and gain traction. Although innovations are key, policy interventions are also important to establish an enabling environment for AI applications in health. Areas in which government policies can provide needed support, examples, and rationales are highlighted. Funding for the development and deployment of AI for health applications is being sought from multiple sources, including foundations, international development partners, industry, and governments. Industry and corporations in Africa have already established funds earmarked for the development of AI for product innovation, process sustainability, and product-market expansion. However, dedicated funds for the development and implementation of research and AI in health remain scarce.

Emerging modalities, proprietary data, and regional partnerships can unlock new horizons for Africa's AI ecosystem. Longitudinal and multiomic models hold great promise, although successfully making the diagnosis inherently remains the hardest part. In time, more research may become algorithmically informed and less dependent on human experts. If the necessary trust can be established, it is even possible that some combinations of tests can be performed without human involvement. Additional cross-border collaborations could allow small datasets to combine into something bigger. As regulations and liabilities evolve, other industries may take the lead in shaping AI development. The specific drivers are not yet clear, but insurance is one of the sectors with the greatest interest in investing in the long-term development of AI. Should this happen on the drug side – in a form compatible with compassionate use – the stakes on the bid–ask spread for such AI capabilities could turn positive.

In the long run, AI could play a role in training itself. The largest compendium of seminal images for any domain remains the medical literature. With AI tools assisting in the writing of such articles, they become increasingly concise and standardized. This lends itself well to the writing of articles where the common denominator is a diagnostic label rather than a modality. Equipped not only with a foolproof diagnostic procedure but also with access to most drug formulations on the market, AI should eventually be able to automate the production of simple procedural and diagnostic reports on demand. Simultaneously, the deployment of longitudinal modeling tools and the rise of private circuitry in such applications will enable a complete remodeling of the data generation and clinical–surgical procedures associated with the diagnosis of rare and/or complex cases. Within months or years, the field will thus have the capacity to grow and/or enrich/regenerate itself by making such services available and allowing interested parties to take care of the actual data collection through the corrective lenses of a diagnostic algorithm.

Despite being in a race against time, and the difficult choices it entails, making data-driven decisions using AI should yield dividends – indeed, these dividends may tempt regulators to leapfrog from less-constrained scenarios toward one in which data privacy concerns are lawfully respected and addressed; Increased flow between nations and across the continent is creating new business and scientific opportunities; infrastructures and expertise are sourced, combined, integrated, refined, and applied effectively across different but closely aligned sectors; and frontline healthcare personnel are helped at a pathologist's or radiologist's elbow, so that behind-the-screen diagnostics are faster and more accurate, and indeed all fronts of human activity are sparked into sudden yet enduring new synergy. AI has been correctly described not as a new sector but as a qualitatively different mode by which to harness – assessment far and away and evaluations jointly, in mutual corroboration – the Earth's many forms of rapidly generated knowledge. The proper domain of AI from that viewpoint is thus the aforementioned decision-making platforms, whose guidance covers, enables, supports, and catalyzes everything from routine manual activity on one side to complex human services and pioneer businesses on the other.

The research landscape traversed here is limited but informative. It embraces the application of AI, not its design and development, in support of cancer diagnosis and prognostic therapy selection for patients from relatively developed African nations and regions. Other healthcare fields and other continents and countries should nevertheless gain insight and guidance from its compartments, pathways, and synthesis, consolidation, and distillation into recommendations for the next generation of AI and related digital twins for medical health and service, those affecting and informing patients, indeed, toward the rapid emergence of digital twins for all domains, from control and command to policy and planning, so that daring, decision-making, and diplomacy manage and maintain the future of people, planet, and prosperity.

Part I

Foundations of Artificial Intelligence and Digital Health in African Oncology

1 The Epidemiological Landscape of Cancer in Africa

Challenges and Opportunities

1.1 INTRODUCTION

Cancer is a leading cause of morbidity and mortality worldwide, responsible for an estimated 18.1 million new cases and 9.6 million deaths in 2018. Approximately 47% of newly diagnosed cancers and nearly 55% of cancer-related deaths occurred in low- and middle-income countries. Africa is currently undergoing an epidemiological transition marked by the convergence of communicable and non-communicable diseases, with cancer emerging as a leading cause of morbidity and mortality (Calvo et al., 2023). In sub-Saharan Africa, the estimated number of new cancer cases is 1.1 million per year, and the region accounts for just over 6% of the global cancer burden. Although fewer cancer cases are diagnosed annually in Africa than in other regions of the world, such as Europe or North America, the rapid increase in these rates has a severe effect on the healthcare system, with an inadequate supply of healthcare resources resulting in challenges with cancer prevention, diagnosis, treatment, and rehabilitation (Christopher et al., 2023). At the same time, this is an opportunity to set up and improve health systems.

In 2019, experts and global stakeholders were asked to highlight the challenges and opportunities for cancer research in Africa. These discussions highlighted a lack of generalizable data from Africa. The number of cancer registries on the continent is still deficient, and those available have poor coverage. Data of variable quality are often housed in disparate accessible settlements, posing several important challenges to cancer control and prevention in Africa. While several other countries have invested heavily over the past decades in cancer research and control programs, Africa has not. Over the years, increased donor funding has led to a further widening of the established cancer research collaboration gap, which has impeded the development of sustainable research capacity in Africa (Payne et al., 2013). Consequently, the research output from African institutions is low compared to other parts of the world, and the primary research evidence landscape continues to be characterized by disparities. The consequences are far-reaching, as insufficient investment in data systems that could support the design and implementation of programs across the continent results in uneven and inequitable outcomes.

Cancer is competing with cardiovascular disease to become the world's second-most important cause of mortality. More than one in six global deaths is due to cancer. It is most frequently localized in Africa, Asia, and Europe, the regions accounting for 70% of the world's cancer burden, with about 10 million annual deaths from cancer globally. Although more than 50% of cancer patients reside in developing countries, four out of every five cancer deaths observed worldwide occur in low- and middle-income countries. The African continent is projected to see the largest increases in both incidence and mortality through 2040 (Karar et al., 2022). An estimated 17 million new cancer cases and 10 million cancer deaths are predicted to occur in 2040, corresponding to increases of 75% and 86% by world region, respectively. Approximately 55% of the increase in new cancer cases is expected to occur in low- and middle-income countries. Over 70% of deaths related to cancer each year occur in low- and middle-income countries.

In Africa, the expected increase in cancer burden is greatest over the coming decades, with a dramatic increase in population aged ≥65 years, who are at the highest risk of cancer, coupled

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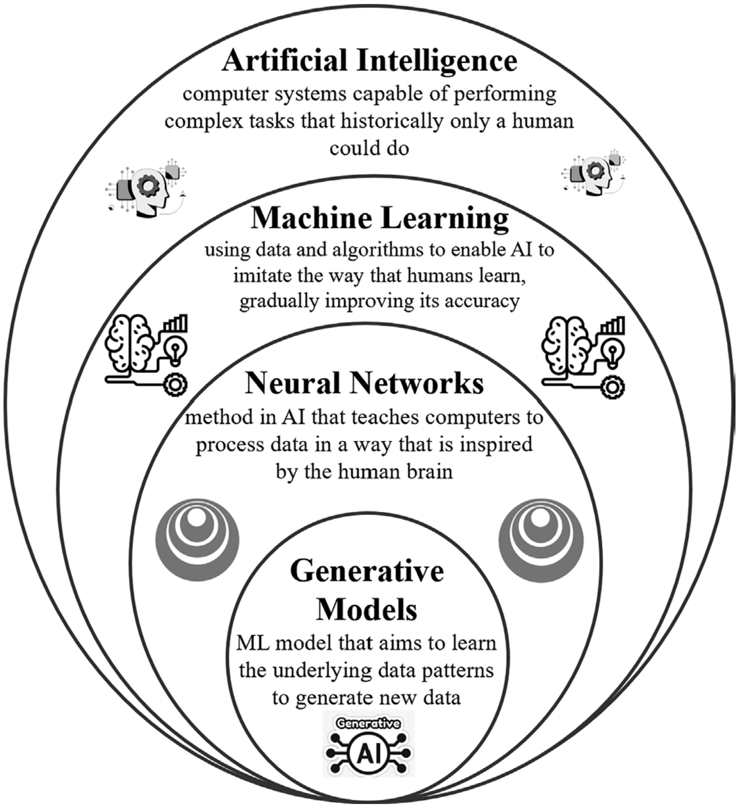

FIGURE 1.1 Expert systems.

with the obesity epidemic linked to a Westernized lifestyle. Regular surveillance of cancer incidence by trained personnel is mandatory for resource-poor countries. However, there is generally a lack of comprehensive data from low- and middle-income countries, including Africa (Elbaruni et al., 2024). Approximately 3.2 million new cancer cases were diagnosed, and about 2.4 million cancer deaths occurred in Africa in 2020. More than 10 types of cancer are on the rise in most countries in Africa, without a cancer registry to record new cases. Cancer epidemiological data for Africa indicate a short period from 1960 to 2020: a steady increase in registries in Africa explains the temporal increase observed for the number of reported cancer incidences. Cancer incidence rates derived from cancer registry data are by far the most appropriate and specific basis for the establishment of cancer control strategies, as supported by expert systems, as presented in Figure 1.1.

1.2 RISK FACTORS FOR CANCER IN AFRICAN POPULATIONS

The heterogeneity in genetic, environmental, and lifestyle factors influences the risk of developing cancer in populations and is recognized to contribute to the development of cancer in African populations. Genetic predisposition to cancer has been identified in specific populations, and genetic, epigenomic, transcriptomic, proteomic, and microbiological studies are currently ongoing in African populations to better define worldwide cancer risk. Associated known disparities in the burden and pathways of carcinogenesis among African populations may also relate to differences in the anatomical site affected by cancer. Several opportunities exist for the mitigation of risk from environmental exposure and lifestyle factors in the African population, with the collaboration of