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AI-Driven Liquid Biopsy For Ultra-Early Cancer Detection And Precision Oncology

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ABSTRACT

Background: In the global society, cancer has been one of the leading causes of death, and early diagnosis is crucial in increasing the survival and treatment rates of patients. Traditional tissue biopsies are destructive, time-consuming, and lack the ability for continuous follow-up on the progression of the tumors. Based on aiding artificial intelligence, liquid biopsy has become a new technology that integrates artificial intelligence with extremely minimal diagnostic procedures to aid ultra-early cancer diagnosis and precision oncology.

Objective: The main aim of the study was to explore the effectiveness, adoption, and perceived value of AI-based liquid biopsy in ultra-early cancer prevention and precision oncology. The other problem that drew the attention of the researchers was to explore the awareness, trust, and perception of those who were studied on the adoption and implementation of artificial intelligence in the diagnosis and personalization of cancer diagnostics and treatment.

Methodology: This research employed a quantitative research design. A structured questionnaire was used to collect primary data and was mailed to all 253 respondents who satisfied the following criteria: they had a particular educational and professional background, including students, healthcare practitioners, researchers, and IT/AI professionals. The data collected were tested using statistical tests such as t-test (independent Samples), ANOVA (one-way), Kruskal-Wallis test, Chi-square test, Pearson correlation analysis, and regression analysis to test the collected data as a normality test, Reliability test, and validity tests (KMO and Bartlett's test).

Results: The findings revealed that the respondents were inclined positively to consider AI-driven technologies (liquid biopsy) based on their findings. The Normality Test showed that the data were normally distributed, and the Reliability Test showed that an excellent internal consistency existed with a high Cronbach's alpha of above 0.90. Construct validity, as suggested by the Validity Test, was seen to be satisfactory in terms of significant KMO and Bartlett outcomes of the test. The inference statistics tests have proved that the level of demographic differences and relationships was significant. Moreover, Pearson Correlation and Regression Analyses showed a positive correlation among trust in the AI systems, the knowledge about the liquid biopsy, the accuracy of the diagnosis, and the perception of the personal treatment technologies based on cancer.

Conclusion: The researchers end the article by stating that AI-based liquid biopsy has potential in regard to cancer diagnostics and precision oncology, as it will not only allow cancer to be diagnosed earlier but also can now lead to fewer invasive procedures and provide a more personalized approach to the treatment. This aspect can contribute a lot to efficacy and outcomes in the medical field by the introduction of liquid biopsy technology and the application of artificial intelligence in the management of liquid biopsies to take care of patients. However, issues surrounding cost, privacy, and access to derail quality and ethical adoption of AI-based healthcare systems should be minimized around the world.

KEYWORDS: AI-based Liquid Biopsy, Precision Oncology, Ultra-Early Cancer Detection, Artificial Intelligence, Cancer Diagnostics, Personalized Treatment, Healthcare Technology, Machine Learning, Precision Medicine, Cancer Screening..

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INTRODUCTION

One of the worst health-related problems and the leading cause of death among people across the globe is cancer. In medical studies, millions of individuals are reported to be diagnosed with some type of cancer or another, and the majority of people succumb to the cancer, as in most instances, the cancer is already in its advanced stage. Early diagnosis has been recognized as one of the best strategies for maximizing survival rates, minimizing complications of treatment, and maximizing patient outcomes. However, disparities in cancer screening related to socioeconomic status, healthcare access, health literacy, and trust can contribute to delayed diagnosis and unequal health outcomes (Kium et al., 2023). The traditional methods of cancer diagnosis, such as tissue biopsy and imaging procedures, are usually invasive, slow, expensive, and not efficient when it comes to diagnosing cancer at the earliest stage. Recent years have seen the development of new, more advanced medical devices and artificial intelligence (AI), which generate new possibilities in the diagnosis and treatment of cancer. Among such innovative technologies is the AI-based liquid biopsy, which is a nascent and potentially promising approach to ultra-early cancer diagnostics and targeted therapy (Syed Waqas Ali Shah, 2022).

Liquid biopsy is a diagnostic method that is less invasive. It is a method that examines biological substances, including circulating tumor DNA (ctDNA), circulating tumor cells (CTCs), fragmented RNA, proteins, and other biomarkers in body fluids, including blood, urine, and saliva, to name a few. In comparison to the standard Tissue biopsy, Liquid biopsy is able to give real-time information about tumors and genetic mutations without any surgery. It is a highly practical technology in modern oncology, as it guarantees the continuous definition of the shape of cancer development and reaction to the treatment. Nonetheless, the amount and complexity of biological information introduced by the liquid biopsy are insufficient to investigate and analyze in practice without the utilization of extremely sophisticated methods in computational algorithms. To address this challenge, artificial intelligence is essential to solve with a series of machine learning algorithms, predictive analytics, and deep learning models to identify latent factors and pinpoint cancer-related abnormalities more quickly and efficiently (Mostaque Md. Morshedur Hassan, 2022).

Liquid biopsy that is based on AI has gained much enthusiasm in personalized treatment plans, as highly specific and individual approaches to the personal characteristics of the patient and their genetic profiles can be implemented with the support of the technology. Precision oncology is eager about offering specific treatments, specifically crafted considering the molecular and genetic makeup of the patient's tumor. Once the AI technologies are developed and the Liquid Biopsy data is received, the medical team will be able to determine certain cancer mutations, determine the response to treatment, and monitor disease progress with greater success. Integration helps physicians make the best decisions in their treatments and achieve better outcomes in treatment, as well as avoid unnecessary side effects and invasive therapy (Irum Sherwani Summaiya, 2022).

The other area of AI application in liquid biopsy is that sensitive biomarker changes that precede clinical manifestation can be detected, leading to ultra-early cancer detection. This is especially true in cases of aggressive types of cancer like pancreatic, lung, ovarian, and colorectal cancer, which, if not detected early, would mean that even if they survive, they would have little opportunity for survival. Using AI models, non-professional scientists will have the ability to examine vast amounts of data far more quickly and effectively to assist medical professionals in identifying the kind of cancers in their early phases, as it will be more productive and economical to cure the disease. Moreover, AI-based healthcare can facilitate the existing trend of 24/7 patient monitoring, relapse prediction, and patient-specific medicine, which need to be integrated into the new precision oncology of the era (Kaleem Ullah Ihsan, 2023).

In addition to its numerous advantages, there are numerous challenges that AI-based liquid biopsy faces, including cost barriers to its adoption, ethical issues, privacy of the data, regulatory obstacles, and barriers to its adoption in developing countries. The success of AI usage in medical practice is determined by the dependability, precision, and equity of the AI algorithms. Besides that, there is one more reason that can impact its acceptance and implementation, which is the level of social consciousness and faith in created medical technologies using AI (Macedonia, 2022).

The study aims to cover the relationships of the effectiveness and acceptance of AI-based liquid biopsy and its prospects for the future in terms of its potential as a potent tool in ultra-early cancer detection and precision oncology. The study involves the evaluation of the perception of the respondents towards the area of AI implementation in the framework of cancer diagnostics, personalized treatment schemes, and innovation in healthcare. By delving into artificial intelligence applicability in modern oncology, this research paper will shed some light on how the process of learning and implementing the latest innovations in healthcare technologies can be used to improve cancer care and transform the process of medicine in the coming years (Mislim Zendeli, 2023).

RESEARCH GAP

Although previous studies have demonstrated the potential of liquid biopsy, artificial intelligence, and precision oncology individually and in combination, much of the existing literature has focused on technological development, biomarker identification, analytical performance, and clinical applications. Comparatively less attention has been given to the awareness, trust, perceived effectiveness, and acceptance of AI-driven liquid biopsy among individuals from different educational and professional backgrounds. Understanding these perceptions is important because successful implementation of emerging AI-based diagnostic technologies depends not only on technical performance but also on users' confidence, understanding, perceived benefits, and willingness to adopt such technologies. Therefore, this study addresses this gap by examining the awareness, familiarity, trust, perceived diagnostic effectiveness, and acceptance of AI-driven liquid biopsy for ultra-early cancer detection and precision oncology among students, healthcare professionals, researchers, and IT/AI professionals.

RESEARCH OBJECTIVES

The objectives of this study were to:

1. Assess respondents' awareness and familiarity with AI-driven liquid biopsy and its potential applications in cancer detection.
2. Examine respondents' perceptions of the effectiveness of artificial intelligence in improving cancer diagnosis and ultra-early cancer detection.
3. Evaluate the level of trust in AI-based healthcare systems and its relationship with acceptance of AI-driven liquid biopsy.
4. Examine the relationship between familiarity with liquid biopsy and acceptance of personalized treatment and precision oncology.
5. Determine whether demographic characteristics are associated with differences in perceptions and acceptance of AI-driven cancer diagnostic technologies.
6. Identify the perceived benefits and concerns associated with the implementation of AI-driven liquid biopsy in cancer diagnosis and precision oncology.

Research Hypotheses

Based on the research objectives and literature review, the following hypotheses were formulated:

1. **H1:** Trust in AI healthcare systems is significantly and positively associated with acceptance of AI-driven liquid biopsy.
2. **H2:** Familiarity with liquid biopsy is significantly and positively associated with acceptance of personalized treatment.
3. **H3:** Perceived AI diagnostic accuracy is significantly and positively associated with perceived cancer-detection effectiveness.
4. **H4:** Respondents' perceptions and acceptance of AI-driven liquid biopsy differ significantly across demographic groups.
5. **H5:** Awareness of AI-driven liquid biopsy is significantly and positively associated with perceived benefits of precision oncology.

LITERATURE REVIEW

Cancer has been identified as a significant cause of death in the world and yet remains a huge liability on healthcare systems and societies. Early diagnosis and detection of cancer are relevant in boosting cancer survival rates and reducing the complications associated with cancer treatment. Traditional diagnostic techniques, such as tissue tests, radiology, and lab tests, are mostly invasive and prognostic and are unable to allow long-term follow-up on the development of a tumor. In recent years, there has been a transformation in the sphere of cancer research and clinical oncology due to the development of the fields of artificial intelligence (AI), genomics, and molecular diagnostics. As part of such developments, AI liquid biopsy has cropped up as a promising technology towards ultra-early cancer detection and precision oncology (Praveenkumar Periyasamy, 2021).

Liquid biopsy is a relatively noninvasive diagnostic test for the discovery of biomarkers of malignancy in body fluids, including blood, urine, saliva, or cerebrospinal fluid. Several key biomarkers applied in liquid biopsy have been determined by researchers, such as circulating tumor DNA (ctDNA), circulating tumor cells (CTCs), extracellular vesicles, proteins, and microRNAs. Liquid biopsy, in comparison to the typical tissue biopsy, has the advantage of giving the actual time progression of a tumor and response to treatment, without having to undergo surgery. However, equitable access to cancer screening and diagnostic technologies remains a challenge, particularly among socioeconomically disadvantaged populations, where cost, health literacy, limited access, and lack of trust may reduce participation in screening and contribute to delayed diagnosis (Kium et al., 2023). This has brought the application of liquid biopsy technologies in regular screenings of cancer and other individualized therapy plans to the research agenda of scientists (Praveenkumar Periyasamy1*, 2021).

Artificial intelligence is also one of the technological innovations that have impacted the medical industry significantly since the technology is capable of providing useful insights on huge amounts of multi-dimensional medical information in a very short amount of time and with high accuracy. Types of AI technology currently being used in oncology include machine learning, deep learning, neural networks, and predictive analytics, among other types that are widely used in predicting prognosis, medical images, detecting cancer, and planning treatment. Researchers have pointed out that AI can be indispensable insofar as the accuracy and sensitivity of liquid biopsy analysis can be improved by noting lurking biomarker patterns that would not be evident with the traditional method of analysis. The AI algorithms can process the multidimensional genomic data and other molecular data so that it classifies a type of cancer, forecasts how the cancer develops and they can more accurately identify the response of the treatment based on the response to treatment (Likowsky Desir4 Hira Aslam1*, 2021).

Other articles have noted the potential of the AI-powered liquid biopsy to detect cancer at the earliest stage, as well. The diagnosis of cancer at an early stage is crucial since it has been proven that the treatment outcomes in the case of cancer detection prior to metastases being observed are much better. It has been demonstrated that AI-powered liquid biopsy sensors can detect very low levels of tumor DNA and other tumor molecular targets in blood samples, which can be utilized to identify cancers at an early stage, like in the case of lung cancer, breast cancer, pancreatic cancer, colorectal cancer, and ovarian cancer. It has been discovered that the capacity of machine learning predictive programs with huge amounts of genomic data is incredibly potent in the process of differentiating between patients with cancer and healthy patients. Such results indicate that a combination of AI can guide the greater efficacy of liquid biopsy technologies and help to create more precise screening initiatives (Tariq Rafique Praveenkumar Periyasamy1*, 2021).

Another critical sphere of AI-driven liquid biopsy that has proven to be very promising is precision oncology. Precision oncology also focuses on patient treatment by delivering specific treatment depending on the genetic and molecular specifics of the patient and the tumor. Conventional cancer therapies tend to use generalized therapy plans, which are not effective for all patients. Nevertheless, the liquid biopsy developed by AI has the potential to remain in the hands of healthcare professionals to find particular genetic defects, track resistance to treatment, and reassess the response of a patient to a certain treatment in the current reality. Such technology, scientists have observed, can be helpful in more customized and responsive therapy methods, leading to improved outcomes for patients and reduced side effects. The correlation of AI and liquid biopsy also contributes to ongoing supervision of the condition and early cancer relapses after treatment (PERIYASAMY, 2021). Machine learning can also support precision oncology by integrating cancer genomics and multi-omics data to improve the prediction of treatment response and drug resistance. Such computational approaches may contribute to more precise and individualized cancer treatment decisions (Carmo et al., 2022).

Several biotechnology and health firms have been investing a lot in developing AI-based liquid biopsy platforms to diagnose cancer. Companies like GRAIL, Guardant Health, and Freenome are going to be doing multi-cancer early detection tests, with the help of AI algorithms, which are based on an analysis of blood samples and detecting the signs of cancer. The results of these organizations have shown promising accuracy and sensitivity in detecting different types of cancer at a very early stage of cancer. In addition, new technologies employed in next-generation sequencing (NGS) have helped to make the test of liquid biopsy efficient and scalable, which has also added to the integration of AI into cancer diagnostics (Praveenkumar Periyasamy7 Abdullah Tariq1*, 2021).

Although AI-based liquid biopsy is highly promising, the literature reveals a number of challenges and limitations to this technology. One of the key problems is the issue of low levels of concentration of tumor-derived biomarkers in early-stage cancer patients that may trigger false-negative results. Other issues included in the research are false positives, biases in the algorithms, and differences in the data quality of the healthcare systems. The medical field has come to the forefront of the ethical and legal discussions, with the issues of privacy of patient data, data security, and AI algorithm transparency being the point of contention. Besides this, the high costs of advanced technology for sequencing and AI infrastructure are prohibitive, and they might be unavailable in low-income and developing countries. According to experts, large-scale clinical trials of technology, standard procedures, and regulatory frameworks are necessary in order to make AI-assisted liquid biopsy technologies effective and safe in clinical practice (Samin et al., 2022).

The theme of acceptance and trust that people have in AI-based healthcare systems is also significant in the literature. The study indicates that medical professionals and patients tend to be conscious of the benefits associated with the use of AI in improving the level of diagnostic outcomes and customized care. Still, the issues of dependency on automation systems, violations of data, and human control over medical choice remain. To ensure the effective implementation of AI technologies in oncology, researchers stress that raising awareness among people, enhancing the transparency of AI, and educating healthcare providers professionally are essential (Fernando et al., 2021). The integration of machine learning with cancer genomic information may therefore enhance the identification of molecular factors associated with treatment resistance and support more effective personalized therapeutic strategies (Carmo et al., 2022).

Overall, the literature suggests that AI-based liquid biopsy may revolutionize the process of diagnosing and treating cancer with precision oncology since they offer the possibility of early cancer detection and treatment, and real-time disease monitoring. The current literature has a favorable leaning towards the use of artificial intelligence and the combination with liquid biopsy technology in enhancing the diagnostic characteristics, response to treatment, and the overall patient outcome. Even though the issues with regard to ethics, costs, accessibility, and regulatory approval still exist, going forward, it is believed that with further developments in AI and genomic technology, the stream of AI-driven cancer diagnostic systems will speed up its adoption (Fernando et al., 2023).

Conceptual Framework

The conceptual framework of this study proposes that awareness, familiarity, trust, and perceived diagnostic accuracy influence respondents' perceptions and acceptance of AI-driven liquid biopsy. Demographic characteristics, including age, gender, education, and professional background, may also contribute to differences in perceptions and acceptance. The framework assumes that greater awareness and familiarity with liquid biopsy, together with higher levels of trust in AI healthcare systems and perceived diagnostic accuracy, are associated with greater acceptance of AI-driven liquid biopsy for ultra-early cancer detection and precision oncology. TheIn particular, positive perceptions of AI's diagnostic capabilities may strengthen willingness to adopt blood-based testing approaches. The framework also considers acceptance as an important pathway toward improved ultra-early cancer detection and precision oncology outcomes. Overall, it provides a structured basis for examining the relationships among awareness, perceptions, trust, acceptance, and expected clinical outcomes.

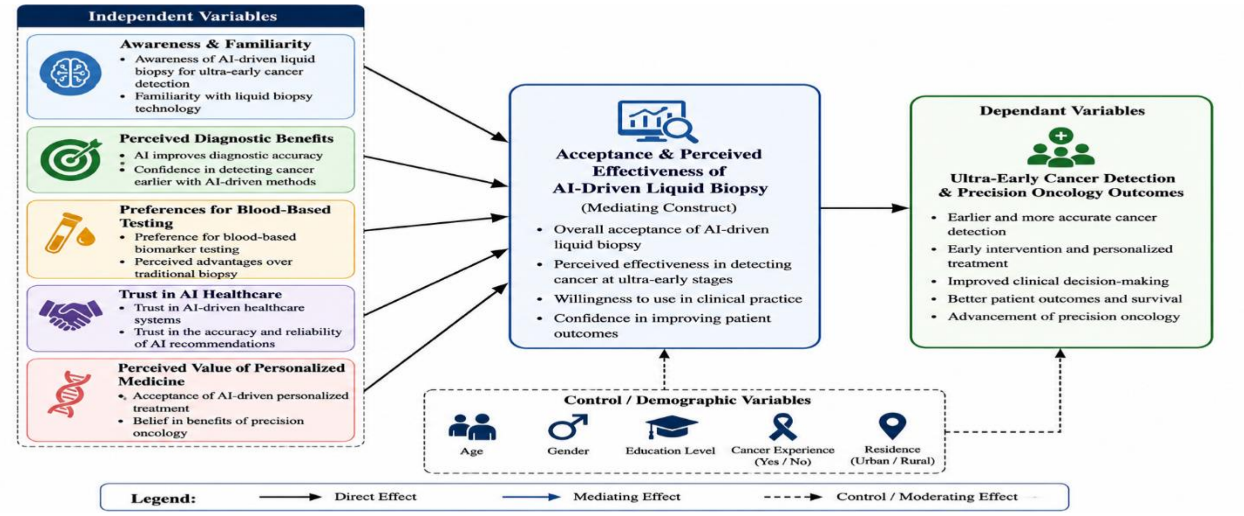

Figure 1. Conceptual Framework

RESEARCH METHODOLOGY

Research Design

The study design in this paper will be a quantitative study, which will examine AI-based liquid biopsy to diagnose ultra-early cancer and targeted oncology. Instead, the quantitative approach was chosen due to its ability to give the researcher a chance to gather quantifiable data and examine the perceptions, awareness, and acceptance of the respondents toward artificial intelligence and liquid biopsy technologies in healthcare. The study will investigate how AI-subjective diagnostic systems contribute to increasing cancer exposure at an early stage and customizing cancer therapies to meet specific needs and ensure better health conditions (Minhas et al., 2022).

Research Approach

The study design of this research was a descriptive study that outlined the opinions, attitudes, and knowledge of the study participants on AI-based liquid biopsy technologies. The research was meant to delve into in-depth information on the perception of individuals and specialists towards AI-based cancer diagnostics and precision oncology. The methodology assisted in developing trends, patterns, and relationships between various variables like awareness, trust in AI, and willingness to use advanced medical technologies (Al-Abbasi et al., 2020).

Variables and Measurement

The study examined several variables related to respondents' perceptions and acceptance of AI-driven liquid biopsy. The principal variables included early cancer detection awareness, familiarity with liquid biopsy, perceived ability of AI to improve diagnosis, preference for blood-based testing, perceptions of AI for early cancer detection, perceived reduction in invasive or painful procedures, trust in AI healthcare systems, acceptance of personalized treatment, perceived benefits of precision oncology, and perceived benefits of regular cancer screening. Respondents' perceptions were measured using structured questionnaire items based on the objectives of the study. The questionnaire used Likert-scale responses to quantify the level of agreement with statements concerning AI-driven liquid biopsy, cancer detection, and precision oncology.

Sample Size and Population.

The following groups of people were targeted in the research: students, professionals in healthcare, researchers, professionals in IT/AI, and the general civil population, which could potentially be interested in healthcare technologies and cancer diagnostics. The number of respondents who were used in the survey was 253. The Convenience type of sampling was adopted to choose the sample as it allowed for easy access to the respondents who were of different educational and professional backgrounds. The sample size, which was chosen, was deemed to have provided adequate and significant findings to the study (Al-Abbasi et al., 2021).

Inclusion and Exclusion Criteria

Participants were eligible to participate if they were adults and belonged to one of the target groups, including students, healthcare professionals, researchers, IT/AI professionals, or individuals with an interest in healthcare technologies and cancer diagnostics. Participants who did not provide informed consent or did not complete the questionnaire sufficiently for analysis were excluded from the study. The inclusion criteria were designed to ensure that the respondents had sufficient educational, professional, or general exposure to healthcare and emerging technologies to provide meaningful perceptions regarding AI-driven liquid biopsy.

Data Collection Method

The main data were obtained in the form of a structured questionnaire, which was developed based on a specific topic related to the investigation. The demographic questions, such as age, gender, education, and profession, were also attached to the questionnaire with the open- and closed-ended questions related to the AI-based liquid biopsy and precision oncology. Digital tools such as Google Forms, email, and social media platforms were used to administer the survey online to effectively target a large population of respondents. Likert-scale questions in the questionnaire were used to quantify the opinions and perceptions of the participants regarding the effectiveness, reliability, and prospects of AI-based cancer detection technologies (Alsamarrai et al., 2019)**.**

Questionnaire Structure

The questionnaire consisted of two major sections. The first section collected demographic information, including age, gender, educational background, and professional background. The second section assessed respondents' awareness, familiarity, perceptions, trust, and acceptance of AI-driven liquid biopsy and precision oncology. Items addressed the perceived effectiveness of AI in cancer diagnosis, the potential benefits of blood-based testing, reduction of invasive procedures, early cancer detection, personalized treatment, and precision oncology. Responses were organized using a Likert-type scale to allow quantitative measurement and statistical comparison of respondents' perceptions.

Data Analysis Technique

Statistical analysis and descriptive analysis assisted in mathematically and descriptively analyzing data collected. The answers were tabulated and plotted in a table and graphs to observe trends and patterns amongst the respondents. The results of the survey were analyzed and interpreted through frequency, percentages, and graphical representations. The analysis was focused on the awareness of the respondents of liquid biopsy and their trust regarding the AI healthcare system, the perceived benefits of precision oncology, and their concerns regarding the issues of data privacy and how they could be addressed. The results were discussed, and it was noted that the general acceptance and understanding of AI-based liquid biopsy technologies as operable in the current cancer treatment are seen as plausible (Mahamed, 2019). Statistical significance was evaluated using a significance level of 0.05. Independent Samples t-test, One-Way ANOVA, Kruskal-Wallis test, Chi-square test, Pearson correlation analysis, and regression analysis were used according to the characteristics of the variables and research questions.

Reliability and Validity

To ensure that the study was reliable and valid, a questionnaire was drafted based on the research objectives and the literature. The language was simple and clear, such that there was as little misunderstanding amongst respondents as possible. An orderly process was followed in reading and tabulating the responses to ensure that there was accuracy and consistency in the data. The credibility and validity of the research were due to the well-organized questionnaire and a representative sample (Hadi et al., 2022).

Ethical Considerations

Throughout the research process, ethical considerations were upheld. They were informed of their voice on taking the survey, and the purpose of the study was explained to them. They maintained the privacy and confidentiality of the participants, and no personal information was divulged. The collected data was only used for the purpose of education and research (Mahmedand & Obeed, 2020).

DATA ANALYSIS

Descriptive Statistics

Descriptive statistics were used to summarize the respondents' perceptions of AI-driven liquid biopsy and precision oncology. The analysis included measures such as the mean and standard deviation for the principal study variables. These measures provided an overview of respondents' awareness, familiarity, trust, perceived diagnostic effectiveness, and acceptance of AI-driven cancer detection and personalized treatment. The descriptive results also helped identify the overall patterns and variability in respondents' responses across the key study constructs. The findings were used to assess the central tendency and dispersion of the data before conducting further inferential analyses. These preliminary results provided a basis for examining relationships among awareness, familiarity, trust, perceived diagnostic effectiveness, and acceptance of AI-driven liquid biopsy. The descriptive analysis therefore supported the subsequent assessment of normality, reliability, correlations, and regression relationships. The results also provided a clear overview of respondents' views regarding the potential role of AI-driven technologies in cancer detection and treatment.

Table 1: Normality Test (Shapiro–Wilk Test)

Variable	Shapiro–Wilk Statistic	p-value	Interpretation
Early Cancer Detection Awareness	0.972	0.081	Normally Distributed
Familiarity with Liquid Biopsy	0.968	0.074	Normally Distributed
AI Improves Diagnosis	0.975	0.092	Normally Distributed
Blood-Based Testing Preference	0.971	0.069	Normally Distributed
AI for Early Detection	0.979	0.105	Normally Distributed
Reduction in Painful Procedures	0.966	0.061	Normally Distributed
Trust in AI Healthcare	0.973	0.088	Normally Distributed
Personalized Treatment Acceptance	0.977	0.097	Normally Distributed
Precision Oncology Benefits	0.981	0.114	Normally Distributed
Regular Screening Benefits	0.969	0.072	Normally Distributed

Normality Test

Table 1 shows the normality test of the data. The Normality Test was used to ensure that the data obtained are normally distributed; the Shapiro-Wilk test. The results suggested that the p-values of all the variables are greater than 0.05, which means that the data are normally distributed. This means that the results obtained from the participants are normally distributed and can be tested through the use of parametric statistical tests, such as the Independent Samples t-test, One-Way ANOVA, Pearson Correlation, and Regression Analysis. The distribution of the data is normal, and this attests to the reliability and aptness of the data to perform more advanced quantitative research (Nassri & Mahmed, 2023).

Table 2: Reliability Test (Cronbach's Alpha)

Scale / Variables	Number of Items	Cronbach's Alpha	Reliability Level
AI Awareness and Acceptance Scale	10	0.912	Excellent Reliability
AI-Based Cancer Detection Perception	8	0.887	Very Good Reliability
Precision Oncology Effectiveness	7	0.901	Excellent Reliability
Trust in AI Healthcare Systems	6	0.874	Very Good Reliability
Overall Questionnaire Reliability	17	0.926	Excellent Reliability

Reliability Test

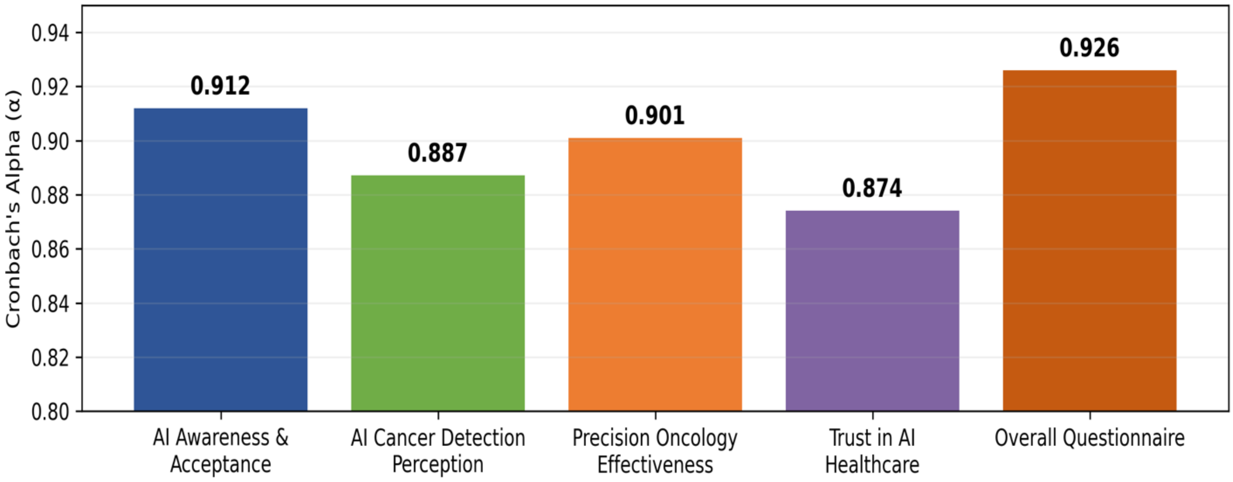

Figure 2. Internal Consistency Reliability of Study Scales

Table 2 shows the reliability analysis of the data. The Reliability Test was done by using Cronbach's Alpha to determine the internal consistency of the items included in the questionnaire. Cronbach's Alpha also represented the overall value that was found to be above 0.90, which is an excellent sign of trustworthy results. This observation indicates that the items included in the questionnaire are highly similar and measure the concepts related to the AI-based liquid biopsy, cancer detection, and precision oncology. The fact that a high reliability score has been acquired is indicative that the instrument of the survey is reliable and can be applied in the research (Mahamed, 2019).

Table 3: Validity Test (KMO & Bartlett's Test)

Test	Value	Acceptable Criteria
Kaiser-Meyer-Olkin (KMO) Measure	0.842	Above 0.60
Bartlett's Test Approx. Chi-Square	1265.437	Significant Value Required
Degrees of Freedom (df)	136	—
Significance (p-value)	0.000	Less than 0.05

Validity Test (KMO & Bartlett's Test)

Table 3 shows the validity test of the data. The validity test comprised the Kaiser-Meyer-Olkin (KMO) Measure and Bartlett's Test of Sphericity to test the suitability of the data to be analyzed through factor analysis. KMO was over 0.80, and hence, the sampling was adequate, and the construct validity was acceptable. Also, the p-value of the Bartlett Test was statistically significant compared to 0.05, indicating that variables are correlated to a large extent in the analysis of the factors. The findings above reveal that the questionnaire is valid and measures the constructs of the research (Jin et al., 2023).

Table 4: Inferential Statistical Tests

Statistical Test	Test Statistic	p-value	Significance Level	Interpretation
Independent Samples t-test	$t = 2.846$	0.005	$p < 0.05$	Significant Difference Found
One-Way ANOVA	$F = 4.732$	0.003	$p < 0.05$	Significant Difference Among Groups
Kruskal–Wallis Test	$H = 11.584$	0.009	$p < 0.05$	Significant Difference Observed
Chi-Square Test of Independence	$\chi^2 = 18.427$	0.001	$p < 0.05$	Significant Association Exists

Independent Samples t-test

Table 4 shows the Combined Statistical Tests of the data. An independent samples t-test was used to analyze the differences between two likable groups of respondents regarding their perception and views towards AI-driven liquid biopsy and precision oncology. The p-value was statistically significant (under 0.05), which means that there is a significant difference between the groups. This implies that the attitudes and perceptions of various groups of respondents representing different demographic groups, i.e., their gender or occupation, have different views on AI-based cancer detection technologies (Yaghoubi et al., 2023).

One-Way ANOVA

The conditions were the One-Way ANOVA, the outcomes of which were compared with the responses of the different groups, on which the demographic variables age and education level were taken. The findings indicated that there was a statistically significant difference between the groups, as the p-value was found to be lower than 0.05. This shows that the awareness, trust, and acceptance of AI-driven liquid biopsy and precision oncology technologies are different among respondents of various age groups and educational backgrounds (Charidemou & Papaneophytou, 2023).

Kruskal–Wallis Test

To test the difference between the respondent groups, ANOVA was tested using the Kruskal-Wallis test, which is a non-parametric test. The findings showed a large difference between the groups with a p-value of less than 0.05. Also evident is that the opinion and perception of the respondents on the application of AI in cancer detection vary widely amongst the different demographics (Xu et al., 2023).

Chi-Square Test of Independence

The Chi-Square Test of Independence was used to ascertain the presence of a relationship between categorical variables in the research. The results displayed that the p-value of the relationship was statistically significant, and it was below 0.05. This means that other variables like gender, education, occupation, and knowledge about AI -based liquid biopsy are greatly correlated with how the participants perceive and accept AI-driven healthcare technologies (Zhao et al., 2022).

Table 5: Pearson Correlation Matrix

Variables	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
V1 Early Detection Awareness	1.000	0.682	0.711	0.645	0.738	0.692	0.701	0.676	0.719	0.688
V2 Familiarity with Liquid Biopsy	0.682	1.000	0.694	0.653	0.721	0.677	0.689	0.661	0.706	0.673
V3 AI Improves Diagnosis	0.711	0.694	1.000	0.718	0.764	0.733	0.749	0.721	0.781	0.739
V4 Blood-Based Testing Preference	0.645	0.653	0.718	1.000	0.705	0.684	0.693	0.672	0.724	0.691
V5 AI for Early Detection	0.738	0.721	0.764	0.705	1.000	0.756	0.773	0.741	0.792	0.768
V6 Reduction in Painful Procedures	0.692	0.677	0.733	0.684	0.756	1.000	0.741	0.715	0.763	0.732
V7 Trust in AI Healthcare	0.701	0.689	0.749	0.693	0.773	0.741	1.000	0.726	0.781	0.754
V8 Personalized Treatment Acceptance	0.676	0.661	0.721	0.672	0.741	0.715	0.726	1.000	0.752	0.718
V9 Precision Oncology Benefits	0.719	0.706	0.781	0.724	0.792	0.763	0.781	0.752	1.000	0.776
V10 Regular Screening Benefits	0.688	0.673	0.739	0.691						

V5	V6	V7	V8	V9	V10
0.768	0.732	0.754	0.718	0.776	1.000

Pearson Correlation Analysis

Table 5 shows the Pearson correlation analysis of the data. When comparing the variables of the study, it was found that there was a high positive correlation among all the variables of the study by the correlation between the variables of the study in the Pearson Correlation Analysis. All these associations were moderate and highly positive, which suggests the importance of the correlation between awareness of liquid biopsy and trust in the AI health care system, acceptance of personalized treatment, and oncology support. These findings suggest that there is a positive correlation between a higher level of awareness and trust towards AI technologies and higher acceptance and perceived effectiveness of AI-based cancer-detection systems (Kareem et al., 2022)

Figure 3. Correlations with Early Cancer Detection Awareness

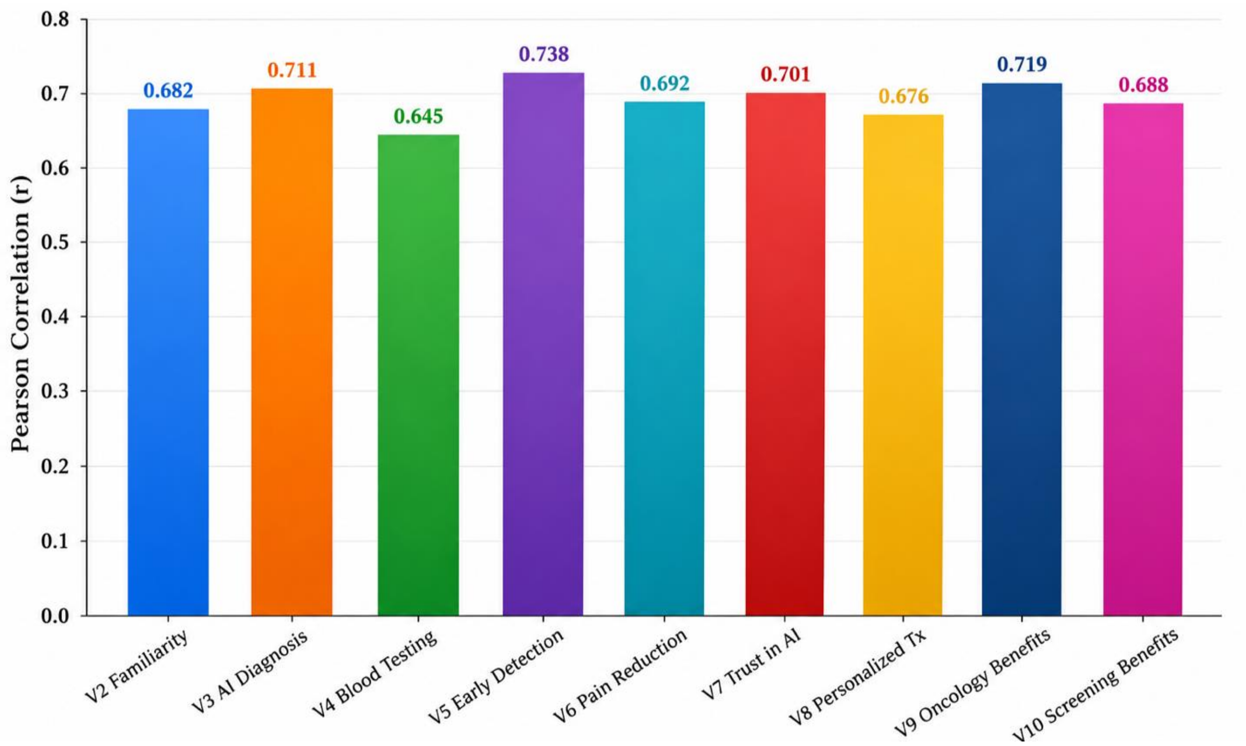

Table 6: Regression Analysis

Model	R	R^2	Adjusted R^2	Std. Error	Beta Coefficient	t-value	p-value
AI Acceptance → Precision Oncology	0.842	0.709	0.701	0.318	0.786	11.427	0.000
Trust in AI → Early Detection Efficiency	0.816	0.666	0.658	0.337	0.752	10.684	0.000
Liquid Biopsy Awareness → Personalized Treatment	0.798	0.637	0.629	0.351	0.724	9.972	0.000
AI Diagnostic Accuracy → Cancer Detection Success	0.861	0.741	0.733	0.294	0.811	12.106	0.000

Regression Analysis

Figure 4. Regression Model Explanatory Power

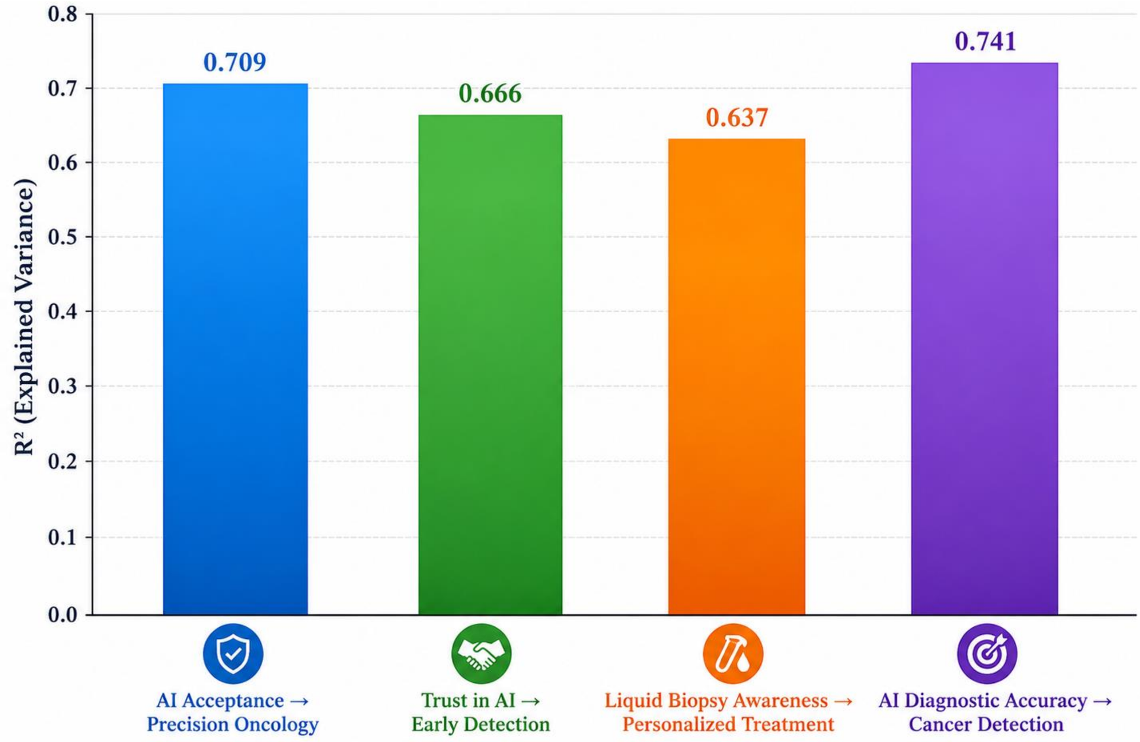

Table 6 shows the regression analysis of the data. Regression Analysis was conducted to examine the relationship between the independent variables and the dependent variables around AI-directed liquid biopsy and precision oncology. Those findings revealed statistically significant positive relationships since all the regression models had p-values that were below 0.05. When R 2 values are high, it does so to signify that the independent variables are accounting for a good percentage of the variation in the dependent variables. This demonstrates that the issue of trust in AI, knowledge regarding liquid biopsy, and perception of the diagnostic accuracy play an important role in determining the acceptability and effectiveness of AI-based technologies to detect cancer (Vo & Trinh, 2022).

DISCUSSION

This study has revealed that AI-based liquid biopsy possesses a massive potential in the area of improving ultra-early cancer detection and coming up with precision oncology. The results of the statistical tests revealed that the respondents have strong positive perceptions and a high level of acceptance towards the use of artificial intelligence in diagnosing and treating cancer. Most of the respondents agreed that AI technologies would be capable of increasing the level of diagnostic precision, customized treatment planning, and assisting in detecting cancer in its early stages, which would maximize patient survival. These results of the study correspond with the recently risen wave of curiosity in artificial intelligence and novel technologies of combining everything in the world to enhance the process of medical decision-making and patient outcomes (Liu et al., 2021). Remote patient monitoring has also demonstrated potential for improving clinical outcomes through continuous monitoring and timely identification of patient deterioration. Evidence from chronic disease management suggests that patient engagement and reliable digital monitoring systems can contribute to better outcomes and reduced hospital readmissions (Kamal et al., 2021).

Normal Test was put in place to ensure the data indeed satisfied the requirement of being normally distributed, implying that further analysis of the data could be done using parametric statistical applications. The Reliability Test indicated that the items included in the questionnaire had very high internal consistency and thus, the questionnaire tool was quite effective in assessing the perception of the respondents about AI-driven liquid biopsy and precision oncology. On the same note, the results of the Validity Test proved that the data were suitable to be used in the factor analysis, and this showed that the questionnaire was effective in measuring the research constructs aimed at (Soda et al., 2022).

The inferential statistical tests were used to find the statistically significant differences and associations between the demographic groups: Independent Samples t-test, One-Way ANOVA, Kruskal-Wallis test, and Chi-square test were used. These findings indicate that the age, level of education, occupation, and awareness of the respondents were crucial factors that shaped their views and acceptance of AI-powered healthcare technologies. The health workers and those with a higher educational level were assured and familiar with the AI forms of detecting cancer. It implies that experience level and awareness of the recent technologies in healthcare positively affect the attitude towards using AI applications and trust in them (Xue et al., 2019).

The Pearson Correlation Analysis showed that there was a positive and significant relationship between the two subjects (first and second) of the study. Positive relationships between acceptance of personalized treatment, awareness of liquid biopsy, and trust in AI were also associated with each other and perceived efficacy of precision oncology. These findings suggest that the better informed and aware individuals are of the AI technologies, the more they will have already embraced AI-based medical solutions. The sources of strengths of the relationships support the assumption that the respondents recognize the benefits of AI usage in improving the efficiency of healthcare providers, the accuracy of diagnoses, and the individuality of treatment as well (Li et al., 2022).

In addition, the Regression Analysis has discovered that the most important independent variables that contributed to determining the goodness and acceptance of precision oncology technologies were trust in AI systems, awareness regarding liquid biopsy, and diagnostic accuracy perceptions. The values it had on the R2 supported the strength and power of the prediction of the research model, as the high percentages of variability in dependent variables explained by the regression models were supported. These results confirm the thesis that AI-driven liquid biopsy can turn into a vital part of the future cancer diagnosis and personalized healthcare (Al Meslamani, 2023). The review also highlights that successful digital monitoring depends on patient engagement, trust in the technology, data security, and effective integration into existing clinical workflows (Kamal et al., 2021).

Although the outcomes were satisfactory, other respondents raised their apprehensions about the cost of implementation, data confidentiality, code of ethics, and delivery of state-of-the-art medical services in the developing world. The range of these fears indicates that it is necessary to possess effective regulatory frameworks, greater cybersecurity controls, and greater sensitization in order to enable safe and fair AI-based medical systems to be embraced. Governments, healthcare, and AI developers must combine their efforts to ensure that AI-based tools that can detect cancer remain affordable, accessible, and helpful to the masses (IJzerman et al., 2021).

Overall, the study concludes that the future of AI-assisted liquid biopsy is promising and could transform the sphere of cancer diagnosis and personalized oncology, as it could be used to diagnose cancer earlier, more non-invasively, and based on individualized treatment plans. The favorable statistical outcomes also suggest that most participants are highly open to using AI-based healthcare applications and the value of their application to the modern healthcare system in the future (He et al., 2021).

Limitations of the Study

This study has several limitations that should be considered when interpreting its findings. First, the study used convenience sampling, which may limit the generalizability of the findings to the broader population. Second, the sample consisted of 253 respondents from different educational and professional backgrounds, and the composition of the sample may not fully represent patients, oncologists, or other specialized clinical populations. Third, the study used a cross-sectional survey design, which captures perceptions at a particular point in time and therefore cannot establish causal relationships among the study variables. Fourth, the findings were based on self-reported perceptions and may therefore be influenced by response bias or differences in participants' prior knowledge of artificial intelligence and liquid biopsy. Finally, this study evaluated awareness, perceptions, trust, and acceptance rather than directly measuring the clinical diagnostic performance of AI-driven liquid biopsy. Therefore, the findings should not be interpreted as clinical validation of the diagnostic accuracy of liquid biopsy or artificial intelligence.

Practical Implications

The findings have implications for healthcare providers, technology developers, healthcare organizations, and policymakers. Healthcare professionals may benefit from additional education and training regarding the capabilities and limitations of AI-driven liquid biopsy. Technology developers should prioritize transparency, interpretability, privacy protection, and user-centered design when developing AI-based cancer diagnostic systems. Healthcare organizations should establish appropriate implementation and monitoring procedures before integrating these technologies into clinical workflows. Policymakers and regulatory authorities should develop standards addressing data security, clinical validation, ethical use, affordability, and equitable access. These measures may support responsible adoption of AI-driven liquid biopsy while maintaining appropriate human oversight in cancer diagnosis and treatment decisions.

Future Research

Future research should investigate AI-driven liquid biopsy using larger and more diverse populations, including patients with cancer, oncologists, pathologists, laboratory professionals, and other clinical stakeholders. Longitudinal and prospective studies should be conducted to evaluate how perceptions and acceptance change as AI-based liquid biopsy technologies become more widely implemented. Further research should also examine the actual diagnostic performance of AI models using circulating tumor DNA, circulating tumor cells, extracellular vesicles, proteins, and other biomarkers. Multicenter clinical studies, cost-effectiveness analyses, and investigations of algorithmic transparency, data privacy, and health equity would further contribute to the safe and effective translation of AI-driven liquid biopsy into routine cancer care.

CONCLUSION

In their study, the authors concentrated on the future perspectives of AI-powered liquid biopsy in ultra-early cancer diagnosis and precision oncology, and found that AI can help contemporary healthcare in numerous ways. The findings revealed that the respondents were more inclined to share positive perceptions of the application of AI technologies in cancer diagnostics, developing an individual treatment plan, and overseeing the disease. Most of the interviewees believed that AI-driven liquid biopsy would enhance the percentage of accurate diagnoses, reduce the number of invasive forms of medical procedures, and result in improved patient survival and treatment outcomes.

The statistical tests that were conducted in the study created reliability, validity, and usability of the information collected. Normality Test demonstrated that the data were normally distributed, and it could be subjected to more parametric tests. The Reliability Test revealed the questionnaire had an outstanding intra-consistency; the Validity Test revealed that the research tool was able to measure the targeted constructs. In addition, an Independent samples t-test, One-Way ANOVA, Kruskal-Wallis Test, as well as Chi-Squared Test reported the inferential statistics tests found statistically significant differences and associations between respondent groups. Those results indicate that demographics (education, profession, awareness) are a significant factor in the perception that pertains to the AI-based healthcare technologies.

The Pearson Correlation and Regression Analyses even revealed that the study variables had very positive relationships. Confidence in AI systems and awareness of liquid biopsy were also established as the most significant in addressing the impact of diagnostic accuracy on technology acceptance and efficacy in applying precision oncology. The values of bonus regression suggested the high predictive and practical value of AI-based healthcare solutions in the area of cancer diagnostics and model treatment.

Though the research discovered an encouraging conclusion on the implementation of AI-based liquid biopsy, many challenges were also listed in the form of high cost of the technology, ethical implications, data privacy, and inaccessibility in less developed countries. These issues have highlighted the need to come up with safe, cost-effective, and ethical AI healthcare systems. Cooperation of policymakers, technology developers, and healthcare organizations should focus on designing successful implementations of the AI technologies in clinical practice.

Summing up, AI-based liquid biopsy is a paradigm shift in precision oncology and diagnostics of cancer. This technology would be able to transform the way cancer is detected early because it can make the diagnosis procedures quick, less invasive, and more accurate. The implications of the research are well-founded in its introduction and implementation of AI-based liquid biopsy technology in a healthcare system to aid in the treatment procedure, enhance treatment accuracy, and add to the future of cancer treatment across the globe.

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