Innovations in cancer diagnosis and treatment: prospects and challenges

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Abstract

The research relevance of cancer diagnostics and treatment is determined by its widespread occurrence and the lack of adequate modern diagnostic methods. The study aims to characterise new diagnostic methods, namely screenings in detecting cancer at early stages of development. To achieve this goal, the bibliosemantic and bibliographic methods were used. Cancer is the leading cause of morbidity and mortality after cardiovascular diseases and injuries in many countries around the world. Various diagnostic and treatment methods are used to combat this problem, including computed tomography, magnetic resonance imaging and positron emission tomography. In addition, modern diagnostic methods such as polymerase chain reaction, mass spectrometry and genomic sequencing play an important role in determining the types of cancer cells and their sensitivity to treatment. These advanced methods can be used to diagnose cancer more accurately and efficiently and choose the most

appropriate treatment strategies for each patient. The practical significance of this topic is to ensure appropriate care for patients with cancer: providing high-quality, efficient, fast and minimally invasive diagnostics using the latest methods, as well as implementing a screening system.

Introduction

Cancer remains one of the most common and dangerous medical problems in the world today. The speed of diagnosis, the success of treatment, and the prognosis of the disease leave much to be desired. For this reason, new approaches and innovations in the field of cancer diagnostics are constantly being sought.[1] According to Siegel *et al.*,[2] the number of cancer cases is expected to increase every year. For example, in the United States, despite technological advances in medicine, 609,820 cancer deaths were recorded. The topic presented is extremely relevant and needs to be studied in connection with the rapid spread of cancer incidence of various origins and locations. The problem occurs in several cancers that remain without visible early symptoms for a long time, or such symptoms are often missed and diagnosed at later stages. Another reason is the diversity and heterogeneity of tumours, and most importantly, the lack of a perfect screening system for early cancer diagnosis. For instance, Merkuri *et al.*[3] addressed the imperfection of cervical cancer diagnosis in Albania. This pathology is the second most common among women aged 14-44, and screenings have been established at the state level for primary examinations. However, complicated cases of the disease have become increasingly common around the world.

Dimitrova *et al.*[4] state that many countries, such as Albania, Macedonia, and Bosnia and Herzegovina, already have decent standards of early cancer detection. However, despite

significant progress, such screenings remain imperfect and require further improvement, as complicated forms of cancer are overlooked due to the lack of diagnostic accuracy. Xhemalaj *et al.*[5] point out that the prevalence of cancer among the population of Albania, including even the capital Tirana, is quite high, which endangers the healthcare system. Moreover, in Albania, malignant tumours cause 13 to 18% of deaths. The author notes that lung cancer is the first among morbidity and mortality, and this number is more than 15%. Given the widespread prevalence of cancer, it is important to introduce not only new diagnostic methods but also therapeutic ones. To put the results in perspective, it would be more instructive to compare the lung cancer rates and treatments in Albania with those of other nations in the area or the world. Thus, Filaj *et al.*[6] described the use of lasers in the treatment of cancer. This method is widely used to correct benign tumours – haemangiomas – and vascular anomalies. In addition, this method should be considered as an innovative approach to tumours of other origins. Although a comparison with other treatment modalities would provide a more comprehensive view of haemangioma management.

Modern sources focus on the latest trends in cancer diagnostics. One of them is diagnostic markers based on RNA and DNA. Wang *et al.*[7] believe that such methods are promising in addressing mRNA, non-coding RNA, circular RNA, and microRNA. The author notes that these types of RNA are the most sensitive in the diagnosis of cancer. Song *et al.*[8] describe another promising method shortly: the determination of cell-free DNA in the patient's plasma. It is believed that part of the tumour DNA enters the bloodstream and can be considered a biomarker of a particular tumour, and this fact may be useful in treatment in the future. However, at the same time, the collection and determination of this DNA can be inconvenient and inaccurate, so this method still needs to be developed. A similar study on the structure of DNA was highlighted by Dolatkhah *et al.*[9] The scientists tested the effectiveness and reliability of DNA detection in the early diagnosis of colorectal cancer. However, colonoscopy

has proven to be a more accurate and effective method, although it is not a new method. In turn, molecular screenings leave more questions than answers, which means that these areas are innovative and promising but still poorly understood. Additionally, it's important to keep in mind that diverse populations and healthcare systems may respond differently to screening techniques.

By offering a thorough and current examination of advancements in cancer detection and therapy, this study seeks to advance previous findings in the field. As opposed to earlier research, which frequently concentrated on particular cancer types or diagnostic techniques, this research adopts a more comprehensive strategy, looking at a wide range of cutting-edge technology and procedures across diverse cancer types. It offers a comprehensive picture of the state of oncology today by combining, for the first time, a review of both diagnostic and therapy breakthroughs. The authors also highlight how these new technologies should be integrated into the current healthcare systems, discussing alternative answers and real-world implementation issues. Furthermore, the authors looked at how Artificial Intelligence (AI) and machine learning can improve cancer diagnosis and treatment planning.

The study aims to describe the main aspects of the latest methods of diagnosing cancer, which can be useful for the timely detection of cancer pathology.

Materials and Methods

Bibliographic and bibliosemantic methods were used in the study of literature, which has significantly improved the quality and depth of the research. The approach to the use of scientometric databases such as Scopus, Web of Science, PubMed, and Google Scholar, as well as other archives, including Research Gate, demonstrates a broad analysis of the current professional literature on the problem under study. The choice of searching by title rather than by topic allowed us to accurately identify relevant research topics, which contributes to the

accuracy and relevance of the information obtained. The absence of language restrictions makes it possible to cover a wide range of scientific literature and consider different points of view and approaches to the problem under study. A number of terms, concepts, phrases and keywords were used to search for scientific information: "cancer," "oncology," "pre-cancerous conditions," "screening," "diagnosis," "treatment," "therapy," "examination," "biopsy," "cervical cancer," "colorectal cancer," "treatment effectiveness," "tumour markers," "biomarkers," "DNA analysis," "RNA analysis," "genetic engineering," "gene mutations," "gene expression," "non-coding genes," "gene alleles," "lung cancer," "biomolecular condensates," "molecular analysis," "circular RNA," "gene regulators," "incidence," "population," "risk group," "smokers," "teratogenic factor," "bad habits," "mortality," "prognosis," "risks," "research perspectives," "standardisation of diagnostics," "ultrasound diagnostics," "computed tomography," "regional spread of the tumour," "regional lymph nodes," "Pancosta syndrome," "low-dose tomography," "health insurance," "diagnostic limitations," "clinical manifestations," "peripheral tumour growth," "paraneoplastic syndromes," "positron emission tomography," "scintigraphy," "gun biopsy," "navigation biopsy," "fibre optic biopsy."

In general, the approach to the problem involves the use of various methods of analysis, synthesis, generalisation, and classification, which contributes to a more complete and deeper understanding of the topic under study. The method of analysis, which includes collecting information and breaking down the main statement into theses, made it possible to systematise the data and highlight key aspects of the problem. Literary analysis, based on the collection and processing of scientific literature, provides access to relevant and authoritative sources, which contributes to qualitative analysis and conclusions. The hermeneutic method used to interpret the texts and identify the main concepts and provisions determined the semantic depth and meaning of key terms in the context of the problem under study. This

action is especially important when researching such a serious problem as the oncology of various localisations and studying modern methods of cancer diagnosis with their advantages and disadvantages. This integrated approach to analysing and processing information allowed us to gain a comprehensive understanding of the problem and formulate informed recommendations and conclusions. The classification method provided information on the clinical division by location of different types of cancer.

In addition, benign neoplasms of various organs were also considered to select the optimal diagnostic method. The integration of statistical data from various countries, such as Albania, Korea, Europe, the United States, Canada, Australia, and Japan, has provided a more complete picture of the prevalence and characteristics of the problem on a global scale. The statistics provide an opportunity to analyse the probable causes of the sharp rise in cancer incidence in different countries, regardless of where they live, and to analyse both standard and advanced diagnostic methods to ensure timely detection of the tumour process. Meta-analysis, as a type of statistical method, is important when analysing large amounts of data from various sources on the topic of oncology diagnostics. This method was used to combine the results of multiple studies to obtain a more generalised and reliable assessment of the effectiveness of diagnostic methods, as well as to assess the degree of consistency of results between different studies. Despite the potential for bias in opinion or data, meta-analysis still provides valuable information to form an average assessment or opinion about the purpose and problem of oncology diagnosis.

Results and Discussion

Cancer is a disease with different genetic characteristics

The results by Wang et al.[10] showed that effective interventions can prevent 30-50% of cancer cases. Early diagnosis is substantial in improving the prognosis and survival of patients with

cancer. The development of new molecular biomarkers for tumours that are highly sensitive and specific and have a low false-positive rate is becoming particularly important.[11] The use of these biomarkers can help detect cancer progression over time. Modern methods of oncology diagnostics include a wide range of technologies, from molecular to imaging. Technologies that play an important role in improving the accuracy and speed of diagnosis: i) radiomics; ii) machine learning; iii) rare biopsies; iv) immunodiagnostics; v) genomic and proteomic diagnostics; vi) blood immunology testing; vii) mass spectrometry.

One of the most promising areas in oncology diagnostics is a personalised approach. This includes analysing the patient's genetic makeup, the molecular characteristics of the tumour and other factors to select the most effective diagnostic and treatment methods for each individual.

There are large differences in how innovative cancer diagnostic technologies are implemented in various nations and healthcare systems. While developed countries like the US, Japan, and many European countries are leading the way in implementing cutting-edge methods like genomic profiling, AI-assisted imaging, and liquid biopsies, many developing nations find it difficult to obtain these advancements because of infrastructure and resource limitations.[12] For example, PET/CT scans are rarely available in low- and middle-income countries, despite being widely used for cancer staging in high-income countries. In a similar vein, the use of genomic testing-based precision medicine techniques is expanding quickly in certain areas but is still out of reach for a large portion of the world's population. These differences in the availability of state-of-the-art diagnostics underscore the necessity of international collaboration and policies aimed at closing the worldwide disparity in cancer care. Adapting and deploying affordable versions of these technologies in areas with limited resources is essential to guaranteeing more equitable access to modern cancer diagnostics globally.

The importance of RNA in cancer diagnosis

Following Cervena *et al.*,[13] long non-coding RNAs (lncRNAs) are substantial in tumour formation and development, regulating the malignant biological activity of tumour cells at the levels of transcription, post-transcription, and gene epigenetics. Their influence on transcription processes organises and coordinates gene expression, which affects various biological functions of the cell, including growth, division, and metastasis. At the post-transcriptional level, lncRNAs can interact with RNA molecules and proteins, regulating mRNA processing and stabilisation and affecting gene transfer mechanisms in cancer. These long, non-coding RNAs can affect the epigenetic landscape of a cell by altering chromatin availability and interactions with regulatory elements. This is of great importance for controlling gene expression and tumour development. For instance, high expression of *SNHG3* can promote tumour cell proliferation and migration by activating signalling pathways such as *TGF-β* and *IL-6/JAK2/STAT3*. This, in turn, leads to an increase in the growth rate of tumour cells and inhibition of apoptosis by inhibiting the expression of *KLF2* and *p21* genes. Recent studies have confirmed that *SNHG3* affects cancer progression by regulating its interaction with microRNAs, in particular miR-384, miR-182-5p, and miR-139-5p.[14, 15] This interaction increases, which leads to a decrease in the effectiveness of control over cellular balance and contributes to the acceleration of cancer progression.

Biopsy is a basic method of cancer screening

Following Park *et al.*[16] and Shende *et al.*,[17] the number of cancer cases in Korea has decreased over the past few years, which can be explained by modern early diagnosis. However, when studying the issue of lung cancer, the study determined that the proportion of patients among men is decreasing, while among women it is increasing. The reason is that more and more men are quitting smoking, and women are smoking more and more often. The author focuses

on the problems of early diagnosis of peripheral lung cancer. One of the most promising diagnostic methods is a biopsy from the pathological focus, but this procedure has several advantages and disadvantages in its use (Table 1).

An important statistic is the fact that more than 85% of ovarian cancer cases occur in women without an increased hereditary risk.[18] Since the ovarian cancer screening procedure requires surgery, it is recommended that the positive predictive value should be at least 10%.[19] This is to ensure that the benefits of screening are balanced against the potential harm of unnecessary procedures. This approach maximises the benefits of screening for women by reducing the likelihood of unnecessary medical interventions. Various methods are used to detect ovarian cancer at an early stage, with ultrasound imaging and blood tests, such as *CA125*, being among the main ones. Transabdominal and, more recently, transvaginal sonography has also been investigated in several large scientific studies. Nebgen *et al.*[18] described that 90% of patients with stage III-IV ovarian cancer can have elevated levels of *CA125* in the blood. However, in stages I-II, the sensitivity of this marker decreases, and only 50-60% of patients may have elevated *CA125* levels. This means that *CA125* cannot always be used effectively to detect early stages of ovarian cancer, and other diagnostic methods such as ultrasound and transvaginal sonography may also be required to fully assess the patient's condition. The same opinion is shared by Budny *et al.*[20] in a description of ovarian and breast cancer. In addition, the authors addressed the heredity and medical history of patients and emphasised the importance of ultrasound, biopsy, and tumour marker testing. A high percentage of ovarian cancer cases are observed in women with genetically determined factors, such as mutations in the *BRCA1* and *BRCA2* genes, as well as the Li-Fraumeni, Cowden, and Peitz-Jeghers syndromes. Women with genetic mutations or syndromes have a significantly increased risk of developing ovarian cancer compared to the general population.[21, 22]

Following Connal *et al.*[23] and Xu *et al.*,[24] surgery is an effective cancer treatment that provides the best chance of a complete cure and is reported to have fewer side effects than chemotherapy and radiotherapy. Early diagnosis of cancer not only saves lives but also significantly reduces treatment costs. However, current clinical tests lack sensitivity and specificity in the early stages of cancer. Many cancers can be asymptomatic in the early stages, making them difficult to detect. The liquid biopsy test can open new opportunities to improve screening and triage at an early stage, increasing the proportion of patients with abnormalities who need further investigation. This improvement in the efficiency of the diagnostic process can help reduce delays in diagnosis and lower healthcare costs. An effective liquid biopsy triage test should be affordable so that it can be used by large populations of patients with nonspecific symptoms. This will allow for regular screening and early detection of pathological changes in liquid biopsy without unnecessary costs and efforts.[25, 26] The use of such a test can also reduce unnecessary diagnostic procedures, overtreatment, and patient anxiety. As a result, it is possible to expect a reduction in healthcare costs and an improvement in the quality of patient care.

Pandey *et al.*[27] and Bradshaw *et al.*[28] addressed the diagnostic capabilities of molecular methods in the detection of gastric cancer. The development and progression of gastric cancer are associated with various molecular biomarkers that play an important role in the diagnosis, prognosis, and selection of treatment methods for this disease. The *HER2* protein (the so-called human epidermal growth factor 2) is one of the key biomarkers of gastric cancer. Increased *HER2* expression is associated with a more aggressive course of gastric cancer and a poorer prognosis. Assessing the level of *HER2* expression is important in selecting the appropriate therapy, as some patients may benefit from targeted anti-*HER2* therapy, such as trastuzumab. The tyrosine kinase receptor of the epidermal growth factor receptor (EGFR) family also plays a significant role in the development and progression of gastric cancer.

EGFR expression is often associated with more aggressive forms of gastric cancer and may affect prognosis and treatment options. Targeted therapy against EGFR may be effective in subgroups of patients with high levels of EGFR expression. Thus, the assessment of HER2 and EGFR expression levels is of great clinical importance in the management of gastric cancer, and the use of targeted therapies against these molecules may be an effective approach in the treatment of certain subtypes of this disease.

Instrumental diagnostic methods in solving the problem of cancer screening

Following Liu *et al.*[29] and Brito *et al.*,[30] Computed Tomography (CT) is widely used to detect and stage primary lesions in patients with unknown primary lesions, particularly those with a particular sensitivity to primary lesions in the lung, pancreas, or kidney, and is useful for detecting metastatic lesions in the liver, lung, and bone. However, it is worth noting that in some cases, CT may miss smaller or inconspicuous lesions without abnormal morphological or vascular changes. This can occur, for example, in cases where the lesions are very small or in areas that are difficult to visualise with CT. Positron emission tomography/computed tomography (PET/CT) is a powerful diagnostic tool that combines functional and structural information to study pathological changes in the body in detail. In the case of gastric cancer and other cancers, PET/CT can be used to determine the extent of tumour spread, detect metastases to other organs, and assess the effectiveness of treatment. This method can be used to visualise areas of increased metabolism, which often correspond to cancer cells, and to accurately localise the tumour.

PET/CT is a powerful diagnostic tool that combines functional and structural information, providing accurate localisation and characterisation of bodily damage. These two methods complement each other, making PET/CT particularly valuable in clinical practice. PET/CT uses a radioactive tracer, usually 18F-fluorodeoxyglucose (*18F-FDG*), which is similar to

glucose.[31] After intravenous injection of 18F-FDG, it is phosphorylated by hexokinase and accumulates in tissues with increased glucose metabolism, such as tumours. *18F-FDG* is not further metabolised and remains in the cells, which allows visualisation of active tumour foci on the scan. *18F-FDG* in PET/CT can be used to detect and evaluate tumour activity, as increased glucose metabolism is typical for most malignant tumours. Thus, PET/CT with *18F-FDG* becomes a molecular probe for the diagnosis of cancer processes, which makes it an important tool for assessing the extent of cancer spread, monitoring the effectiveness of treatment, and making decisions on further treatment. This method provides more detailed information about the volume, size, and activity of tumours, which helps in making treatment decisions and determining prognosis.[32] Studies confirm that the concentration of 18F-fluorodeoxyglucose (*18F-FDG*) used in PET/CT can effectively distinguish malignant lesions from benign ones. *18F-FDG* is an analogue of glucose and accumulates in tissues with increased glucose metabolism, which is typical for tumour cells. Therefore, on a PET/CT scan, areas with increased glucose metabolism activity may indicate the presence of cancer or other malignant processes. The high diagnostic accuracy provided by PET/CT can be used to determine the stage of the disease, assess its spread in the body, and determine the effectiveness of treatment. This is especially important for planning the optimal treatment strategy and monitoring the dynamics of the disease. The use of *18F-FDG* PET/CT imaging allows the detection of primary tumour lesions with high diagnostic value. The results by Gharehzadehshirazi *et al.*[33] have shown a decrease in the incidence of unknown primary lesions among head and neck cancers from 2-9 to 1-2% after the introduction of PET/CT. In addition, PET/CT can simultaneously detect other metastatic sites and assess their extent, which has a significant impact on determining the stage of the tumour, its recurrence, and the choice of treatment methods. Consequently, PET/CT plays a key role in the diagnosis of CUP, providing a more accurate and comprehensive assessment of patients with unknown primary

lesions. Magnetic Resonance Imaging (MRI) can also be used to diagnose stomach cancer, especially if the tumour is suspected to have invaded neighbouring structures or metastasised. MRI provides higher image resolution and contrast, especially in soft tissues, making it a useful tool for detailed assessment of the tumour process.[34]

Table 2 provides a comparative overview of various imaging techniques mentioned before that are used in cancer diagnostics, highlighting their strengths, limitations, and primary applications.

Although the diagnosis of cancer can be much improved with these cutting-edge imaging methods, there are a number of obstacles to overcome in their use. Many healthcare facilities may find the expensive cost of equipment, particularly for PET/CT and MRI, to be unaffordable, especially in environments with low resources. Furthermore, these technologies frequently call for specific training for both use and interpretation, which can result in a staffing shortage. These sophisticated procedures typically offer more precision and detail when compared to more conventional techniques like X-rays.[35] For example, PET/CT might identify metabolically active tumours that traditional CT alone might miss, which could result in an earlier diagnosis and better patient outcomes. But the price of each exam goes up with this greater precision. It is also important to carefully consider the diagnostic benefits of CT and PET/CT radiation exposure vs. radiation exposure, particularly in situations when repeat imaging is necessary. Despite these difficulties, the enhanced diagnostic powers of these sophisticated procedures can result in more accurate staging, better treatment planning, and possibly better patient outcomes compared to more conventional approaches. For instance, MRI is very useful for tracking treatment response over time since it may give comprehensive soft tissue imaging without exposing the patient to radiation. A key difficulty in enhancing overall cancer care is striking the correct balance between introducing these cutting-edge

technologies and guaranteeing universal access to fundamental diagnostic tools as healthcare systems continue to change.[36]

The development of nanotechnology opens broad prospects for the diagnosis and treatment of cancer. According to Jin *et al.*[37] and Gupta *et al.*,[38] nanotechnology is a promising area of research that can significantly improve the diagnosis, treatment, and monitoring of cancer. Nanoparticles and nano vectors can be used to deliver drugs directly to tumour cells, which increases the effectiveness of treatment and reduces side effects. Nanoparticles can be used to deliver gene constructs to tumour cells, which modulate their function and regulate growth and division. Various nanomaterials, such as gold nanoparticles and quantum dots, can be used in these applications due to their unique physical and chemical properties. The use of nanotechnology in oncology opens new opportunities to improve the diagnosis and treatment of cancer, and research in this area may lead to the development of new innovative methods of combating this disease.[39] These materials can work at the molecular level, which can be used for accurate cancer diagnosis and visualisation of pathological processes. For instance, nanoparticles can be loaded with drugs and delivered directly to the tumour, providing precise and targeted treatment. Nanotechnologies are also used to develop nanosensors for detecting cancer biomarkers with high sensitivity and specificity.[40] All these advances in nanotechnology open new opportunities for early diagnosis and effective treatment of cancer, which will significantly improve the prognosis and quality of life of patients.

Thakur *et al.*[41] described the possibility of predicting the occurrence of cancer in their research. As determined, the known gene signature can be successfully used for histopathological classification of non-small cell lung cancer. Ji and Cui,[42] Bahrami and Ferns[43] presented one method of cancer prognosis based on gene expression. The main purpose of this classifier is to predict early-stage recurrence of the disease in patients with colorectal cancer. This gene expression-based classifier identifies patients at increased risk of

colorectal cancer recurrence and prescribes additional treatment or monitoring promptly. This method can improve treatment results and reduce the likelihood of recurrence. Such studies open new opportunities for an individualised approach to cancer treatment and improve the efficiency of predicting treatment outcomes based on genetic data.

Recent years have brought significant advances in genomic and transcriptomic engineering based on the CRISPR system. The CRISPR-Cas13 RNA-targeting system is a unique tool with potential for cancer diagnosis, therapy, and research. Cas13, as part of this system, has several biochemical properties that make it a promising tool in the fight against cancer. Cas13-based diagnostic methods offer early detection and monitoring of cancer markers from liquid biopsy samples such as blood or urine without the need for sophisticated devices. This can simplify the diagnostic process and improve the results of disease treatment, as it will allow the detection of cancer at early stages when treatment is more effective.[44] In addition, Cas13 can be used for targeted cancer therapy by degrading and manipulating cancer-associated transcripts. This method has high efficiency and specificity, which makes it promising for use in the treatment of cancer. Thus, the RNA-targeted CRISPR-Cas13 system opens new opportunities in cancer diagnostics, therapy, and research, which can significantly affect the practice of clinical oncology and improve patient outcomes. This, in turn, opens new opportunities for the development of innovative treatments aimed at precisely targeting cancer cells with minimal side effects.

In cancer therapy, the CRISPR-Cas13 system can be used for targeted editing of the tumour cell genome, which allows for the inactivation of oncogenes or enhancing the activity of tumour suppressor genes. This fact opens up prospects for the development of innovative cancer treatment methods with high efficiency and safety. In cancer research, the CRISPR-Cas13 system plays an important role in identifying new molecular mechanisms of tumour development, investigating mechanisms of drug resistance, and finding new therapeutic

targets. This contributes to the development of more effective methods of cancer diagnosis and treatment. These new technologies allow researchers to better understand the mechanisms of cancer development, identify genes that may be responsible for drug resistance, and discover new molecular markers that can be used as therapeutic targets.[45,46] In addition, the CRISPR-Cas13 system is applicable for precise RNA editing, which opens new opportunities for the development of personalised cancer treatments. Researchers actively using CRISPR-Cas13 technologies can develop new next-generation cancer diagnostic and treatment strategies that can be effective and safe for patients. PSA and ACPP are just two examples of protein biomarkers found in areas of high concentration in tissues, and many others are being studied. In addition to selective gene expression, the expression of tissue-specific proteins can result from mechanisms such as differential splicing, which generates tissue-specific variants.[47,48]

While new technologies have the potential to revolutionise cancer diagnosis, a lot of them use AI, which also raises significant ethical concerns. The possibility of bias in AI algorithms, which might result in differences in diagnosis and treatment is one of the main problems. AI systems may generate biassed results and disadvantage some groups based on factors such as ethnicity, gender, or socioeconomic position if they are trained on datasets that are not representative of varied communities. Furthermore, maintaining confidence in AI decision-making processes depends on their transparency. Clear explanations and accountability systems are necessary for patients and healthcare professionals to be able to comprehend and critically examine the reasoning behind AI-driven decisions. The use of AI in cancer diagnosis could worsen already-existing healthcare disparities and erode patient confidence in new technologies if these ethical issues are not resolved.

Post-translational processing and modification of proteins are important aspects of their functional regulation. In the human body, proteins can undergo various types of post-

translational modifications, such as phosphorylation, glycosylation, acetylation, methylation, and others, which can significantly affect their structure, function, and interaction with other molecules. The proteome is the set of all proteins synthesised in a cell or organism, and it represents a more complex level of organisation of biological systems than the genome. As estimated by Yadav *et al*.,[49] in general, many different proteoforms can exist in the human body due to various types of post-translational modifications and alternative splicing. One example of a protein modification used as a biomarker for malignant diseases, as mentioned, is *CA19-9*. *CA19-9* is a glycoprotein, and its levels may be elevated in the blood of patients with certain types of cancer, such as pancreatic and gastric cancer. Changes in *CA19-9* glycosylation can be used as a disease marker and in the diagnosis of cancer. Thus, the understanding of post-translational modifications of proteins and their role in pathology contributes to the development of new methods of diagnosis and therapy of various diseases, including cancer. Although oncofoetal antigens may be considered an unexpected source of tumour-specific markers, tumours seem to regularly express tumour-specific modified proteins or neoantigens resulting from mutations. These neoantigens are of interest because they can stimulate the body's immune response to fight tumours. In addition, they can serve as targets for diagnostic or therapeutic applications.[49] Thus, the study of neoantigens opens new prospects for the development of effective methods of cancer diagnosis and treatment. Recent advances in immune-oncology therapy targeting *PD-1*, *PD-L1*, and *CTLA4* proteins are opening new perspectives in cancer treatment. Studies show that many tumours stimulate specific immune responses. However, progressive tumours can develop mechanisms to avoid the immune response, which necessitates the improvement of treatment methods.[50] One of the key aspects of this research is the identification of new molecular mechanisms underlying the interaction between tumours and the immune system.[51] This describes why some tumours become resistant to immunotherapy, while others respond effectively to this therapy. One of

these mechanisms is the tumour's ability to neutralise the immune response through molecular mechanisms, such as *PD-L1* expression or the production of immunomodulators. This makes them less vulnerable to immune system attacks. However, given the ongoing research, it is possible to develop new treatments that can overcome these mechanisms. Studies also show those immune responses can be directed to specific targets in the tumour.[52,53] This opens the possibility of developing individualised immunotherapy that addresses the molecular characteristics of each patient's specific tumour.

RNA plays an important role in many aspects of oncology, including diagnosis, prognosis, disease progression, therapy selection, and monitoring of treatment efficacy. Some microRNAs may be associated with cancer and serve as biomarkers for diagnosis or prognosis. For example, fusion RNAs: in some cases of cancer, genes can be rearranged or fused, leading to the formation of fusion proteins.[54] The detection of fusion RNAs can indicate specific mutations that are targeted for drug therapy. These circulating RNAs can serve as non-invasive biomarkers for the diagnosis, prognosis, and monitoring of cancer. RNA sequencing: modern RNA sequencing methods can be used to analyse gene expression on a large scale and identify new changes in the genome that may be associated with cancer.

The role of DNA in cancer diagnosis

DNA is also important in oncology and is used to diagnose, predict, and treat cancer. Genetic mutations: changes in DNA can lead to the development of cancer. Some genetic mutations can be inherited, while others can be caused by external factors, such as ultraviolet radiation or chemical carcinogens. DNA analysis can identify these mutations and establish their association with specific types of cancer. Genetic tests can identify individuals at high risk of developing cancer as a result of specific genetic variants. This can help in the detection and prevention of the disease. Determination of microsatellite instability can be used to diagnose

hereditary forms of cancer and select treatments, such as immunotherapy.[55] All of these aspects demonstrate the importance of DNA analysis in oncology for the diagnosis, prognosis, and treatment of cancer.

Modern methods of molecular analysis of cancer used in diagnosis and treatment are often expensive and require sophisticated equipment. For example, genetic tests, DNA sequencing, and other molecular techniques can be costly and require specialised equipment and qualified personnel to perform them.[56] In addition, targeted therapeutic agents such as monoclonal antibodies and small molecule drugs may have off-target effects and are available only for a limited range of cancer-causing targets.[57] This limits their effectiveness and use in a wide range of cancers. In this regard, there is a constant need to develop universal, effective, and accurate tools for the diagnosis and treatment of cancer. These tools may include new molecular analysis technologies that are more affordable and easier to use, as well as innovative treatments that provide targeted effects on cancer cells with minimal side effects. Such developments can significantly improve the efficiency and results of the fight against cancer.

Conclusions

Thus, modern technologies play a key role in the development of cancer diagnostic methods. They ensure not only early detection of cancer but also the accuracy and objectivity of the diagnosis. Immunohistochemical methods, molecular genetic research, and medical image processing have become essential tools in modern oncological diagnostics. Diagnosing cancer remains an important but also challenging problem in medical practice. Ways to address this problem include the development of new technologies, improved screening methods, and increased health literacy among the population. Significant progress in the diagnosis and treatment of cancer can only be achieved through joint efforts.

The overall progress in oncology diagnostics has resulted in a significant improvement in the ability to detect and treat cancer. Innovative methods, together with personalised approaches, are opening new prospects for improving the effectiveness of the fight against this disease. Future research in oncology diagnostics may include the development of new technologies, such as nanotechnology and molecular sensors, as well as the search for new biomarkers and other disease markers. An important component is the ability to closely monitor patients during treatment, which helps to detect any changes in the course of therapy in time and adjust it if necessary. This approach to the diagnosis and monitoring of patients with central and endobronchial lesions helps to increase the effectiveness of treatment and improve prognosis.

The growing interest in health and regular medical check-ups, together with ongoing research and development of new treatments, has led to a significant increase in demand for the purchase of instruments for routine diagnostics as well as for companion diagnostics. This demand is growing, as accurate and rapid diagnostics play a critical role in the detection and treatment of various diseases. Innovative treatments require accurate and reliable diagnostic results, which makes molecular and tissue science very important in modern medicine. Cancer screening tests play an important role in the early detection of the disease in asymptomatic patients to reduce mortality and morbidity. Early detection of cancer can start treatment at earlier stages when the disease has not yet reached an advanced level, which increases the chances of a complete cure or increases the patient's life expectancy and quality of life. The second goal of cancer screening tests is to reduce the incidence of cancer by detecting and treating its precursors or pre-cancerous conditions. This helps to prevent the development of cancer in the future and reduce the overall number of cases. Such screening tests play a key role in preventing and controlling cancer, as they allow the detection and treatment of

cancerous precursors, which can significantly reduce the risk of developing cancer and help maintain health.

Prospects for further research in this area include a thorough study of instrumental diagnostic methods as well as further in-depth research into genetic, modulatory, and chemical components that can help diagnose cancer at an early stage.

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Table 1. Characteristics of different types of biopsies

Type of biopsy	Advantages	Disadvantages
Fibre optic bronchoscopy	The diagnostic efficiency of detecting central and endobronchial lesions has been significantly improved.	The efficiency of diagnosis of non-endobronchial and peripheral lesions is low
Ultrasound-guided endobronchial transbronchial needle aspiration	Real-time ultrasound imaging facilitates the detection of central lung lesions and some lymph nodes located in the mediastinal, paratracheal, subcarinal, hilar, and interlobular regions. Also provides the ability to collect cells and lung tissue fragments for further analysis.	Assessment of peripheral lung and other lymph node involvement may be limited
Endobronchial transbronchial ultrasound-guided needle aspiration with a special guiding sheath	Real-time ultrasound imaging provides improved access to more peripheral lesions. Also provides the ability to collect cells and lung tissue fragments for further analysis.	The high cost of professorship and the need for specialist skills
Bronchoscopy with navigation capability	The purchase of a reconstructed and virtual roadmap helps to improve access to more peripheral lesions. Also helps collect cells and lung tissue fragments.	High requirements of the navigation system and high cost

	The diagnostic efficiency of biopsy needles	Pneumothorax and
Pistol biopsy	is high. Ensure that sufficient lung tissue is	pulmonary bleeding
	collected for analysis.	are common
		complications

Source: compiled by the authors based on[16].

Table 2. Comparison of imaging techniques in cancer diagnostics

Imaging technique	Strength	Limitations	Main applications in cancer diagnostics
CT	- High resolution for bone and lung tissue - Quick scan time - Widely available	- Limited soft tissue contrast - Radiation exposure - May miss smaller lesions	- Detecting and staging primary lesions - Identifying metastases in liver, lung, and bone
MRI	- Excellent soft tissue contrast - No radiation exposure - Multiplanar imaging	- Long scan times - Expensive - Not suitable for patients with certain metal implants	- Detailed assessment of soft tissue tumours - Brain and spinal cord imaging - Evaluating tumour invasion into surrounding structures
PET/CT	- Combines functional and anatomical information	- Lower spatial resolution than CT or MRI alone - Expensive	- Detecting primary tumours of unknown origin

	- High sensitivity for metabolically active tumours - Whole-body imaging	- Limited availability	- Assessing treatment response - Identifying distant metastases
Ultrasound	- Real-time imaging - No radiation exposure - Portable and relatively inexpensive	- Operator-dependent - Limited depth penetration - Not effective for imaging bone or air-filled organs	- Guiding biopsies - Evaluating superficial masses - Assessing blood flow in tumours

Source: compiled by the authors.