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A Comparative Analysis of Startups Applying AI in Clinical Oncology

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***Abstract*—The rise and exploitation of artificial intelligence (AI) in general and in particular the medical field is fuelled by breakthroughs in deep learning (DL), advances in computing hardware devices, as well as the exponential growth of clinical data used for decision-making. Modern oncological research is intensively adopting AI-based technologies, with most of the related elements such as machine learning (ML) and DL models being utilised to improve the accuracy and efficiency of cancer diagnosis, prevention and treatment, with studies showing that AI could have many additional applications in cancer care.**

In most countries, numerous AI technologies have received governmental approvals for use in oncology, most notably in radiology. In response to the growing interest in the use of AI technologies in clinical oncology, the number of AI start-ups that concentrate their efforts on combating cancer has surged. The present research study adopts a mixed methodological approach to perform a comparative analysis of the top five AI start-ups that are focused on the application of AI technologies in clinical oncology. The five chosen AI start-ups include: CancerIQ (USA); Panakeia (UK); MultiplAI Health (UK); MNM Bioscience (USA) and X-Zell in Singapore. The selection of the AI start-ups was based on the availability of statistical metrics of interest to the study and the impact of their projects and applications on clinical oncology. The study performs a quantitative and qualitative analysis of selected metrics associated with the use of AI in clinical oncology and the related financial performance metrics.

Keywords*—*AI, Artificial Intelligence, Care Pathway, Clinical Decision Support, Deep Learning, DL, Omics, Oncology, Precision Medicine, Start-ups

I. Introduction

The technological advancements of modern era are increasingly becoming a critical component of society, especially with the unprecedented emergence and rise of AI. In health sciences, the application of AI has shifted from prospect to reality in recent years with studies showing that AI could have a wide range of applications in medicine and health care [1]. In clinical oncology, AI is being directly used for the purpose of cancer diagnosis, with ML and DL models in particular being utilized to improve the accuracy and efficiency of making the diagnosis [1-3]. An overview of radiomics, with applications of AI, is shown in Fig. 1.

In most countries, a plethora of AI technologies have received governmental approvals for use in oncology, notably in radiology [4]. It is reported that AI-associated devices approved for use in oncology settings were most commonly used in radiology (54.9%) and pathology (19.7%) with the devices being used for breast cancer (31.0%) more often than for other types of cancer [5].

Despite the technological advancements in the recent past, oncological research and treatment methods still remain rudimentary and the health outcomes of patients often remain bleak. However, the recent developments and application of AI in cancer diagnosis and treatment is inspiring hope of a bright future in oncological research, by providing health care professionals with highly accurate and precise diagnostic tools. An example of the applications of various methods of AI along the patient pathway is shown in Fig. 2, below.

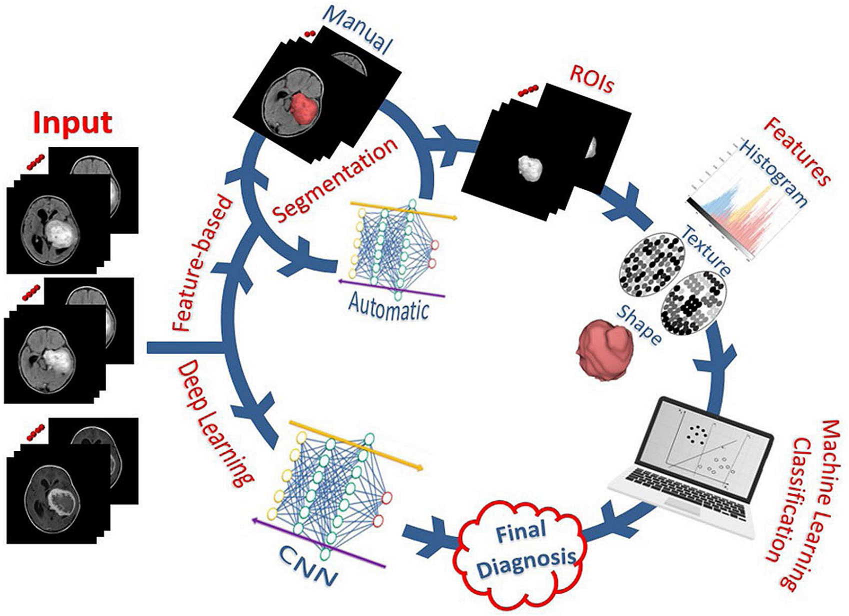

Fig. 1. Overview of Radiomics [1].

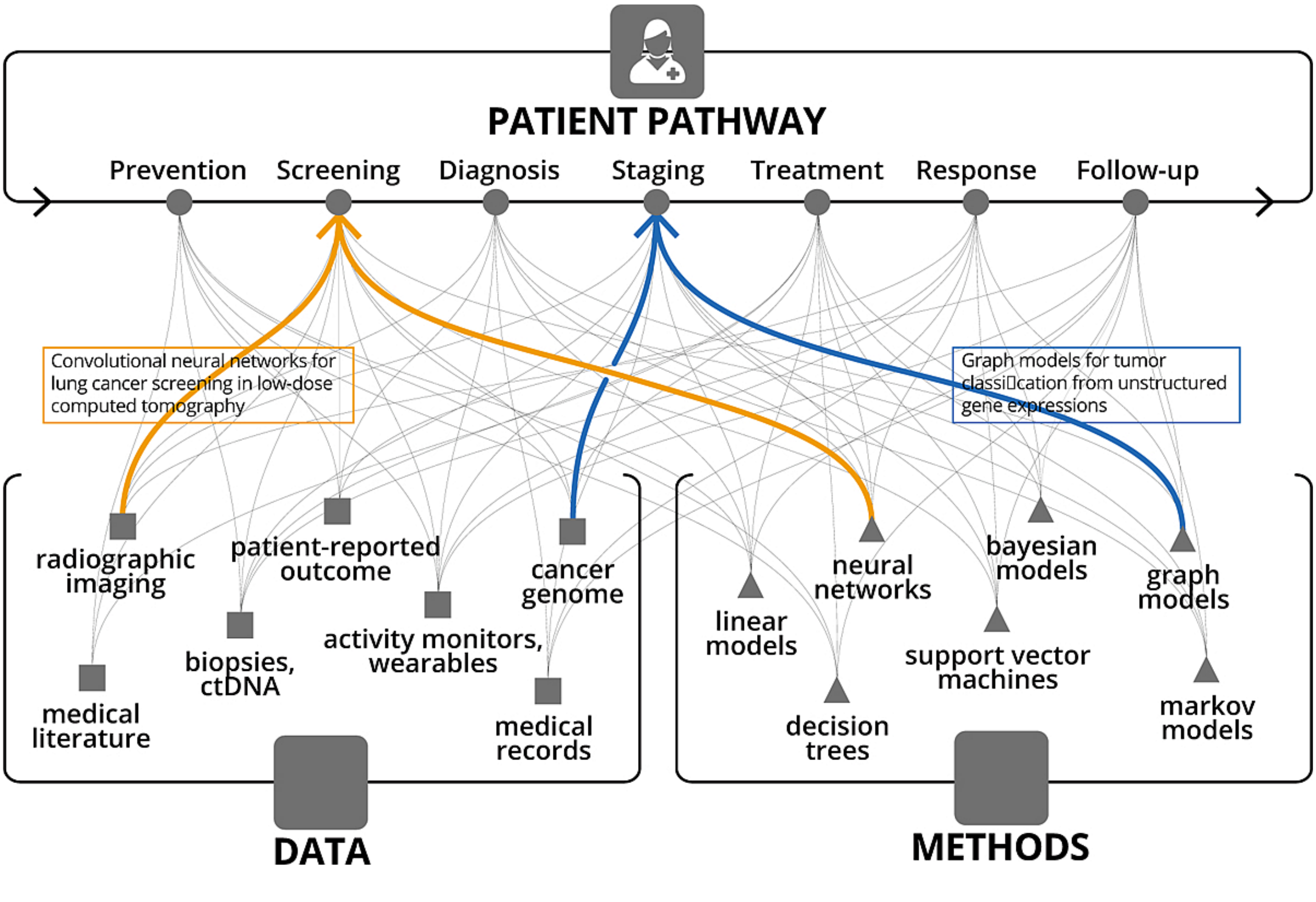

Fig. 2. Applications of AI along the Cancer Patient Pathway [2].

With the increased interest in the application of AI technologies in clinical oncology, there has been a proliferation of AI start-ups that focus on fighting cancer using AI [6]. Currently, AI start-ups are emerging as game-changers, making a significant difference in the fight against cancer. This highlights the need to understand the metrics and patterns, both qualitative and quantitative, associated with these start-ups.

The concept of AI start-ups has become a common business model that has significantly changed over the years in the face of technology and innovation - it has been used to provide novel solutions across various sectors such as healthcare, finance and research. A primary characteristic of AI start-ups that distinguishes the model from the traditional business models is the application of cutting-edge AI technologies including ML algorithms and neural networks, to address complex problems and drive innovation [7]. Due to their ability to provide scalable and intelligent solutions to complex problems, AI-based start-ups are currently upending the traditional business models as witnessed by the increase in the development of cloud computing models and DL infrastructure such as Google Cloud Platform™ (GCP), Microsoft Azure® and Amazon Web Services (AWS™), that are employed by AI firms for designing and implementing the intended solutions [7-8]. The foundation of the technological infrastructure of AI start-ups is built on innovation, which employs different tools for analysis of information and is based on large capacity frameworks with specific control components [7]. On the same note, the key to the success of most AI start-ups is based on hiring individuals with technical and academic competencies such as program designers, DL engineers, information researchers, and specialists of specific fields [7,9]. Assembling a diverse and highly competent workforce is important in development and implementation of innovative ideas to solve the problems of interest [7]. The growth and success of AI start-ups relies also on funding and investment from government recognition and investors with interest in the area of focus of the start-up [7]. The success of an AI start-up, therefore, is based on different factors that are associated with the field of interest, human capital, technological infrastructure and investor funding.

In clinical oncology, start-ups are increasingly adopting AI-based technologies to improve patient outcomes and reduce mortality rates. On surface value, AI start-ups are using AI technologies to speed up the diagnostic processes through analysis of images and identification of cancer patterns and development of customized treatment plans for the patients based on their genetic composition [3,10]. With the ever-advancing technologies, most AI clinical oncology start-ups employ innovative complex systems including algorithms, DL analytical tools and genomics to solve real-world medical problems associated with cancer [3,10,11]. Moreover, most of the start-ups are effectively incorporating a mathematical lens which views the patient's treatment path as an optimisation problem, with various diverse data streams combined as inputs into a mathematical model that can be iteratively adjusted until the desired output is achieved and the appropriate action is taken [2]. Typically, the design of a system hinges on the amount and characteristics of the data it handles. The data, such as the patient clinical symptoms, medical history, biometrics and environmental factors, can vary greatly in terms of structure, representation, dimensionality and storage requirements [2-3]. In relation to cancer genomics, AI-based technologies can be used for analysis of genomic data from cancer patients and the clinical interpretation of genetic variants, which can be important in early detection and treatment of different cancerous variants [12-13].

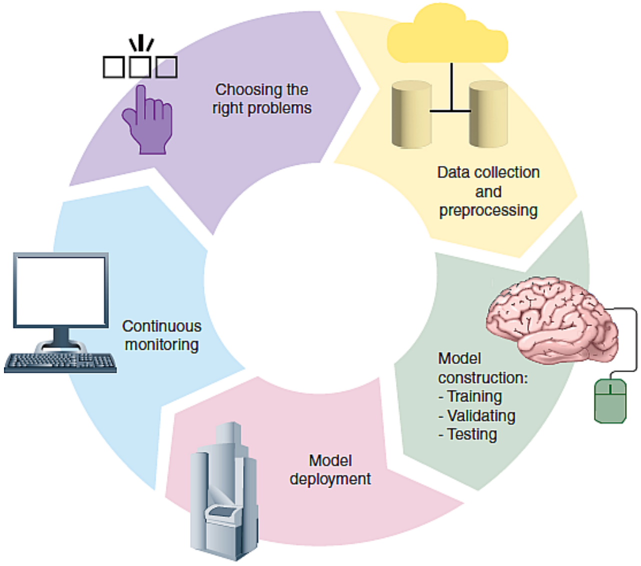

Fig. 3. Using the health care data cycle and AI for creating the best ML [3].

The effective implementation of the appropriate AI model reliant upon the use of the health care data cycle is shown in Fig. 3, above.

AI technologies offer two key advantages in studying cancer genomics: multitask learning and multimodal learning [12]. Multitask learning allows the AI program to train on several different tasks concurrently, by sharing the data and model parameters and components. This not only reduces the training time and resources, but can also increase the accuracy of each individual task - since the model can identify shared patterns across the tasks. For example, when trying to predict the effect of a certain drug on various types of cancer, the model can learn from the commonalities between different cancer types whilst also focusing on the specific characteristics of each type. Multimodal learning involves integration of different types of clinical data such as genetic sequences, chromatin accessibility or gene expression data, enabling a more comprehensive understanding and analysis of the disease. Considering the pathological complexities associated with different types of cancer, AI-based technologies can play a crucial rôle in integration of multilayered data which can enhance the outcomes of clinical oncology research and early detection and prevention of cancer.

An understanding of the different modes of application of AI-based technologies in clinical oncology can provide insightful information on optimisation of related models by start-ups for early detection, prevention and treatment of cancer. Also, the analysis of metrics of AI-related start-ups in cancer research can be of significance in identifying the strengths of different technological systems that can contribute to the success of future start-ups as well as the challenges that might hinder the successful application of the systems by the start-ups. As the intricate web of clinical oncology data grows more complex, so too do the analytical tools required to untangle its hidden patterns. This underscores the importance of identifying and assessing individual AI models and start-ups that specialize in analysing specific data streams at key decision points throughout a patient's treatment process [2-3]. In this regard, it is illogical to assume the possibility of developing a unifying dynamic model for precision oncological research considering the vast differences in the domains of data quality and quantity in different types of cancers [2]. Currently, most AI start-ups are intensively using complex AI algorithmic models to analyse the existing large oncological data with a number of initiatives being proposed for streamlining and unifying the process of the data collection [2,10]. However, considering the innately heterogeneous and fragmented nature of oncological data, very few studies have performed a comparative analysis of AI start-up metrics associated with clinical oncology. To this end, the primary objective of the present research study is to fill the existing research gap by performing a comparative analysis of top five AI start-ups that are focused on clinical oncology. The study takes into consideration different metrics including the technological infrastructure, funding, applications and projects of the selected start-ups and aims to provide useful insights on the application of AI in clinical oncology.

II. Methodology

In this study we have assessed the application of AI in clinical oncology with a focus on the technological infrastructure, funding, applications and projects of selected AI-based start-ups within the domain of oncology. To achieve the intended objective, the study adopts a mixed methodological approach which involves both qualitative and quantitative techniques to identify cutting-edge AI advancements and their practical applications in the clinical setting. The qualitative methodology was adopted to provide an analytical review of existing literature on the applications of AI in clinical oncology while the quantitative methodology was employed to analyse the statistical metrics of AI start-ups associated with applications or projects related to clinical oncology.

A. *Qualitative*

From the perspective of the qualitative methodological approach, the study employed the three-step review framework by Kraus *et al.* [14] which involved planning, conducting and reporting of a review. The planning step of the review entailed the formulation of the inclusion and exclusion criteria of the materials related to the topic of the analysis. The formulated inclusion and exclusion criteria were used to choose the relevant articles that met the intended objectives of the study. The materials included those that focused on the application of AI on clinical oncology and those that focused on AI start-ups. Any additional article associated with AI start-ups in clinical oncology that could not be identified through database searches was identified through cross-referencing and manual searching of the references of the included studies, reviews and meta-analyses on the topic. The Boolean operators and the keywords used for the material research included 'AI start-ups', 'oncology', 'machine learning', 'deep learning' and 'radiomics'. Before reporting the results of the review, the duplicated materials were discarded and those to be included were selected using a multi-step screening strategy. Furthermore, during the screening process, the materials whose abstracts were irrelevant to the topic and those which were considered to be editorials or commentaries were excluded. The screening process entailed the extraction of specific facets of information associated with the application of AI in clinical oncology and the projects related to the AI start-ups that focused on the topic.

B. *Quantitative*

The quantitative methodology entailed the search and extraction of metrics of interest of five top AI start-ups in the field of clinical oncology. The data collection process involved collaboration with an external research assistant who provided access to key operational metrics and performance indicators of the selected AI start-ups in clinical oncology. The chosen five AI start-ups included: CancerIQ in the United States, Panakeia in the United Kingdom, MultiplAI Health in the United Kingdom, MNM Bioscience in the United States of America and X-Zell in Singapore. The selection of the AI start-ups was based on the availability of statistical metrics of interest to the study and the impact of their applications and projects on clinical oncology. The statistical metrics of interest related to the operation of the associated AI applications included funding information and the number of clinical facilities that use the AI applications provided by the start-up, while those related to the performance of the AI applications included the accuracy, precision and recall of the application, as well as the probability of patient survival after 24 months. In relation to funding, the statistical metrics consist of the initial funding amounts, total amount of funding raised and the number of funding rounds for the start-up. The information on the funding was sourced from the AI start-up websites and related financial analyses websites such as CB Insights. In terms of the functionality of the AI applications, accuracy reflects the percentage of predictions that were correct, and is calculated as follows:

Accuracy = (TP + TN) / (TP + TN + FP + FN), where:
TP: True positives; TN: True negatives
FP: False positives;FN: False negatives

Precision reflects the effectiveness of the model in accurately identifying positive samples and is computed as follows:

Precision = TP / (TP + FP), where:
TP: True positive; FP: False positive

Recall is the proportion of true positives the model correctly classified, and is computed as follows:

Recall = TP / (TP + FN), where:
TP: True positive; FN: False negative

It is important to note that the values of the AI-related metrics were based on values reported by the start-ups at a certain moment in time and might not be a true representation of the exact values considering there is a continual use of the related applications and the numbers are constantly subject to change. Moreover, we note that the numbers are based on approximate values.

III. Findings

Based on the inclusion and exclusion criteria of the qualitative methodology we identified a total of 62 recent studies that focused on AI projects and applications in clinical oncology, with an emphasis on start-ups. After the duplicate sources were discarded, only 43 articles and research materials remained. Out of the remaining studies, 13 could not be accessed past the abstracts and only 30 were obtained for detailed eligibility assessment. Furthermore, four studies did not meet the eligibility criteria since they were only commentaries and editorial reviews and were, therefore, excluded from the final list. Consequently, a total of 26 research materials were eligible for inclusion in the research.

In relation to the quantitative methodology, the selected metrics of the chosen AI start-ups are shown in Tables I, II and III, below:

TABLE I. Founding, Funding and Facilities.

Start-Up	Country of Origin	Year Est.	Funding (million)	Total Amount Raised	Funding Rounds	~№ of Clinical Facilities
CancerIQ	USA	2013	$20	$23.87 million	7	200
Panakeia	UK	2018	Pre-Seed	$3.79 million	5	150
MultiplAI Health	UK	2019	Grant	$3.2 million	3	70
MNM Bioscience	USA	2018	$2.6	$5.8 million	6	90
X-Zell	Singapore	2014	$5.6	$5.6 million	4	50

TABLE II. AI APPLICATIONS AND PROJECTS DEVELOPED BY THE START-UPS.

Start-ups	Applications/Projects
CancerIQ	Screening Toolkit and Navigator, Self-Assessment and Specialist, High-Risk Program and Manager.
Panakeia	PANProfiler Breast (ER, PR, HER2)
MultiplAI Health	MultiplAI Superbiomarker.
MNM Bioscience	The ARETEAI Platform, MNM177.
X-Zell	X-Zell Single-cell Detection Technology.

TABLE III. PERFORMANCE METRICS.

Start-Up	Accuracy	Precision	Recall	P(Patient Survival)
CancerIQ	65%	78%	35%	**55%**
Panakeia	59%	79%	30%	40%
MultiplAI Health	60%	68%	37%	35.5%
MNM Bioscience	50%	62%	32%	40%
X-Zell	55%	59%	30%	33%

The five start-ups originate from diverse regions: CancerIQ and MNM Bioscience from the USA, Panakeia and MultiplAI Health from the UK and X-Zell from Singapore. Their years of founding range from 2013 to 2019, indicating varying degrees of maturity and experience in the field. Notably, CancerIQ and X-Zell, founded in 2013 and 2014 respectively, have had more time to establish themselves compared to the relatively newer Panakeia (2018), MultiplAI Health (2019), and MNM Bioscience (2018).

When it comes to funding, as shown in Table I, CancerIQ stands out, with nearly $24 million raised over seven rounds, more than four times the funds that the other start-ups had. In contrast, the two UK based start-ups, Panakeia and MultiplAI report significantly lower funding levels of $3.79 million and $3.2 million respectively. MNM Bioscience has raised $5.8 million over six rounds, while X-Zell has secured $5.6 million over four rounds. This disparity in funding highlights the varying levels of investor confidence, availability of resources and government support, which can impact each start-up's ability to scale and innovate.

In terms of clinical facilities, CancerIQ leads with approximately 200 facilities, followed by Panakeia with 150, MultiplAI Health with 70, MNM Bioscience with 90 and X-Zell with 50. This metric underscores CancerIQ's broad clinical reach and its capacity to impact a larger patient population. The probability of patient survival also varies, with CancerIQ achieving the highest at 55%, followed by Panakeia at 40.01%, MNM Bioscience at 40%, MultiplAI Health at 35.5%, and X-Zell at 33%. These figures suggest that CancerIQ's solutions might be more effective in improving patient outcomes compared to its peers.

Accuracy, precision, and recall are critical metrics for evaluating the performance of AI applications in clinical settings. As shown in Table III, CancerIQ again leads with an accuracy of 65%, while Panakeia, MultiplAI Health, MNM Bioscience, and X-Zell report accuracies of 59%, 60%, 50% and 55% respectively. Precision rates are highest for Panakeia at 79%, followed closely by CancerIQ at 78%, MultiplAI Health at 68%, MNM Bioscience at 62%, and X-Zell at 59%. Recall rates, which measure the ability to identify positive cases, are somewhat lower across the board: CancerIQ at 35%, Panakeia at 30%, MultiplAI Health at 37%, MNM Bioscience at 32%, and X-Zell at 30%.

IV. Discussion

With AI becoming a necessary tool in modern health sciences, the present study provides timely insights on the application of AI in clinical oncology. Currently, cancer is one of the most prevalent human diseases that affect millions of people globally but with rudimentary treatment methods that reduces the chances of patient survival. According to Kann [2], the resurgence of interest in application of AI in clinical oncology stems from the emergence of powerful DL algorithms and the availability of ever-more-powerful computing hardware devices, as well as the exponential growth of clinical data used for decision-making. The rise of oncology as a focal point of medical research has further led to increased interest in the application of AI-based technologies based on the evidential benefits and transformative changes brought about by these technologies, including customized care, early detection, diagnostic tools and treatment methodologies [2, 15-16]. Elkhader *et al.*, [11] report that recent advancements in AI hold promise as valuable supportive tools for clinicians, aiding in diagnosing and predicting the course of cancer, utilising various platforms and techniques like digital pathology. Most AI-based start-ups in clinical oncology have focused on advances in diagnostic tools for early incidences of cancer, which have provided hope for early detection of the disease [11, 17-18]. According to the study results, CancerIQ is one of the start-ups that is actively employing AI for early detection of cancer, using a Self-assessment and specialist application that offer an enhanced cancer risk assessment experience for all types of cancers for individual patients. As an oncological AI start-up, CancerIQ uses updated clinical datasets that can assist the care providers to interpret real-time data for early cancer testing, detection and screening interventions. Based on the findings, AI-based technologies can play a crucial rôle in clinical oncology through early detection, genetic testing and diagnosis of cancer.

AI can be an important tool for the analysis of multi-dimensional oncological data that is increasingly being generated during routine care. In modern health research and care, clinical decisions are often reliant on complex dynamic data streams that are continuously updated throughout a patient's treatment journey, including clinical presentations, medical history, pathological information and genomics [2, 19-21]. Multi-dimensional oncological data holds the key to personalized cancer care and AI is instrumental in unlocking its potential [22]. In the context of the current research, two of the chosen AI start-ups have applications that are specifically designed for analysis of oncological data to inform clinical decisions. First, CancerIQ provides applications and screening tools that allows the frontline care providers to engage their patients and collect data such as cancer risk profile, including hereditary, lifestyle and adherence risk factors which can be analysed to design an effective and customized prevention and treatment plans for the patients. For example, a case study of MarinHealth Medical Center that utilized CancerIQ's services reported an increase in risk-identified referrals from 46% to 78%, resulting in a ×3.9 growth of genetic service capacity, from 132 consults per year to 521 consults annually. PanakeIA also uses the PANProfiler Breast (ER, PR, HER2) application to leverage genomics data and AI, and seamlessly integrates with existing digital workflows and data to provide accurate results that inform the clinical decisions of care providers. On the same note, the PANProfiler Breast application provides the added advantage of reducing the necessity for extended laboratory testing and delivers reliable results to patients and their healthcare providers.

Farina *et al.* [3] highlight the rôle of AI in cancer data extraction, processing, analysis, interpretation and integration, as highlighted in Fig. 3 previously, which is supported by a wide range of existing oncological scientific literature. To understand the rôle of AI in analysis of oncological data, It is important to acknowledge the complexity and diversity of the data obtained throughout a patient's cancer treatment journey, including doctors' notes (both typed and dictated), laboratory test results, findings from tissue analysis (histopathological data), medical imaging data (e.g., X-rays, MRIs [magnetic resonance imaging]) and information directly reported by patients about their health [2-3, 16]. MultiplAI Health, one of the UK-based AI start-ups, leverages its MultiplAI Superbiomarker to analyse raw cancer patient data, including blood molecular variations indicative of elevated cancer risk. This analysis underpins a novel blood screening test that combines RNA sequencing and AI to identify the disease at an early stage. Another start-up, MNM Bioscience, uses the "ARETEai" platform that similarly integrates proprietary databases with advanced AI algorithms and different omics data such as whole genome sequencing (WGS) to transform data into meaningful insights that can be used by care providers to formulate appropriate prevention and treatment plans for the patients. According to Hamamoto *et al.* [23], AI tools such as ML and DL techniques can be used to analyse omics data to reveal the accumulation of a variety of epigenomic and genomic abnormalities associated with cancer cells, which can be used for early detection of cancer. X-ZELL also fuses omics data and AI-based single-cell detection technology for early clinical identification of cancer.

MultiplAI Health, MNM Bioscience and X-ZELL exemplify the power of AI in cancer research. Their innovative solutions focus on extracting, processing, analysing, interpreting and integrating various data sources related to cancer, with the purpose of creating clear and understandable reports that empower healthcare providers to make informed decisions and provide the necessary medical attention to their patients.

According to Wang *et al.* [16], the early detection of cancer requires revolutionized image analysis which can be achieved by DL techniques and AI that can annotate skin lesions to provide accurate results. A wide range of existing oncological start-ups have effectively applied AI-based technologies in cancer medical imaging. A growing body of scientific literature demonstrates the potential of AI-powered medical imaging analysis in revolutionizing cancer diagnosis. DL models, in particular, are trained on vast datasets of medical images obtained through various imaging techniques, such as ultrasounds, X-rays, MRI, computed tomography (CT/CAT), positron-emission tomography (PET) and digital pathology, allowing them to identify potential abnormalities and patterns that may indicate cancer [2-3, 21, 24-26]. These algorithms provide computer-aided image interpretation and radiomics for analysis of images with increased speed and accuracy, automatically extracting critical measurements like size, shape, volume, position and symmetry [2, 20-21]. Further, the algorithms can be used for analysis of imaging data obtained throughout the standard cancer care pathway, encompassing tasks such as lesion detection, classification according to tissue type, segmentation to determine the location and define the extent of the disease, comprehensive characterisation of tumour properties, and monitoring of treatment response. [3, 18,27].

An example of successful application of AI tools in cancer imaging is the classification of dermatoscopy (also known as dermoscopy or epiluminescence microscopy) images, where DL algorithms have been able to identify and label skin lesions (among which also melanoma) with an accuracy matching that of experienced dermatologists [5,19,28]. As for the chosen start-ups in the present research, X-Zell's single-cell detection technology employs AI-based tools for analysis of dermatological images for early detection of significant cancers.

According to Bi *et al.* [6], DL algorithms can be used to develop cancer biomarkers through tumour vasculature imaging and digital pathological analysis of collagen fibres which can be important in early detection of the disease. MultiplAI Health makes use of genetic data and AI to analyse a broad spectrum of blood biomarkers through RNA sequencing and DL. Their approach creates a powerful "superbiomarker" for early and accurate detection of cancers and cardiovascular diseases. The test, which requires only a simple blood sample, can be used for preventative screening and post-treatment monitoring, offering a cost-effective and accessible solution that can be administered remotely. MultiplAI's advanced RNA sequencing and data transformation processes ensure efficient and precise biomarker analysis, making comprehensive screening feasible for a global population.

As the oldest start-up in this study, CancerIQ has had more time to develop its technology and establish a market presence. Its North American origin might also have contributed to higher funding availability. Like CancerIQ, MNM Bioscience benefits from the USA's strong investment environment but is newer and still building its presence. CancerIQ's significantly higher funding and amount raised indicate strong investor confidence and a solid business model. The higher number of funding rounds (7) suggests sustained interest and potentially continuous innovation. Panakeia and MultiplAI Health, being newer, have raised less but are in the crucial early stages of development. There is a positive correlation between the amount of funding and the number of clinical facilities. CancerIQ, with the highest funding, also has the most extensive clinical reach (200 facilities). This suggests that higher financial resources enable broader deployment and integration within clinical environments.

CancerIQ's extensive funding, higher clinical facility integration and robust patient survival rate, which correlates with its higher accuracy and precision, position it as a leader among the five start-ups in this study. CancerIQ's highest survival probability (55%) can be linked to its comprehensive risk assessment tools and personalised treatment plans, demonstrating a direct impact on patient outcomes. Panakeia with its strong precision rate and substantial clinical facility presence also shows promise. Its focus on genomics and integration with digital workflows contributes to its effectiveness, particularly in the context of reducing laboratory test dependence. MultiplAI Health and MNM Bioscience, despite their lower funding and clinical reach, exhibit innovative approaches through their respective applications, focusing on blood screening and genomic data analysis. MultiplAI Health has the highest recall, indicating it is effective at identifying true positives, which is the most crucial aspect of early cancer detection.

While accuracy and precision are generally high across the board, Panakeia stands out with the highest precision (79%), indicating it is exceptionally good at correctly identifying patients without the disease, likely due to its genomics-based approach. Panakeia's high precision and reasonably good survival probability (40.01%) suggest that minimizing false positives could contribute to better patient management and outcomes, as unnecessary treatments are reduced.

MultiplAI Health's highest recall (37%) highlights its strength in early detection, crucial for successful treatment outcomes. This suggests that its RNA sequencing and AI approach is particularly effective in identifying true positive cases.

The ingenuity of AI start-ups, coupled with the transformative power of DL in medical imaging analysis, is forging a new frontier in cancer diagnosis. These start-ups are not merely leveraging cutting-edge technology; they are actively translating its potential into tangible solutions for early detection, accurate diagnosis, and personalised treatment approaches. This innovative spirit, combined with ongoing advancements in AI, holds immense promise for revolutionizing cancer care and empowering healthcare professionals in their fight against this terrible disease.

V. Extended Research Findings Regarding AI in Medical Start-ups

This section presents an overview of the general and latest applications of AI in start-ups, especially related to the medical domain. Fig. 3, below, shows the current and emerging opportunities of AI in the domain of multimodal biomedical AI and the complex inter-relationship between the various data modalities and opportunities.

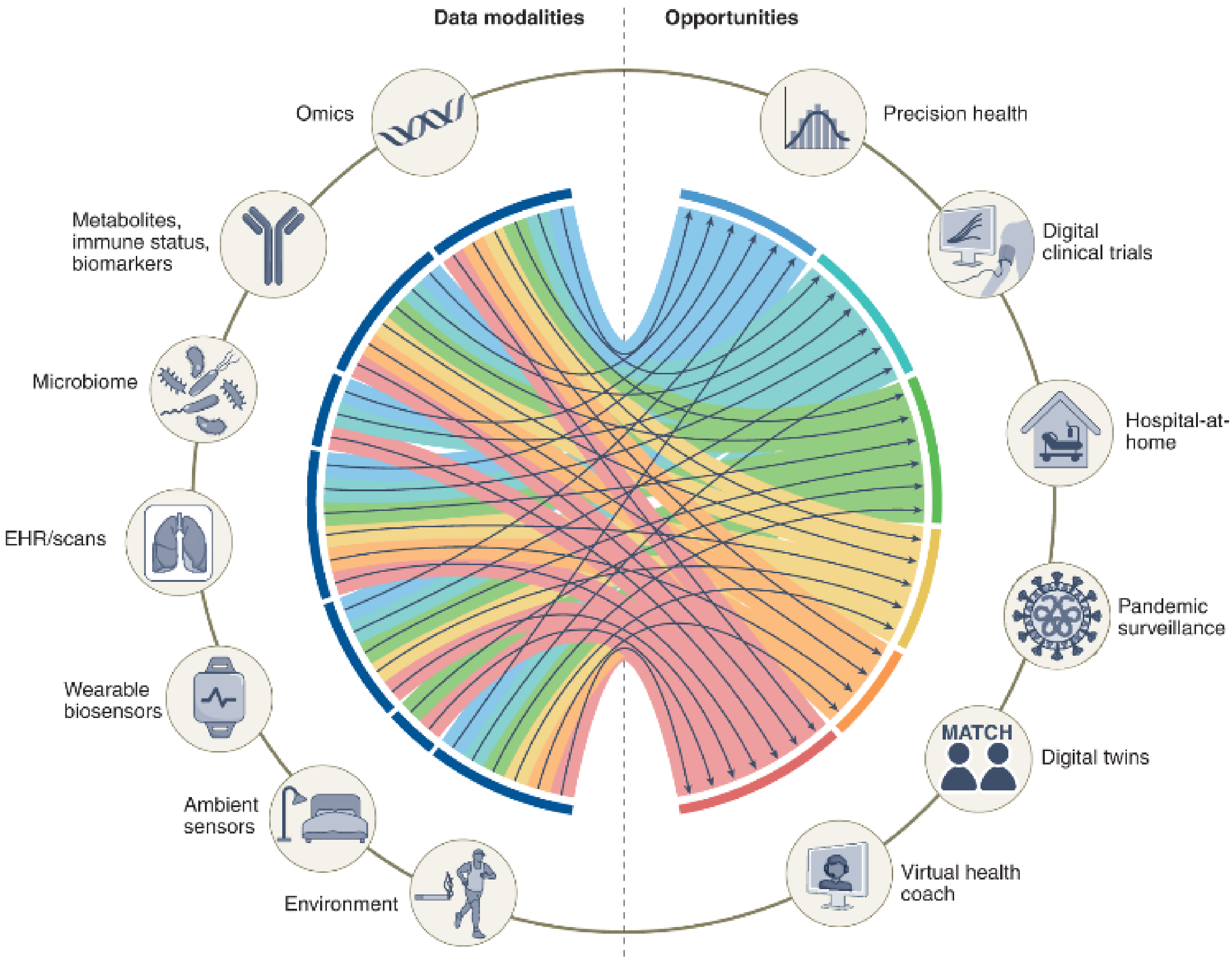

Fig. 4. Opportunities of Multimodal Biomedical AI [29].

The funding from venture capitalists into digital health, specifically in the application of AI appears to be slowing down, as shown in Fig. 5, as the technology is stabilising and maturing. However, the global annual compound growth rate (CAGR) shows a rate of 33.3% for the utilisation of AI in oncology, as shown in Fig. 6, below.

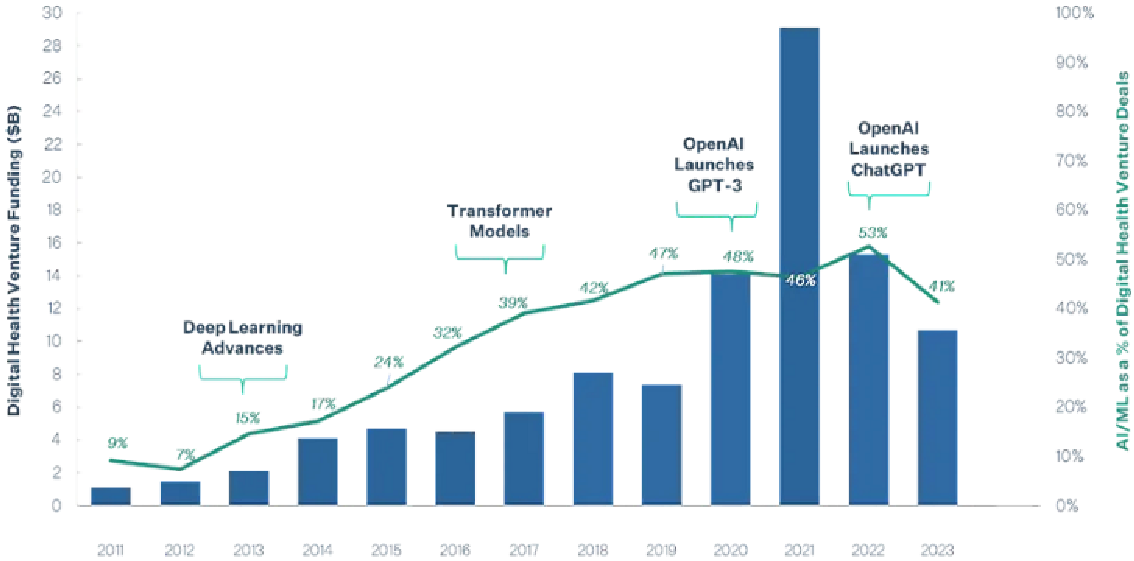

Fig. 5. Digital Health Venture Funding [30].

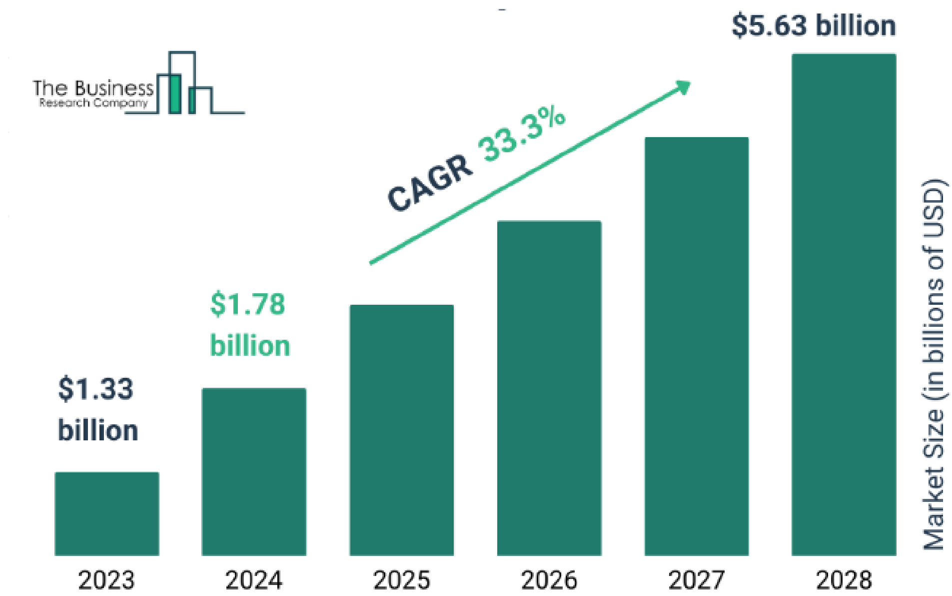

Fig. 6. Growth of Market Size of AI in Oncology [31].

Tracking AI in Healthcare on the innovation maturity curve, as showin in Fig. 7, below, still shows that it is in the early phase of the development stage.

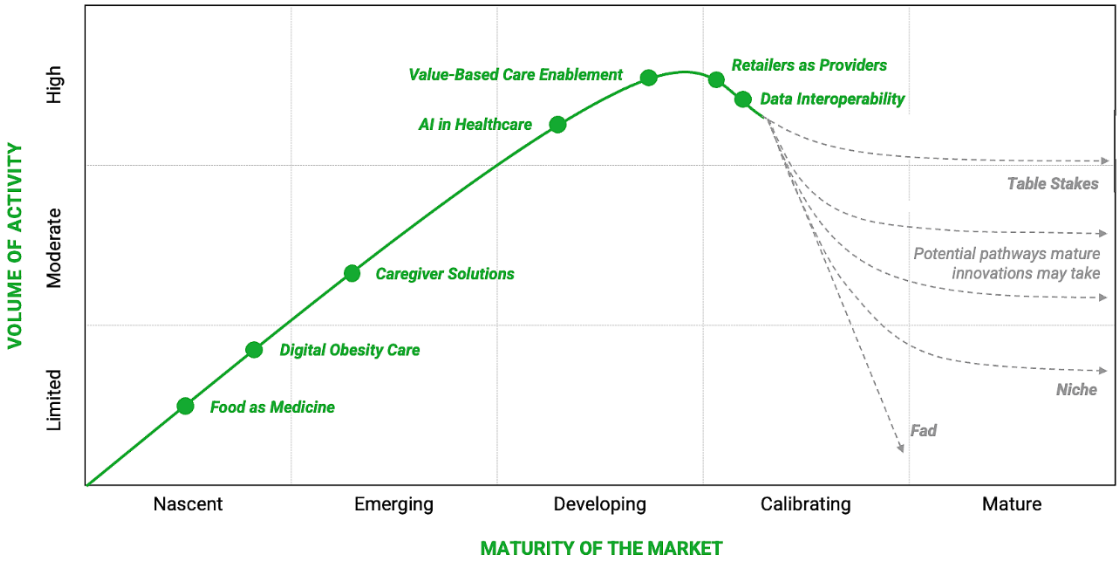

Fig. 7. AI in Healthcare on the Innovation Maturity Curve [32].

The geographical distribution of AI in Oncology is predominantly concentrated in North America, the region with the highest incidence of cancer, with 43.6% of the global market share [33] in 2023 [33], as shown in Fig. 8, below.

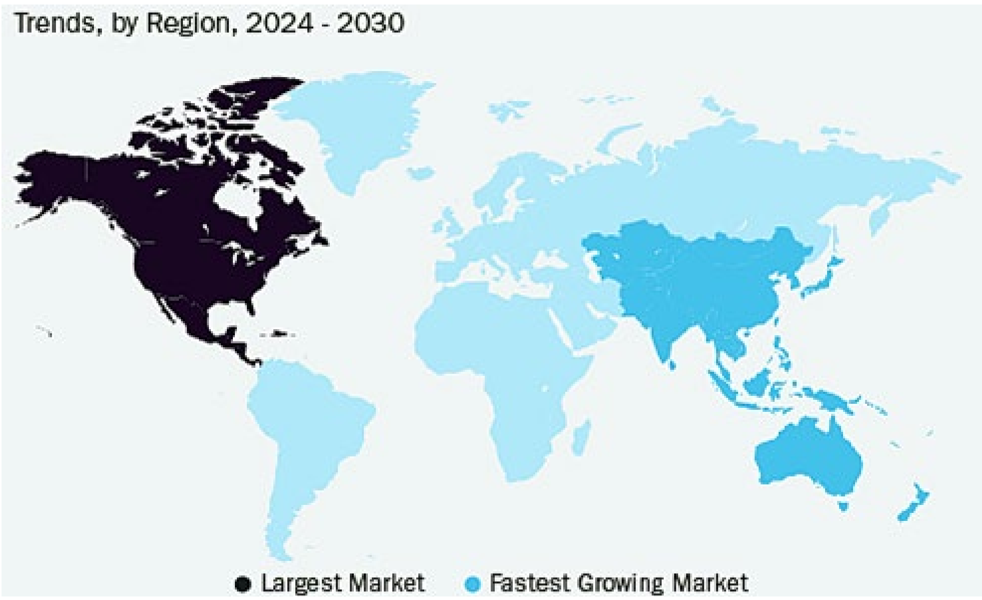

Fig. 8. Geographical Distribution of AI in Oncology [33].

The full application and adoption of AI in Oncology is still being limited due to three factors, identified in [34], these being: sparsity of corpus of clinical evidence; efficacy-outcome lacuna and non-familiarity of the new AI in medicine and healthcare ecosystem. However, [33] have proposed these pertinent recommendations to the key stakeholders, as shown in Table IV, below.

TABLE IV. ACTION PLAN TO STAKEHOLDERS FOR AI IN ONCOLOGY ADOPTION [33].

Current issues	Action plans	Stakeholders
Lack of interoperability between hospitals	• Engage with medical informatics system vendors to facilitate integration of AI and secure data storage.	Healthcare providers
Lack of validation of AI quality/efficacy	• Conduct tests using independent external data to validate, optimise and audit AI efficacy.	
Lack of standardisation in evaluation and validation of AI	• Develop and mandate the use of standard oncology terminologies and ontologies. • Set the standards required to evaluate the performance of AI-based tools systematically. • Establish an up-to-date regulatory and legal frameworks for different AI based on implementation risks.	Commissioners and regulators
Lack of integration of implementation science framework	• Establish consensus regarding trial protocol involving AI to standardise reporting. • Conduct AI studies that validate patient-centred outcomes and cost/time/resource effectiveness. • Promote implementation science research to learn optimal methods to AI deployment in cancer care.	Academics and healthcare providers
Lack of workforce training	• Level up on knowledge of AI and basics of medical informatics. • Prepare for disruption and adapt to changes in nature of work with the integration of AI.	Healthcare professionals

VI. CONCLUSION

The rapid emergence of AI start-ups in oncological research, with their potential to revolutionize early detection and treatment, highlights the need for an understanding of the metrics and patterns associated with them within this specific domain. The recent surge in AI applications for cancer treatment is fuelled by advancements in DL algorithms and high-performance computing hardware, coupled with the explosion of clinical data for decision support. AI is revolutionizing cancer care by providing clinicians with advanced platforms and techniques to support their decision-making in diagnosis and prognosis.

CancerIQ is one of the start-ups that is actively using AI for early detection of cancer. Their two platforms, Self-assessment and Specialist, offer an enhanced cancer risk assessment experience for all types of cancers and for different types of patients. Another start-up, PanakeIA, uses the PANProfiler Breast application to leverage genomics data and AI and integrates with existing digital workflows and data to provide accurate results that inform the clinical decisions of healthcare providers. Another AI tool, the MultiplAI Superbiomarker developed by MultiplAI Health, can analyze crude cancer patient data, including blood molecular variances that indicate an increased risk of cancer, leveraging RNA sequencing coupled with sophisticated dimensionality-reducing data pre-processing and DL algorithms. MNM Bioscience leverages the ARETEai platform, which integrates its proprietary databases with advanced AI algorithms and diverse omics data, such as whole genome sequencing for oncological data analysis, while X-ZELL fuses omics data and AI-driven single-cell analysis for early detection of clinically relevant malignancies. Findings clearly highlight the rôle and significance of application of AI in early detection, diagnosis, prevention and treatment of cancer.

CancerIQ emerges as a leader among the five chosen start-ups due to its extensive funding, broad clinical reach, high prediction accuracy, and significant impact on patient survival. Panakeia and MultiplAI Health show promise with high precision and recall respectively, indicating their potential for effective cancer detection and management. MNM Bioscience and X-Zell, while still developing, bring innovative approaches to the table with their focus on genomic data and single-cell detection technology.

These start-ups collectively demonstrate the transformative potential of AI in oncology, each contributing uniquely to the field. Their varying strengths and focuses provide a comprehensive view of how AI can enhance cancer detection, diagnosis and treatment, ultimately improving patient outcomes and advancing the future of healthcare.

VII. Future Research Directions

The rapid evolution of AI technologies in clinical oncology presents numerous avenues for future research. The following are several key directions that could enhance the understanding and application of AI in this vital field.

A. *Longitudinal Studies on AI Implementation*

Future research should focus on longitudinal studies that assess the long-term impact of AI applications in clinical oncology. These studies can provide insights into how AI influences patient outcomes, treatment efficacy and healthcare costs over time. By analysing data across extended periods, researchers can identify trends and potential areas for improvement in AI systems.

B. *Integration of Multi-Modal Data Sources*

Exploring the integration of diverse data sources, such as genomic, imaging and electronic health records will be crucial. Future research should investigate how multi-modal data can enhance the accuracy and predictive power of AI algorithms in clinical decision-making. Understanding the coaction between these data types could lead to more personalised treatment strategies.

C. *Ethical and Regulatory Frameworks*

As AI technologies become more prevalent in clinical oncology, there is an acute need to develop comprehensive ethical and regulatory frameworks. Future studies should address the ethical implications of AI use, including issues of bias, transparency and patient consent. Research should also explore the rôle of regulatory bodies in overseeing AI applications to ensure patient safety and data integrity.

D. *Patient-Centric AI Systems*

Investigating the development of patient-centric AI systems is another important direction. Future research could focus on how AI can be designed to enhance patient engagement and improve communication between healthcare providers and patients. Understanding patient perspectives on AI use in oncology will be essential for fostering trust and acceptance.

E. *Collaboration Between Start-ups and Established Institutions*

Research should also explore the dynamics of collaborations between AI start-ups and established healthcare institutions. Understanding the factors that contribute to successful partnerships can provide valuable insights into how innovations can be effectively translated into clinical practice. This includes examining the challenges faced by start-ups in scaling their technologies within existing healthcare frameworks.

F. *Economic Impact and Cost-Benefit Analysis*

Future studies should conduct comprehensive economic analyses to evaluate the cost-effectiveness of AI implementations in clinical oncology. Researching the economic impact of AI-driven solutions can guide decision-makers in prioritising investments in AI technologies and provide a clearer picture of the potential return on investment for healthcare systems.

G. *Training and Education*

Finally, research should focus on the training and education of healthcare professionals in using AI tools. Investigating effective educational strategies and curricula that integrate AI competencies into oncology training programmes will help ensure that clinicians are well-equipped to utilise these technologies effectively.

By addressing these future research directions, the field of AI in clinical oncology can advance significantly, ultimately leading to improved patient outcomes and more efficient healthcare delivery systems.

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