REVIEW

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Personalised Approach in Oncology to Improve the Efficiency of Patient Diagnosis and Treatment

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Abstract

Objective: This study aimed to identify the main directions and recent advancements in personalised approaches to cancer diagnosis and treatment, based on a comprehensive analysis of current clinical and technological practices. **Methods:** The study employed a systematic literature review of 62 peer-reviewed publications from 2019-2025 across major scientific databases, using predefined inclusion and exclusion criteria. **Results:** According to the analysis, the most promising diagnostic tools in personalised oncology are liquid biopsy, next-generation sequencing, and omics technologies like proteomics and metabolomics. These tools allow for molecular characterisation, early detection, and dynamic monitoring of tumour progression and response to treatment. Targeted therapy, immunotherapy, and genomic approaches showed the most promise for personalised cancer treatment among therapeutic approaches, especially when aided by pharmacogenomics and molecular profiling. It was discovered that combining artificial intelligence with imaging modalities improves outcome prediction, treatment planning, and diagnostic accuracy. The results highlight how crucial it is to integrate therapeutic and diagnostic advancements to enhance clinical judgement, patient outcomes, and the overall effectiveness of oncology healthcare. **Conclusion:** According to the study's findings, applying individualised therapeutic approaches in combination with genomic, proteomic, metabolomic, and imaging technologies greatly improves the accuracy, efficacy, and safety of cancer diagnosis and treatment.

Keywords: liquid biopsy- targeted therapy- molecular targets- precision oncology- pharmacogenomics

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Introduction

A paradigm shift in medicine is a gradual abandonment of a unified approach to treatment in favour of a personalised one was driven by the evolution of medical science, which was reflected in the development of genetics (sequencing of the human genome), pharmacogenomics, improved molecular diagnostic methods and the integration of information technology into the healthcare sector. This increased the effectiveness of proactive medicine aimed at preventing and early diagnosing diseases, and reactive medicine in the treatment of existing diseases.

The main problem of the study was related to the heterogeneity of cancer, which involves substantial genetic, epigenetic, and molecular variability not only between different cancer types but also among patients with the same histological diagnosis. Differential drug responses, resistance to traditional therapies, and inconsistent prognoses are frequently caused by this intratumor and interpatient variability, which reduces the efficacy of standardised treatment protocols. Personalised oncology, on the contrary, provides a focused approach by using unique tumour profiles to direct the choice of diagnostic methods and treatment plans. In order to improve efficacy, reduce side effects, and ultimately improve patient survival and quality of life, this strategy makes it possible to identify actionable mutations, optimises drug selection and dosage, and supports dynamic treatment adjustments.

Ways to overcome the problem of heterogeneity in precision oncology were investigated by Choucair et al. [1]. The researchers determined a high potential of next-generation sequencing (NGS) and liquid biopsy as tools that incorporate the genomic characteristics of patients to reduce the impact of tumour heterogeneity. The high efficiency of NGS in the identification of cancer

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biomarkers and the search for molecular targets for anticancer therapy was also emphasised by Supplitt et al. [2]. The main advantage of personalised cancer treatment, compared to the traditional approach, is the transition from histopathological and organic classification to molecular classification, which is enabled by transcriptomics. The growing role of NGS in oncology, especially in personalised medicine, was also emphasised by Hussen et al. [3]. The authors noted the effectiveness of NGS in the ability to identify genetic variations that affect a patient's response to drugs, thus optimising therapy.

In a review of the application of precision medicine and cancer genomics in paediatric oncology, O'Donohue et al. [4] highlighted the effectiveness of whole genome and transcriptome sequencing for diagnosis clarification, risk stratification, and treatment decision-making. A study by Sadee et al. [5] analysed the clinical relevance of pharmacogenes – receptors, drug metabolism and transport enzymes to assess the potential impact of pharmacogenomics on the personalisation of therapy and optimisation of existing treatments, including protein, gene, cell, virotherapy and radiotherapy.

Analysing the use of artificial intelligence (AI) for the diagnosis and treatment of this type of cancer, Uchikov et al. [6] determined that AI in personalised medicine can be used for risk stratification and predicting the response to treatment. A study conducted by Hasa et al. [7] established a correlation between changes in the BRCA1 and BRCA2 genes and a high risk of the same type of cancer, highlighting the diagnostic value of such mutations as genetic markers of the disease.

These papers investigated certain aspects of a personalised approach to the treatment of various types of cancer, but they did not formulate a general concept that could be used for a comprehensive analysis of genetic, molecular, clinical and demographic data to improve the effectiveness of proactive and reactive medicine. The current study, on the other hand, provides an integrated review that integrates contemporary therapeutic approaches and diagnostic technologies into a single framework, enabling a more thorough assessment of personalised oncology. The study offers a more comprehensive view of the clinical usefulness, efficacy, and implementation potential of tailored approaches in oncology by methodically analysing both diagnostic and treatment modalities across cancer types.

The study aimed to identify key areas and achievements in the field of personalised approach to the diagnosis and treatment of cancer. The study objectives included a review of relevant scientific sources on the current state of the personalised approach in oncology and the identification of modern trends in cancer diagnosis and treatment that incorporate individual patient characteristics.

The literature on clinical oncology, genetics and genomics, molecular biology, pharmacogenomics, immunology and bioinformatics was analysed among publications published in the Pubmed, Google Scholar and Scopus scientometric databases. The search was based on the following keywords: "personalised medicine", "precision medicine", "oncogenomics", "molecular oncology", "targeted therapy", "immunotherapy", "biomarkers", "genomic profiling", "molecular diagnostics", "pharmacogenomics", "next-generation sequencing/NGS", "liquid biopsy", "transcriptomics", "proteomics", "metabolomics", "machine learning in oncology", "clinical trials", "biobanks". Based on the analysis of titles and abstracts, the initial selection of publications was made (Figure 1). The final sample was formed using inclusion and exclusion criteria.

Modern methods of early detection and monitoring of cancer in the context of personalised medicine

The most effective modern methods of early detection and monitoring of cancer are liquid biopsy, genomics and transcriptomics using NGS technology, proteomics, metabolomics and imaging methods.

Liquid biopsy includes analysing biological fluids (blood, urine, cerebrospinal fluid), which helps detect biomarkers that provide valuable information about the tumour [8]. The detection of circulating tumour deoxyribonucleic acid (DNA) (ctDNA) – a DNA fragment released from tumour cells into the bloodstream, identifies genetic mutations specific to a particular type of cancer [9]. Notably, in addition to ctDNA itself, epigenetic changes in tumours and other biomarkers circulating in the blood are an informative marker of tumour development [10]. Tracking of these changes can detect cancer at early stages, as they can occur even before genetic mutations

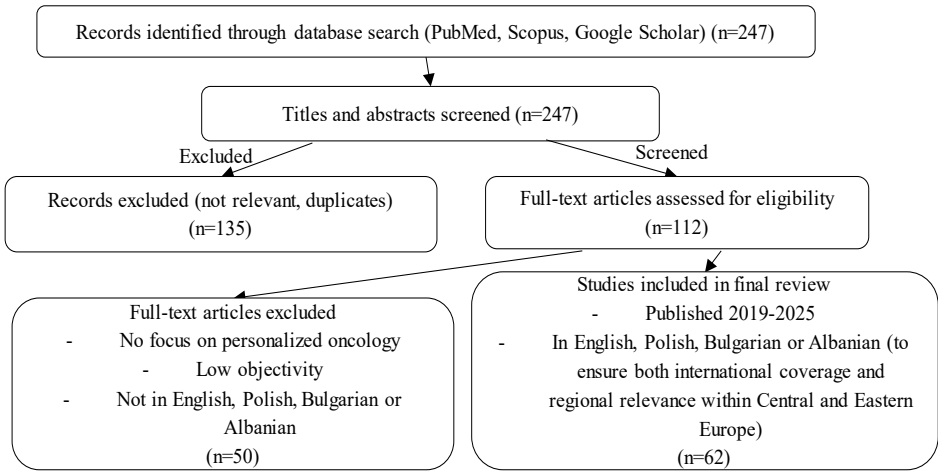

Figure 1. Selection Process for Included Studies on Personalised Oncology

appear. Epigenetic changes can also be used to monitor the response to therapy and predict the risk of relapse.

Tumour markers are specific proteins whose levels in the blood may be elevated in certain types of cancer, unlike oncoproteins, immunomodulatory proteins, growth factors and proteins associated with metastasis, which are usually found in the blood and tumour tissues [11]. Prostate-specific antigen found in prostate cancer, CA-125 in ovarian cancer, and carcinoembryonic antigen in colon cancer are released by tumour cells directly into the bloodstream [12]. Their levels in the blood can be used for diagnosis, monitoring treatment effectiveness, and predicting the risk of recurrence.

When tumour tissue is inaccessible or the patient's condition precludes invasive procedures, liquid biopsy is better than traditional tissue biopsy [13]. It offers a dynamic perspective of tumour heterogeneity, facilitating real-time tracking of the course of the disease and the effectiveness of treatment. This technique helps identify actionable mutations and resistance mechanisms, which is especially useful in lung, breast, colorectal, and prostate cancers. For instance, liquid biopsy is used to detect EGFR mutations in non-small cell lung cancer and facilitates the monitoring of PIK3CA mutations in breast cancer.

NGS is a potent molecular genetic diagnostic method used in personalised oncology. This technology can sequence millions of DNA fragments (determined in order) simultaneously, enabling fast and efficient analysis of the tumour genome and detecting a wide range of genetic changes. NGS can detect not only known but also rare and new genetic mutations associated with cancer, for example, mutations in the *ATM, CHEK2,* and *PALB2* genes, which are associated with an increased risk of breast cancer but are less common than mutations in the *BRCA1/2* genes [14, 15]. Furthermore, NGS can analyse not only coding regions of DNA, but also non-coding regions, where mutations can also occur [16]. This technology also can detect changes in the number of copies of oncogene amplification genes or tumour suppressor gene deletions.

The availability and quantity of infrastructure for conducting NGS research is an indicator of the level of development of personalised oncology in a country, as its application requires the combination of highly qualified personnel and specialised equipment [17]. Despite its complexity and high cost, NGS has great potential for expansion worldwide, as evidenced by the projected global market size for next-generation DNA sequencing, which is estimated at USD 52.4 billion from 2025 to 2033 [18]. These global statistics are confirmed by the results of individual studies. For example, when estimating the public costs associated with cancer diagnosis in Bulgaria, M. Dimitrova et al. [19] estimated them at EUR 4 million per year and expressed their expectation that they would increase significantly in the coming years due to the introduction of NGS.

Proteomics analyses tumour cell proteins to identify changes in their structure, function and interaction [20]. It demonstrates which proteins are produced by cancer cells and in what quantities, which highlights which processes in the cell are disrupted and which of these can be targeted with drugs. For instance, in some types of breast cancer, there is overexpression of the HER2 protein, and its detection allows the use of targeted therapy aimed at HER2 [21]. The main tools used in proteomics include mass spectrometry, two-dimensional gel electrophoresis, immunological methods, in particular, enzyme-linked immunosorbent assay (ELISA) and Western blotting [22].

Metabolomics analyses the metabolites of tumour cells to detect changes in their metabolism [23]. The method can identify metabolic biomarkers for early cancer diagnosis, predict the risk of recurrence, evaluate the effectiveness of treatment and identify new metabolic targets for therapy. As in proteomics, mass spectrometry is a key technology in metabolomics. Other effective methods for metabolite analysis include nuclear magnetic resonance, which analyses metabolites based on their nuclear magnetic properties, and liquid and gas chromatography [24]. Proteomics and metabolomics complement each other, providing a more complete picture of tumour biology, as changes in proteins often lead to changes in metabolic processes, and vice versa.

Imaging techniques are key in oncology in the early detection, staging and monitoring of cancer [25]. Positron emission tomography, which uses radioactive isotopes injected into the patient's body that accumulate in tumour cells that have a high metabolism, can be combined with computed tomography, which provides detailed anatomical images that enable precise tumour localisation, into PET-CT. The use of different radioactive isotopes can visualise different types of tumours, and the use of CT contrast agents improves the visualisation of anatomical structures. The early detection of tumours and cancer recurrence provided by PET-CT can assess the effectiveness of treatment by measuring changes in the metabolic activity of the tumour and planning radiotherapy [26]. Magnetic resonance imaging (MRI) uses magnetic fields and radio waves to create detailed images of organs and tissues. As this method is particularly useful for imaging soft tissue, it is used in oncology to detect cancer of the brain, rectum, prostate and other organs [27].

Imaging methods have certain limitations related to the location and characteristics of tumours. CT is less informative for breast, prostate and stomach cancer and is not informative for skin and blood cancer [28]. Ultrasound is used in combination with mammography, CT, and MRI to detect breast, liver, kidney, pancreas, ovarian, prostate, thyroid, bladder, neck, and head cancers, but this test usually does not detect lung, colon, stomach, bones, skin and blood [29]. During the selection of a particular diagnostic method in personalised oncology, in addition to their advantages, it accounts for their limitations, availability and combination options, as well as the possibility of using AI and machine learning technologies (Table 1).

AI greatly improves personalised oncology diagnostic capabilities by accurately and quickly processing complex imaging, genomic, and molecular data. Deep learning algorithms and other AI-powered tools are being used more and more to interpret digital pathology slides and radiological scans in order to enable accurate tumour classification and early detection. AI also helps with

Table 1. Limitations, Availability and AI Capabilities of Personalised Cancer Diagnostic Methods

Methods	Characteristics			
	Limitations	Availability	Combination options	Applications of AI/ machine learning
Liquid biopsy	Low ctDNA/CTC in early stages; complex interpretation	Moderate cost; requires PCR/NGS equipment and trained personnel	With imaging (localisation), NGS (profiling), proteomics/ metabolomics (functional)	Detection of rare biomarkers; response prediction
NGS technologies	Requires high-quality DNA; complex data	High cost; needs sequencers, bioinformatics infrastructure	With liquid biopsy (monitoring), proteomics (functional), imaging (genotype-phenotype)	Variant detection; risk and treatment prediction
Proteomics and metabolomics	High cost and complexity; standardisation needed	Very high cost; requires mass spectrometry and experts	With NGS (genetic impact), liquid biopsy (biomarker tracking), imaging (phenotype link)	Subtype classification; metabolic profiling
Imaging methods (CT, MRI, PET-CT, mammography)	Limited molecular resolution; may miss some cancers	High initial cost; available in major hospitals	With molecular methods for integrating structural and molecular data	Tumour segmentation; radiomics

compiled by the authors based on Sollini et al. [30], Brown et al. [31].

the analysis of NGS and liquid biopsy data, finding rare mutations and molecular signatures that direct individualised diagnostic pathways. This technological integration allows for real-time tumour dynamics monitoring, risk stratification, and improved diagnostic precision.

Accounting for the advantages and limitations of these methods, using their combinations, as well as leveraging AI and machine learning capabilities, can ensure the most effective early detection and monitoring of cancer, which will improve treatment outcomes and increase patient survival rates.

Individualised cancer treatment strategies: Modern approaches and prospects

A personalised approach to cancer treatment includes targeted therapy, immunotherapy, genomic therapy, personalised chemotherapy and radiotherapy, and surgery. Targeted therapy uses drugs to target specific molecular targets in cancer cells, ensuring personalization and minimal damage to healthy cells. It is tailored to the molecular profile of the tumour. An important characteristic of targeted drugs is the ability to block signalling pathways necessary for the growth and survival of cancer cells, stop the formation of new blood vessels feeding the tumour, and promote apoptosis of cancer cells [32]. Targeted therapy uses drugs like tyrosine kinase inhibitors, proteasome inhibitors, and PARP inhibitors to block enzymes involved in cancer cell growth and division, protein degradation, and DNA repair respectively [33].

Immunotherapy is a treatment method that boost the immune system's ability to recognise and destroy cancer cells, target tumour antigens found on the surface of cancer cells and modulate immune checkpoints to activate the immune response to tumour development [34]. These goals are achieved using checkpoint inhibitor drugs that block proteins that suppress T-lymphocyte activity, which involves modifying them in the laboratory to express chimeric antigen receptors (CAR) [35]. Since immunotherapy uses the body's immune system, the response to it may vary from patient to patient and, in some cases, can cause serious side effects. Immunotherapy is most effective when combined with other treatments, especially targeted therapy or chemotherapy. The creation of therapeutic cancer vaccines is a new field in contemporary immunotherapy. In contrast to preventative vaccinations, these aim to elicit an immune response against cancer cells that are already present by exposing the patient to antigens specific to their tumour. According to Zaidi et al. [36], these vaccines produced strong T-cell responses and detectable tumour regression in glioblastoma, non-small cell lung cancer, and melanoma during successful early-phase trials. These results highlight neoantigen vaccines' potential as a promising element of personalised oncology.

Genomic therapy in oncology uses genetic technologies to treat cancer, incorporating the individual genetic characteristics of the tumour and the patient. The main methods include gene therapy and CRISPR-Cas9 technology. Gene therapy involves introducing therapeutic genes into cancer cells to correct genetic defects or genes that encode anti-cancer proteins [37]. CRISPR-Cas9 technology can be used to correct genetic mutations, block oncogenes, or modify immune cells to attack cancer cells [38]. Genomic therapy has significant advantages in cancer treatment, including high accuracy and potentially high efficacy, but also significant limitations, such as high cost, technical complexity, and potential side effects.

Personalised chemotherapy as a method of cancer treatment was developed by adapting traditional chemotherapy to the individual characteristics of each patient [39]. This method addresses the genetic, molecular and clinical characteristics of the tumour and the patient's body (age, health status, kidney and liver function, the presence of comorbidities) to optimise the choice of drugs, their dosage and administration regimen. Pharmacogenomic testing can help determine which chemotherapy drugs will be most effective for a particular patient, as well as the optimal doses [40]. Analysis of the genetic and molecular characteristics of a tumour allows the identification of specific targets that can be targeted with chemotherapy drugs. This treatment method is used for breast, lung, colon, ovarian and other cancers, especially in cases of aggressive cancer or lack of response to standard chemotherapy. Similarly, radiotherapy was

also developed to adapt radiation therapy to the individual characteristics of each patient's tumour and healthy tissues. Such adaptation is made possible using modern imaging techniques, CT, MRI and PET-CT [41]. Effective methods that enable precise and safest radiation exposure include intensity-modulated radiation therapy, stereotactic radiation therapy, proton therapy, and adaptive radiation therapy.

Robotic surgery is a modern method of surgical intervention that uses robotic systems to perform operations [42]. It combines the advantages of traditional open surgery and laparoscopy, enabling complex operations with high precision and minimal damage to healthy tissue. Robotic systems have tools that can rotate 360 degrees, allowing surgeons to perform complex manipulations in hard-to-reach places [43]. The movements of the instruments are controlled by the surgeon with high precision, which reduces the risk of damage to surrounding tissues, in particular, precision is achieved by reducing the tremor of the surgeon's hands. These systems also provide a three-dimensional image of the surgical field, allowing surgeons to see anatomical structures better. An important advantage of robotic surgery is its minimal invasiveness, as it is performed through small incisions, which reduces blood loss, pain and the risk of infection.

For the effective use of the treatments under consideration, it is necessary to account for their availability, limitations, combination options, and the possibility of using AI (Table 2).

AI helps with personalised therapy in cancer treatment by facilitating treatment optimisation and predictive modelling based on patient profiles. Large-scale clinical and molecular datasets can be analysed by machine learning algorithms to forecast resistance mechanisms, optimise dosage, and predict drug response. AI also facilitates the creation of flexible treatment plans by incorporating tumour response and continuous patient data. It also helps discover new therapeutic targets and synergistic drug combinations, which advances the creation of highly customised and successful treatment plans.

A comparative flowchart has been created to show the structural distinctions between traditional and personalised oncology approaches in order to improve conceptual clarity (Figure 2). This graphic illustrates the

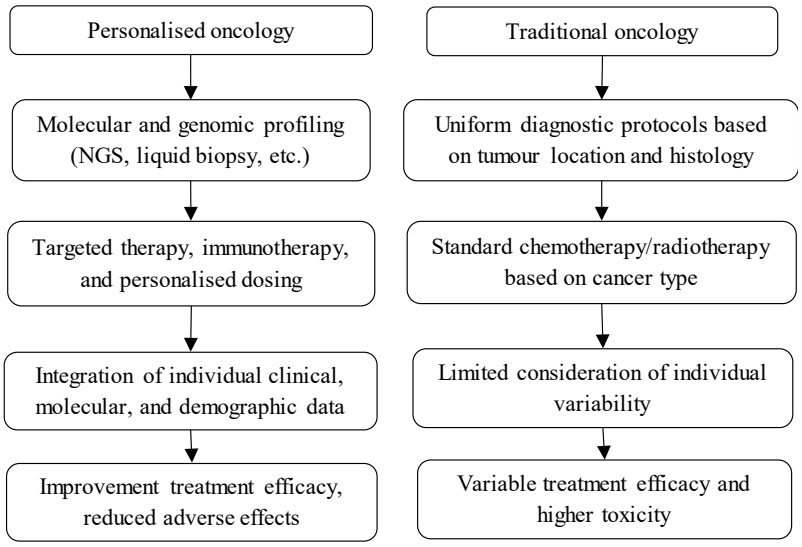

Figure 2. Conceptual Comparison of Traditional and Personalised Approaches in Oncology

Table 2. Limitations, Availability, Combinations, and Possibilities of AI in Personalised Oncology Treatment Strategies

Methods	Characteristics			
	Limitations	Availability	Combination options	Applications of AI/machine learning
Targeted therapy	Requires specific targets; possible resistance & side effects	High cost; needs molecular diagnostics and skilled oncologists	With immunotherapy, chemo or radio for broader targeting	Target ID; drug response prediction; resistance analysis
Immunotherapy	Effective only in some patients; risk of immune-related effects	High cost; CAR-T needs specialised centres	With targeted therapy, chemo, radio for synergy	Immune profiling; response prediction; side effect management
Genomic therapy	Early-stage; delivery and ethical issues	Very high cost; requires gene-editing labs and trial experience	With other therapies to boost efficacy and delivery	Target gene selection; safety prediction; protocol optimisation
Personalised chemotherapy, radiotherapy	Toxicity (chemo); localisation challenges (radio)	Chemo more affordable; radio needs specialised infrastructure	With each other or with immuno/targeted for enhancement	Toxicity prediction; adaptive radio planning; biomarker analysis
Surgical intervention	Invasive; limited for metastatic or hard-to-access tumours	Variable cost; needs advanced surgical and robotic systems	With adjuvant/neoadjuvant treatments; AI for planning	Surgical planning; intraoperative navigation; recurrence prediction

compiled by the author based on Bhinder et al. [44], Sharshenbaeva et al. [45].

fundamental change from standard, population-based treatment models to data-driven, tailored approaches that incorporate patient-specific factors, targeted therapies, and molecular diagnostics. The choice of a personalised treatment method depends on the type of cancer, the stage of the disease, the genetic and molecular characteristics of the tumour, and the patient's characteristics.

In conclusions, the main methods of cancer diagnosis in the context of personalised oncology are liquid biopsy, genomics and transcriptomics using NGS technology, proteomics and metabolomics, and imaging methods. Liquid biopsy analyses biological fluids to identify biomarkers that contain valuable information about the tumour. NGS technology is designed to analyse the tumour genome and detect known and rare genetic mutations for diagnosis, identify targets for targeted therapy, and assess tumour resistance to treatment and the probability of disease recurrence. Based on the analysis of tumour cell proteins, proteomics describes which processes in the cell are disrupted and how drugs can influence these disruptions. Metabolomics focuses on the analysis of metabolites and the identification of metabolic biomarkers of cancer. The most effective imaging methods are PET-CT, and MRI, while CT, US and mammography have limitations in the detection of certain types of cancer.

The most effective methods of personalised treatment in oncology include targeted therapy, immunotherapy, genomic therapy, personalised chemo- and radiotherapy, as well as modern surgical methods. Targeted therapy affects molecular targets in cancer cells involved in the development and growth of the tumour. Immunotherapy is aimed at enhancing the ability of the patient's immune system to recognise and destroy cancer cells. The principle of genomic therapy focuses on correcting or blocking genetic mutations responsible for the development of cancer. Personalised chemo- and radiotherapy are adaptations of traditional therapies to the individual characteristics of each patient. Modern surgical techniques use robotic systems to perform operations, retaining the benefits of open surgery and laparoscopy, but with increased accuracy and safety.

Given the characteristics and specifics of the considered methods of cancer diagnosis and treatment, it is recommended to select appropriate combinations of them, depending on the individual characteristics of each patient. A limitation of the study was the lack of national statistics on the implementation level of personalised approaches for the current assessment of the industry and determination of further prospects. Further research could focus on ways to integrate AI into personalised oncology.

Author Contribution Statement

RG and RT: conceptualization. KB and KS: methodology, investigation, formal analysis. RG and RT: writing – original draft. KS and SS: review & editing. RG: supervision and project administration..

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None.

Competing interests

The authors declare no conflict of interest.

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