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## A Precise Review: Cancer Diagnosis, Detection, and Treatment in Light of Informatics

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#### ABSTRACT

**Background:** Cancer, recognized as one of the most lethal diseases of the 21st century, poses a grave threat to human lives. Scientists are persistently engaged in a quest to find effective treatments for this disease. Cancer informatics offers a fresh perspective by focusing on the comprehensive and efficient acquisition, storage, and utilization of cancer-related information. It aims to enhance our understanding and management of cancer by optimizing the processes involved in accessing and analyzing cancer data.

**Aim:** We explore technological advancements that leverage the potential of cancer informatics to achieve rapid diagnosis and successful treatment of these life-threatening illnesses. Specifically, we delve into the utilization of artificial neural networking, which employs statistical, probabilistic, and optimization techniques to enable machines to learn from past instances. This enables them to identify intricate trends that may be challenging to discern within extensive, chaotic, or complex datasets.

**Bioinformatics:** OMICS technologies exhibit high-throughput interfaces that enable the comprehensive exploration of the genome, epigenome, transcriptome, proteome, and metabolome in an unbiased manner on a global scale. Furthermore, we examined the concept of Precision medicine (PM), which disruptively takes into account both individual variations and population characteristics to deliver customized treatment approaches. Additionally, Nanotechnology holds tremendous promise in transforming medicine to become more personalized, predictive, and preemptive. Lastly, Radiotherapy (RT) plays a crucial role in cancer care, benefiting approximately 50% of all patients, and is an indispensable component of their treatment plans. **Conclusion:** While we delve into these modern techniques, it is important to acknowledge that every technology has its limitations, which we have also addressed in this review. However, amidst these limitations, we have explored the specific types of cancer for which each technique holds the most promise and benefits. This discussion offers a silver lining by highlighting the potential areas where these techniques can be particularly advantageous.

**Keywords:** Radiotherapy; Nanotechnology; Artificial Neural Network; OMICS technologies; Precision medicine

#### INTRODUCTION

The future of cancer informatics rely on the continual advancement of methodologies that can identify crucial altered pathways susceptible to targeted molecular or immunological therapies. The increasing customization of medical treatments based on individual patient characteristics has become possible through ongoing improvements in our understanding of disease physiological processes. The proliferation of omics information (such as proteomics and metabolomics) and computer systems (such as patient matching algorithms) that facilitated the development and matching of targeted agents. These advancements

offer improved outcomes while minimizing unnecessary treatment side effects. They also aid in unravelling the inter- and intra-tumor heterogeneity, which often poses challenges to successful therapy and contributes to treatment failures and drug resistance [1]. High-throughput omics studies, including genomics, proteomics, metabolomics, and transcriptomics, generate vast and increasingly specific datasets that are extracted with great value. The fields of radiomics and pathomics have shed light on the potential of routine diagnostic technologies such as magnetic resonance imaging (MRI), computed tomography (CT), positron emission tomography (PET) imaging, and immunohistochemical tissue analysis.

Nanomedicine integrates nanotechnology approaches to enhance drug delivery, pharmaceutical properties, imaging, and diagnosis, paving the way for theranostics. The ability to isolate, characterize, and functionally profile extracellular nanometer-scale vesicles opens new avenues for therapeutic and diagnostic applications of these intercellular carriers of RNA, DNA, and proteins. Tissue processing and high-throughput fluorimetry techniques support the development of novel tools like BH3 profiling, which predicts cellular responses to chemotherapy agents. The concept of radiosensitization of cancer cells has been studied for almost five decades, but recent advancements are leading to the emergence of more efficient small molecules (oxygen/oxygen mimics), macromolecules (miRNA, siRNA, peptides), and engineered radiosensitizers based on nanomaterials [2]. In current study technological advancements that leverage the potential of cancer informatics to achieve rapid diagnosis and successful treatment of these life-threatening illnesses have been explored.

### **Technological Advancements**

#### **Artificial Neural Network (ANN) with Machine Learning Approach**

Recent advancements in both the fields of biology and informatics have spurred researchers to consider the role of computational methods in the vast field of cancer research. Particularly, the focus has been on the benefits offered by artificial intelligence (AI) and machine learning approaches compared to existing cancer diagnosis and treatment techniques. Machine learning, a subset of AI, employs various statistical, probabilistic, and optimization methods that enable machines to learn from previous instances and identify patterns that may be challenging to discern from large, complex, or chaotic datasets. This capability is particularly well-suited for medical applications, especially those reliant on complex proteomic and genomic data. Machine learning has found extensive use in cancer diagnosis and detection, and more recently, it has been applied to cancer prognosis and prediction.

The latter approach is particularly fascinating as it aligns with the growing trend toward personalized and predictive treatment. Artificial neural networks (ANNs) are a type of AI that mimics the functioning of the human brain through algorithmic models. Neural networks are particularly effective in deciphering nonlinear data, which is often encountered in biological research studies. By leveraging neural network technology, cancer diagnosis can be performed more efficiently and with reduced reliance on invasive procedures, while also interpreting the outcomes of imaging techniques. Furthermore, neural networks can be trained to assess individual prognosis and develop treatment plans with a level of accuracy comparable to experienced physicians. These advancements empower both medical professionals and patients in making informed decisions about healthcare. As major computational initiatives, such as Microsoft's recent endeavor to "solve" cancer with computer science, continue to progress, it has become increasingly evident that the future of medical research will rely on techniques like neural networking and other forms of AI [3, 4].

#### **Omics Technology**

OMICS technologies are characterized by high-throughput interfaces that facilitate the comprehensive investigation of the genome, epigenome, transcriptome, proteome, and metabolome in an unbiased and global manner [5]. The OMICS field encompasses various domains, ranging from genomics (focused on the genome sequence) to proteomics (examining large sets of proteins and proteomes) and metabolomics (analysing large sets of small molecules, the metabolome). Within genomics, there are subfields such as genotyping (focused on genome sequencing), transcriptomics (studying genomic activity), and epigenomics (exploring cell function and epigenetic regulation).

OMICS methods are employed to unravel the complexity of biological systems and the molecular characteristics underlying intricate cellular phenotypes. Various techniques have been developed to decipher different aspects of biological structures, such as gene, RNA, and protein concentrations [5, 6]. Adopting a multi-omics approach to analyze human cancer samples enhances our understanding of cancer biology and advances omics research. This strategy involves generating multiple types of omics data from each individual cell sample, including genome sequence, functional information (e.g., DNA allele frequency), epigenome, transcriptome, proteome, and metabolomics data. By integrating these datasets, we can identify key genes and processes driving specific phenotypes, such as tumor progression [7].

With the advent of OMICS technology and big data analytics, we can now gather comprehensive molecular information about diseased cells, effectively identify subtle patterns in the data, and gain deeper insights into individual patients' disease history and well-being. Researchers are now able to combine terabytes of data generated by high-throughput techniques with clinically relevant phenotypes, such as drug responses or patient outcomes, using machine learning methods. Developing techniques for big data analytics and data integration frameworks enables medical scientists to draw insights from diverse omics data types and generate precise clinical predictions, aiding in the formulation of individualized treatment plans [8].

Several research articles have demonstrated the potential of OMICS profiling in precision oncology. While histopathological assessment still forms the basis of most oncological diagnoses, recent studies have shown that OMICS data can complement and enhance pathological diagnosis. Molecular databases, in particular, can provide valuable tumor subtyping information and reveal clinically significant molecular aberrations that were previously unidentified. Thus, OMICS profiling holds promise in facilitating cancer diagnosis and advancing personalized cancer treatment. The fundamental principle of OMICS research is that it enables open-ended discovery, not solely driven by preconceived hypotheses [7].

The latest advancements in OMICS methods serve as valuable tools for dissecting the abnormal cellular features at the core of complex diseases like cancer. Integrating OMICS data with well-defined epidemiological data from cohort studies enhances our ability to link genetic alterations with environmental exposures and specific clinical phenotypes. This integration has the potential to enhance our current understanding of cancer biology and ultimately improve patient treatment [8].

### Precision Medicine

Precision medicine (PM) is a disruptive notion that brings into consideration individual variation as well as population characteristics to provide personalized treatment; this strategy expands biological understanding and investigates the excellent variety of people. PM involves customizing a person's healthcare based on individual-level measurements. It also utilizes statistics and understanding from the remainder of the population. To provide tailored healthcare, PM depends on both biological individuality and population understanding [9]. This emerging advanced approach leads to powerful discoveries and many new treatments that are tailored to unique features such as individual genetic makeup or an individual's tumor's genetic profile. Diagnostic testing focuses on the genetic material, cell assessment, or molecular assessment of the patient. It includes analysis of molecular diagnosis and imaging soft wares. One of PM's primary objectives is to use the ever-growing knowledge of biology to provide precise and customized procedures to individuals [9, 10]. The precision treatment of cancer is mainly focused on matching the tumor mutations of the patient with the suitable targeted therapy. Numerous genetic or molecular assays accessible for tumor screening have been explored. The biggest advantage, however, came from next-generation sequencing (NGS) (Figure 1).

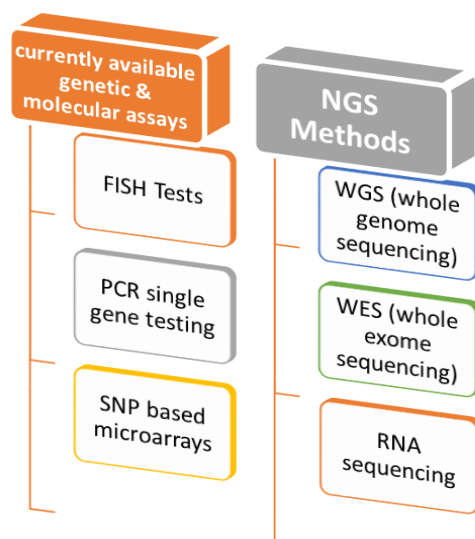


Figure 1. List of next generation sequencing methods.

### Next Generation Sequencing

NGS is a swift technology that enables massively parallel sequencing of genomic pieces in a single run, producing thousands to millions of short "reads." It can identify point mutations including single nucleotide polymorphisms as well as small insertions/deletions (indels) in large quantities of genes at once (usually less than 20–30 base pairs). NGS can also recognize

unanticipated targetable mutations, copy number variations, differentially expressed genes, and gene fusions in combination with strong computing assets and instruments to shop, process, and evaluate the information. All-in-all NGS offers many advantages over the single-drug and single-genetic test [11].

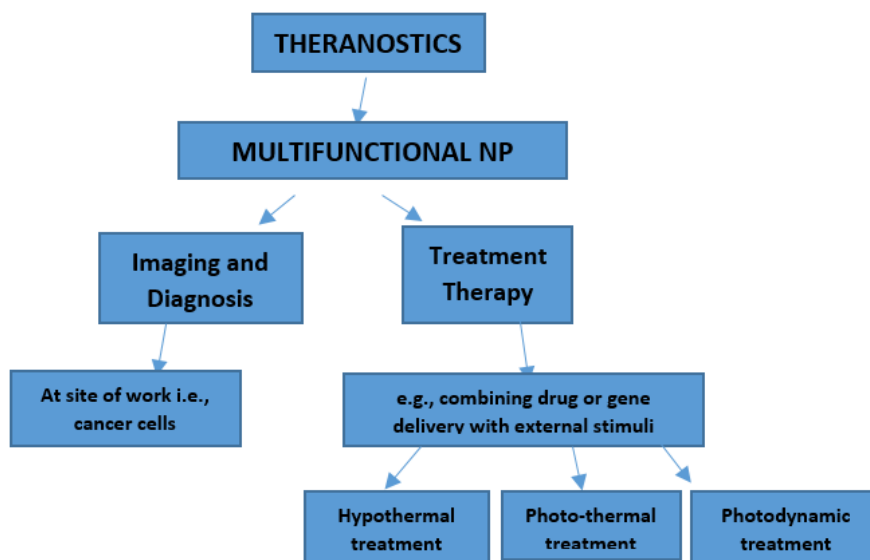
PM itself is an expensive approach, the cost mainly falls in millions of dollars. Technologies such as DNA sequencing, for which a large amount of DNA is required, is still too costly to carry out. Drugs that have developed to target a person's genetic or molecular characteristics are likely expensive too.

### Nanomedicine

Huge developments in the prosperity and implementation of nanotechnology in cancer identification, diagnosis, and treatment have taken place in latest years. This advancement has resulted in the evolving "cancer nanomedicine" sector [12]. Another fact is nanotechnology that has the potential to make medicine more personalized, predictive and pre-emptive. It is a form of nanotechnology applied to the biomedical field where engineered nanoparticles (NPs) with dimensions of less than 100 nm are used primarily for the treatment of disease, and cancer. Such intelligent and extremely designed NPs offer benefits in passively or aggressively targeting drugs with elevated solubility, bioavailability, biocompatibility, and multi-functionality concerning traditional cancer therapies [2].

A key characteristic of nanoparticles, such as liposomes, magnetic nanoparticles, quantum dots, metal nanoparticles, silica nanoparticles, polymersomes and dendrimers, etc., are target specific. Varying nanoparticles have been intensively used as vehicles for the delivery of chemotherapeutic drugs, genes, photodynamic and photothermal agents to improve their therapeutic effectiveness, or as molecular imaging devices for the detection and monitoring of cancer development due to their outstanding electronic, magnetic, optical and structural properties. As a result, several types of sophisticated NPs have been formulated as multi-target inhibitors and as nanoimaging systems for targeted drug delivery. Recently, it has been proposed to operate the combination of therapy and diagnosis using the same nanoparticle, thus introducing the concept of theranostics into the field of nanomedicine as explained in Figure 2.

Nanomedicine implemented with theranostic nanoparticles is promising and can solve the prevalent disadvantages of standard cancer therapies, i.e., absence of high selectivity and discrimination between healthy and cancer cells, negative impacts on healthy cells, acquired drug resistance, and absence of early diagnosis and molecular imaging techniques. Nanomedicine can provide powerful tools to assess the bio-distribution of drugs in vivo, visualize the release of drugs from a given nanoparticle in a non-invasive manner, and predict and monitor the therapeutic outcome in real-time. Cancer nanomedicine has therefore drawn extensive attention from government and private study institutes and entrepreneurs alike [13].



**Figure 2.** Combination of therapy and diagnosis using the same nanoparticle introducing the concept of theranostics into the field of nanomedicine.

### **Radiotherapy (Treatment and Detection)**

Radiotherapy (RT) performs a vital part in cancer care, with about 50% of all patients benefiting from RT in their ailment treatment. Radiation oncologists coordinate a multidisciplinary strategy for cancer treatment with medical and surgical oncologists. RT is a course of treatment and fuel for technological advances. Over the past few decades, RT techniques have changed significantly due to improvements in engineering and computing. It evolve from conventional radiation using simple treatment fields to highly conformal RT techniques, such as intensity-modulated RT (IMRT), intensity-modulated arc therapy (IMAT) and stereotactic RT (SRT), aimed at improving results by increasing the dose to target and minimizing the toxicity to normal tissue and critical organs.

Technological advances were largely the result of the integration of image information in each treatment phase, from simulation to planning to delivery. Treatment planning systems (TPs) provide sophisticated fusion algorithms and image registration [14]. Advances in radiation oncology and the associated ability to precisely target tumors with highly focused radiation have resulted in local control and survival improvements for cancer types. Recent cases include the use of stereotactic body radiation therapy (SBRT) for early-phase treatment, and non-small cell lung cancer (NSCLC), where the hypo fractional dose schemes supplied in 5 fractions have considerably enhanced local control and increased survival. Indeed, it stated that the achievement connected with early phase NSCLC SBRT-based treatment could be effective due to the significantly elevated ablative quantities given to tumors under image-guided radiation therapy (IGRT), which allowed extremely focused and precise targeting. SBRT's achievement in early-stage lung cancers and the development of this therapy model for other therapy sites may have a significant impact on present and future clinical procedures [15]. Technological advances have made it possible to directly integrate imaging technology into radiation treatment systems to improve the accuracy and precision of radiation delivery. In addition to addressing a clinical need to better control the placement of the dose within the body, image-guided radiotherapy has enabled field innovators to accelerate their exploration of several different radiation delivery paradigms, including reduction of toxicity, dose escalation, hypo fractionation, voxelization, and adaptation. While these methods are already ground breaking developments in radiation oncology, as part of the wider objective of personalized cancer medicine, they are expected to operate synergistically with other cancer treatment technologies (including biomarker strategies, and novel systemic and local therapies) [14]. In the following, we have described briefly the high-precision RT methods currently known in clinical practice along with the basic prerequisite for precisely locating the target volume during the preparation and distribution of therapy.

#### **Intensity Modulated Radiotherapy**

In the early 1990s, intensity modulation was implemented in the release of 3D conformal radiation treatment (3D-CRT) as a further refinement. The use of computer-controlled multi-leaf collimators (MLCs) and advanced treatment planning optimization algorithms to create the desired dose variation within the radiation field has made IMRT possible. In contrast, standard planning techniques, where the dose distribution only be modified using a hit-and-flaw approach (changing field weight, angle and shape) for example with IMRT. The radiation oncologist defines the doses and dose/volume constraints for the tumor and the surrounding healthy organs and the TPS determines the optimal flow of each field resulting in a tailored dose distribution (inverse planning). Usually, IMRT was supplied in the past using a standard LINAC with a static field geometry. Developments in IMRT methods mainly focused on decreasing therapy treatment frequencies by turning various IMRT static fields into continually revolving modulation of scaffold intensity. IMRT / IMAT techniques facilitate different dose levels to deliver to different parts of the tumor (for example, a hypoxic tumor area, identified by functional imaging, may give a boost dose). Approaches using concurrent embedded boost (SIB) and distribution of conventionally fractionated or hypo-fractionated dose-escalated RT using IMRT methods explored as an option to standard RT for various anatomical locations: chest, head and throat, prostate [14].

#### **Stereotactic Body Radiotherapy**

Stereotactic body radiotherapy (SBRT) is usually a modality of tumor-ablative radiation using vital techniques capable of destroying the target with a heavy dose correctly and accurately while geometrically sparing innocent healthy tissues [17]. SBRT structures can produce very conformal therapy schedules outside the goal with a high dose gradient. This method enables secure and effective therapy across a wide range of anatomical sites, neighbouring to critical organs, and even close to or within prior RT sites. The accuracy of target delineation and the implementation of inter-and intra-fractional tumor motion compensation strategies (especially for lung and upper abdomen tumors) are essential requirements for SBRT. The wider accessibility of in-room imaging and sophisticated therapy distribution technologies implies SBRT is offered by many organizations. SBRT's local ablative capacity challenges surgery as the gold-standard and could become the norm for early-stage lung cancer patients who are operable but at a heavy risk of morbidity. Indeed, SBRT calls virtual surgery or radio ablation as it can have a local radical

curative effect similar to surgery in many cases, such as the lung. This modern technology uses image guidance and the distribution of radiation doses to give elevated ablative radiation doses to the tumor. It was initially created as a breakthrough in the treatment of brain tumors (stereotactic radiation surgery) and increased use for extracranial locations including thorax. In standard radiation medicines, SBRT enables the supply of high-dose radiation per portion (e.g. 20Gy) to the tumor versus 1.8 or 2Gy per unit. Tumors >5cm in size are usually delivered without the involvement of the lymph node. Because of a high fractional dose and big quantity of healthy tissue handled, larger tumors have elevated probability of toxicity. Indications for the use of stereotactic radiation in lung cancer include tumors <5cm with negative lymph nodes; tumors >2cm from the tracheobronchial tree (middle tumors) can also be located [18].

Clinical trials in a multitude of organs and locations have shown that in accurately screened patients, SBRT yields excellent results. Given its brief course, absence of need for recovery, and favourable overall toxicity profile, it is highly hoped that SBRT will achieve a prominent position in the treatment of metastatic cancer as a consolidating partner with systemic treatment. SBRT has established a spot in the routine cancer-fighting arena with significant published knowledge, accessible techniques and instruction, and many patients in need of local treatment. Its weakness relates to the possibility of causing difficult-to-manage toxicity (e.g., ulceration, stenosis, fibrosis, and even necrosis) that may occur considerably later after treatment, particularly near the body's many tubular structures (e.g., organ hila, bowel) [17].

### **Particle Beam Therapy**

Particle therapy has been increasingly used in the previous decade, especially protons. Distributions of radiation dose for proton therapy often appear to be better than those for photon-based IMRT treatments, especially as they reduce the dose of low and intermediate radiation to normal tissue [18]. Indeed, it is necessary to conduct potential clinical trials to compare proton therapy with photon IMRT. In addition, proton therapy is at the level of motion management during significant technological development, evolving from passively scattered beams to active scanned ones. Lastly, proton therapy may be useful in a stereotactic regimen, but there are currently no clinical series support this hypothesis. Proton therapy has been used globally, especially in pediatric patients, for eye, base of skull and spine cancers. Proton therapy in kids has a reduced incidence of vision and hearing impairment, neurocognitive degeneration, and second cancers than with other RT modalities. In addition, heavy particles, such as carbon ions, are especially indicated for tumors that are highly radio-resistant because their biological efficacy is higher than that of photons and protons [14]. Proton therapy is new and although it has dosimetry advantages theoretically, independent evaluation is still to assess its strengths and weaknesses.

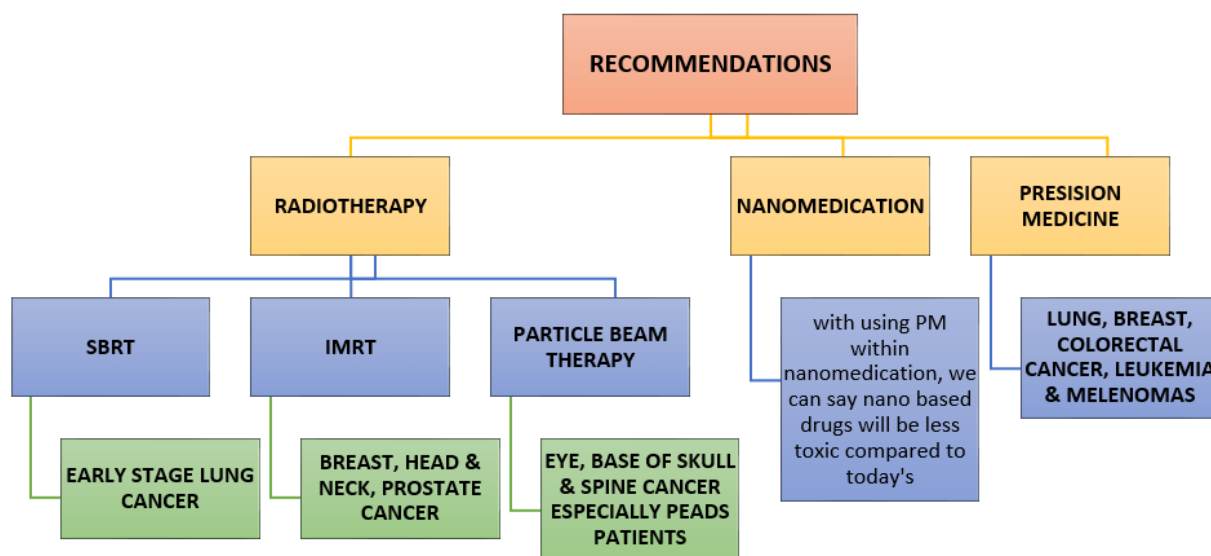
### **Localisation within Treatment**

#### **Image Guided Radiotherapy**

Technological inventions have enabled the direct integration of imaging technology into the radiation treatment system to improve the accuracy and precision of radiation delivery by monitoring the dose positioning in the body. As therapy margins become tighter and more conformal, the potential for missing tumors increases owing to organ movement and changes in patient configuration [19]. When critical structures are near the tumor, the healthy organs may also inadvertently radiate by a slight positional mistake. IGRT enables the detection of such mistakes by pre-radiotherapy imaging data that enables correction. One such instance is pre-treatment daily cone-beam CT scans. The enhanced precision made dose escalation possible, which has enabled several tumor sites, such as head and neck cancers and prostate cancers, to improve the therapeutic ratio [20]. IGRT has been enhanced by device growth that enables patient repositioning using MRI. MRI offers superb visualization of soft tissue and offers several imaging methods to identify motion, function, and physiology without giving the patient any extra dose. IGRT not only enables the precision of the therapy to be improved by minimizing the uncertainty of the interfraction situation but also by monitoring systematic adjustments in the form and position of the tumor volume and healthy tissue (weight loss and tumor regression), which implies that the plan can be suitably modified [14].

### **RECOMMENDATIONS**

Cancer is entitled as one of the deadliest diseases of the 21st century endangering the lives of humanity but there are advancements in approaches for treatment and diagnosis for this disease. Below are recommendations regarding all the techniques and methodologies discussed for which type of cancer they are most beneficial against in this article as shown in the diagram.



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#### CONFLICT OF INTEREST

The authors declare no conflict of interest.

#### AUTHOR CONTRIBUTION

All the authors equally contributed to this manuscript.

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