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Cancer Theranostics: An Emerging Field for Cancer Research, Diagnosis and Therapy

Ikalo David Oseghale [a*], Courage Ushiobafoh Godday [b], Godwin Mmaduabuchi Ikokwu [c] and Virtue Oniso Okhemukhokho [d]

[a] Department of Biochemistry, University of Benin, Nigeria.
[b] Department of Biomedical Sciences, Keele University, England, United Kingdom.
[c] Faculty of Pharmacy, University of Benin, Nigeria.
[d] University of Essex, United Kingdom.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

According to the World Health Organization (WHO) report in 2022, cancer is a leading cause of death worldwide, accounting for nearly 10 million deaths in 2020, or nearly one in six deaths, with cases amounting to breast cancer (2.26 million cases), lungs cancer (2.21 million cases), colon and rectum (1.93 million cases), prostate cancer (1.41 million cases) amongst several others. Many cancers can be cured if detected early and treated effectively. At a time like this, the world is in dire need of better and earlier method of cancer detection and diagnosis – this is where cancer theranostic comes in. Cancer theranostics, as the name implies combines cancer diagnosis and cancer therapy with the aim of achieving early diagnosis, accurate molecular imaging, and precise treatment for cancer or tumor cells at the right time and dispensing proper dose of medication, followed by real-time monitoring of treatment efficacy, it aims to improve multi-step procedures and reduce delay in treatment of patients. With the molecular imaging approach in cancer theranostics such as magnetic resonance imaging (mMRI), positron emission tomography (PET), single-photon emission computed tomography (SPECT), ultrasound (US), photoacoustic imaging (PAI), and optical imaging (OI), all of which have overtime been proven to be efficient in the early detection of cancer or tumor cells, and as such help in early treatment and eradication of the disease, it would be right to say that with advances in the precision of identifying biomarkers and

**Corresponding author: E-mail: ikalo.oseghale@gmail.com;*

imaging and mapping of tumor or cancer cells, cancer treatment in years to come would give an excellent accuracy in diagnosis and treatment, and such treatment would be cheap and affordable.

Keywords: Cancer; theranostics; imaging; biomarkers; nanotheranostics.

1. INTRODUCTION

"Although the term "theranostics" was reported to be coined by US consultant John Funkhouser in a press release from the company Cardiovascular Diagnostic in August 1998 to describe a material that combines the modalities of therapy and diagnostic imaging, this basic principle had been applied to imaging and treatment of thyroid diseases for over 50 years. In the year 1941, Saul Hertz was the first to use it therapeutically in patients with hyperthyroidism and later those with thyroid cancer" [1]. "Theranostics can be defined as the pairing of diagnostic biomarkers with therapeutic agents that share a specific target in diseased cells or tissues" [2]. "The diagnostic test is able to identify patient who will likely respond to a particular therapy, fail to respond to a given drug or eventually exhibit adverse effects, it is also able to monitor patients response to a specific treatment" [3].

"Cancer theranostics, as the name implies combines cancer diagnosis and cancer therapy with the aim of achieving early diagnosis, accurate molecular imaging, and precise treatment for cancer or tumor cells at the right time and dispensing proper dose of medication, followed by real-time monitoring of treatment efficacy" [4]. Cancer theranostic Book Chapter 1).

2. BIOMARKERS IN CANCER THERANOSTICS

2.1 DNA as a Biomarker in Cancer Theranostics

Because DNA controls the generation of the proteins necessary for a cell's function and organization over its lifetime, the genetic information encoded inside DNA requires stability. DNA biomarkers are the biomarkers that provide as an explicit representation of this stability [5]. DNA biomarkers can be utilized in the staging process during cancer identification and therapy by measuring serum DNA [sDNA] concentrations as a sign of the disease's presence and progression. DNA biomarkers can also be oncogene, tumor suppressor, and mismatch repair gene mutations. An illustration is the HRAS gene, which causes the codon 12 glycine-to-valine mutation. The HRAS gene is a member of the group of genes known as oncogenes. Oncogenes have the capacity to transform healthy cells into malignant ones when they are altered. The HRAS gene is a member of the Ras family of oncogenes, which also contains the KRAS and NRAS genes [6]. "The HRAS gene encodes a protein called H-Ras, which is mainly responsible for controlling cell division. The H-Ras protein communicates with the cell's nucleus through a process known as signal transduction, relaying instructions from outside the cell that tell it to grow or divide. A mutation in the RAS gene results in a protein with normal guanosine triphosphate (GTP) binding but no GTPase activity, causing the resulting RAS protein to be activated all the time as seen and leading to uncontrolled cell division. The H-Ras protein is a GTPase encoded with enzymatic GTPase activities, the HRAS protein converts GTP to GDP, it also acts as a switch, and it is turned" [6].

2.2 miRNA as a Biomarker in Cancer Theranostics

"miRNAs are members of a large class of non-coding RNA originally discovered in Caenorhabditis elegans in 1993, initially regarded as ncRNA (non-coding RNA), miRNAs are encoded by a large precursor RNA called pri-miR by RNA polymerase II or III (RNA Pol II or III). The nuclear RNAse III enzyme RNase III Drosha and the RNA-binding protein DGCR8 convert primary miRNAs (primiRNAs) into 70 nucleotide long precursor miRNAs in the canonical pathway for miRNA synthesis (pre-miRNAs). Exportin-5 (Exp-5) transports pre-miRNAs from the nucleus to the cytoplasm by binding to the RAN-GTP protein and nucleoporins there. Dicer RNase III, an endonuclease that converts pre-miRNAs into mature single-stranded miRNAs, eventually causes the maturation" [7,8]. "To carry out their biological duties, molecules are incorporated into the RNA induced silencing complex (RISC).

These two enzymes, along with their cofactors Argonaute 2 (EIF2C2/Ago2), Trans-Activation-Responsive RNA-Binding Protein (TRBP), and DiGeorge Syndrome Critical Region Gene 8 (DGCR8)/Pasha, are necessary for the maturation of miRNAs. The RNA-induced silencing complex is created when one of the two strands is integrated into a complex that also includes the protein Ago2 (RISC). MiRNA controls the expression of protein-coding genes by either suppressing translation or cleaving RNA transcripts in a sequence complementarity-based manner through its interaction with the RISC complex. Changes in the level of expression of each protein component of the miRNA processing system can affect how cells operate, which can lead to the development of tumors. Some of the unregulated miRNAs can be passively or actively released from tumor cells into the environment at the end of their synthesis. Despite these two opposing theories, extracellular miRNAs are well-known" [7,8].

2.3 Exosomes as a Biomarker in Cancer Theranostics

Most eukaryotic cells create exosomes, membrane-bound extracellular vesicles, in the endosomal compartment. It is believed that normal vesicular trafficking is disrupted under cellular stress conditions, such as signaling dysregulation (a cancer hallmark), which has an impact on the normal protein, lipid, and nucleic acid contents of exosomes. Exosomes function as transporters of signaling information to other nearby or distant cells and of undesired material from the cells in normal circumstances. In this approach, each deviation from the usual alters the exosome composition and provides a window into how the cells are functioning differently and how they are responding to stimuli. Oncogenic chemicals found in cancer cell-derived EVs are potentially functional and support the development, progression, and metastasis of cancer by fostering a favorable environment [9].

3. MECHANISM OF TUMOR-TARGETED NANOMEDICINES FOR CANCER THERANOSTICS

Nanomedicines help to increase the biodistribution and target accumulation of chemotherapy medications, which helps to maintain a healthy balance between their effectiveness and toxicity. Liposomes, polymer-drug conjugates, and polymeric micelles are among the several forms of nanomedicines that have been studied over the years; they rely on techniques including passive targeting, active targeting, and triggered release for improved tumor-directed drug delivery.

3.1 Passive Targeting

By integrating the therapeutic substance into a macromolecule or nanoparticle that passively enters the target organ, passive targeting is accomplished. Drug success in passive targeting is based on how long they have been in circulation. The nanoparticle is covered with a coating to accomplish this. Blood vessels that leak often and a lack of functioning lymphatics are characteristics of solid tumors. As a result, nanoparticles up to 250 nm are capable of efficiently retaining themselves in tumors throughout time and are prone to extravasation over the aberrant endothelium lining. The Enhanced Permeability and Retention (EPR) effect, which is a phenomenon, serves as the foundation for passive tumor targeting using nanomedicines. Doxil, a chemotherapy drug with a particle size of 100 nm used to treat cancer, is a classic illustration of this phenomena and is well suited for EPR-mediated passive targeting. According to clinical research, Doxil has a longer circulation time than free doxorubicin, which results in a 60-fold greater area under the plasma concentration-time curve (AUC) of the drug. When compared to free doxorubicin, the clearance and volume of distribution of Doxil both considerably decrease at the same time. Malignant effusions, AIDS-related Kaposi sarcoma (ARKS) skin lesions, and a variety of solid tumors have all shown Doxil's ability to accumulate and extravasate in tumors via the EPR effect, which results in tumor accumulation that is typically 15 times higher than that of the free medication.

"To take advantage of the EPR effect, prolonged circulation kinetics are crucial. The extended blood circulation period of nanoparticles depends on a few conditions that must be met. First, the right particle size is necessary; formulations with a size of less than 5 nm are promptly excreted by the kidneys, while those with a size of less than 200 nm are more likely to be quickly absorbed by macrophages. Second, to reduce protein opsonization and recognition by the mononuclear phagocyte system (MPS) and thereby lengthen the half-life of nanoparticles in circulation, the effectiveness of surface coating of nanoparticles with neutral hydrophilic polymers, such as poly

(ethylene glycol) (PEG), is required. Thirdly, stability, which is often less important for liposomes and is particularly problematic for nanoparticles that self-assemble from amphiphilic polymers, such as polymeric micelles. Rapid disintegration of polymeric micelles and other self-assembled polymeric nanoformulations is frequently observed due to the massive dilution effect of nanoparticles upon intravenous (i.v.) injection as well as interactions of polymeric building blocks with serum proteins and other blood components" [10].

3.2 Active Targeting

By offering targeting compounds that can engage these receptors, active targeting takes use of the surface receptors on cancer cells that are (over) expressed. Actively targeted nanomedicines have recognition patterns added to their surfaces that bind only to receptors that are (over-)expressed at the target region, such as those produced by tumor or endothelial cells. Small compounds (like folic acid), peptides (like RGD), proteins (like transferrin), nanobodies, and aptamers are examples of frequently employed targeting ligands. Along with nanocarriers, targeted ligands have been added to radioisotopes and pharmaceuticals to enable molecular imaging and radio-immunotherapy. However, different outcomes on the effectiveness of tumor targeting using nanoparticles with or without active targeting ligands have been reported. This is true even though a large number of studies have exclusively demonstrated significantly higher cell uptake of actively targeted nanoparticles in vitro. For instance, tumor tissues exhibited 10–30-fold higher concentrations of actively targeted magnetic nanoparticles (MNP) than the non–targeted counterpart. These particles were modified with anti–HER2 monoclonal antibody. Studies utilizing folic acid- and RGD-modified layered double hydroxides (LDHs) and paclitaxel-loaded nanocarriers showed similar outcomes [10].

4. LDL: THE STANDARD LIPOPROTEIN FOR CANCER DIAGNOSTICS

The nanocarrier can circulate for a prolonged length of time while mainly escaping the reticuloendothelial cells involved in the body's defenses by mimicking the endogenous shape and structure of lipoproteins. The low-density (LDL) and high-density (HDL) classes of lipoproteins can wriggle deeper inside tumors due to their small size (less than 30 nm). In addition, lipoproteins can be directed onto different cancer receptors or at endogenous receptors that have been linked to cancer. One of the hydrophobic substances carried by lipoproteins is cholesterol. It controls the fluidity of the lipid bilayer and serves as a vital part of the plasma membrane in the body. Dietary sources or de novo biogenesis are the two sources of cholesterol. Leukemia patients also had a higher likelihood of having hypocholesterolemia, it was noticed as early as 1930. Later research revealed that the enhanced LDLR presentation in the tumor may be the cause of the hypocholesterolemia. Other cancer forms have also been observed to fit this hypothesis. For more than 20 years, researchers have employed LDL that has been labelled with radiotracers to scan and characterize the buildup of LDL tumors in animals. The most popular radiolabels for in vivo imaging are technetium-99m (99mTc), iodine-131 (131I), and iodine-125 (125I). Covalent alteration of the protein was carried out utilizing radioactive iodine monochloride or reductive coupling of sodium dithionite with [99mTc] pertechnetate. Studies using animals carrying B16 melanoma revealed buildup in the tumor after 18 hours. Although the resolution of the gamma camera utilized to record the buildup of radiolabeled LDL was subpar, it gave a real-time look of the distribution of LDL within the host. Other imaging modalities and probes have also been employed to observe additional disease conditions in addition to gamma imaging. The smallest lipoprotein, HDL, may also be useful for medication targeting and uptake into cancer cells despite the fact that LDL has demonstrated potential as a drug nanocarrier for cancer imaging and therapy. (Ng, K.K. et al. 2011)

5. LIPID- AND POLYMER-BASED NANOSTRUCTURES FOR CANCER THERANOSTICS

5.1 Liposome-based Nanotheranostics

"Drug delivery systems for cancer treatment using liposomes are well-established. They have a diameter of roughly 100 nm and are closed spherical vesicles formed of a lipid bilayer made of either synthetic or natural phospholipids. Thin lipid films are typically hydrated before being physically extruded or sonicated to create those with single bilayers. Hydrophobic and hydrophilic pharmaceuticals can be encapsulated using a variety of techniques in an aqueous phase that

fills the core of the liposome as a result of the synthesis process. Due to their exceptional capacities to encapsulate both therapeutic and diagnostic agents, shield the encapsulated agents from the environment, prolong the lifetime of the encapsulated agents in systemic circulation, and be functionalized with various targeting ligands for cell- or tissue-specific delivery, liposomes have been widely used as delivery vehicles" [11].

5.2 Polymer-based Nanotheranostics

Polymeric nanoparticles (NPs) are a class of nanocarriers with sizes ranging from 1 to 1000 nm that can be used for a variety of drug delivery applications. They can be loaded with active substances and surface-absorbed onto the polymeric core or entrapped inside the polymeric core. It is possible to create polymeric NPs through co-polymer self-assembly or by conjugating many functional units to soluble macromolecules. Various therapeutic or imaging agents can be loaded into polymeric NP cores in a typical self-assembled formulation, and the sustained and controlled release of these agents is achieved through surface or bulk erosion, diffusion through the polymer matrix, swelling followed by diffusion, or stimulation by the local environment. Additionally, accurate drug loading and further control over drug release profiles are made possible by conjugating drug molecules to the polymer backbone. Polymeric cores are protected by stealth substances like PEG to maintain stability while reducing immunogenicity. Additional targeting moieties can be added to the surface. In the development of biocompatible polymeric NPs, natural materials like chitosan and cyclodextrin have garnered considerable attention [12].

6. CONTEXTUALIZATION OF THERANOSTICS IN NUCLEAR MEDICINE

Nuclear medicine imaging is primarily founded on the idea of employing radioactive isotopes coupled to certain molecules (i.e., radiopharmaceutical agents or radiotracers) to analyze important biologic pathways, particularly the pathophysiologic characteristics of illnesses. Nuclear medicine therapy works in a similar manner: radiopharmaceutical substances are utilized to target diseased tissue, and radiation is administered at the cellular level by way of a particular chemical and/or biologic affinity. Since electromagnetic radiation (i.e., rays) can be detected by imaging systems (scintigraphy, SPECT, and PET), and because particulate irradiations have cytotoxic (i.e., therapeutic) properties, each radioisotope's imaging or therapeutic potential is determined according to the type of radiation emitted. Radiation with α particles and radiation with β particles are the two main types of particulate radiation utilized for therapeutic purposes (which are electrons). Both of these radiation types have a significant energy transfer to tissues that causes DNA destruction and serious cellular harm. The α particles are more massive and have a higher energy. Some isotopes, like lutetium 177 [^{177}Lu], can generate electromagnetic radiation as well as particle radiation, enabling simultaneous imaging and treatment. The mechanism of nuclear medicine theranostics is thus to combine the emission properties of certain radioisotopes with particular compounds that target important physiological pathways. Theranostic pairs are radiopharmaceuticals used in diagnostic and therapeutic procedures that target the same cellular structure or biological function. There are hybrid theranostic pairs made from a radiopharmaceutical agent and a diagnostic or therapeutic component from another modality, such as immunohistochemical staining and nonradioactive targeted therapies like antibody and tyrosine kinase inhibitor treatments, which should be noted even though the majority of the theranostic pairs currently used in nuclear medicine are made from radiopharmaceuticals alone. Therefore, a single intended target can be imaged or treated using arrows from many classes [2].

7. MOLECULAR IMAGING IN CANCER THERANOSTICS

Molecular imaging is a field of medical imaging that uses sophisticated diagnostics imaging techniques to provide detailed pictures/ information and visualize happenings in the body of living things at molecular and cellular levels. It is able to provide information that is unobtainable with other imaging technologies or that would require more invasive procedures such as biopsy or surgery, it is able to identify tumor/cancer at its earliest stage and give its precise location. There are various imaging modalities that can be used for noninvasive molecular imaging, examples are molecular magnetic resonance imaging (mMRI), positron emission tomography (PET), single-photon emission computed tomography (SPECT), ultrasound (US), photoacoustic imaging (PAI), and optical imaging (OI).

7.1 Mechanism of Molecular Imaging?

In occurrences of tumor growth in the body, biochemical activities of cells in and around the tumor begin to change. As disease progresses, this abnormal cellular activity begins to affect body tissue and structures, causing anatomical changes that may be seen to appear different in density than the normal areas. Most molecular imaging procedures make use of an imaging device and an imaging agent, or probe, i.e. a contrast agent (e.g., a microbubble, metal ion, or radioactive isotope) is injected into a patient's bloodstream and an imaging modality (e.g., ultrasound, MRI, CT, PET) is used to track its movement in the body. After being injected into the body, the imaging agent builds up in a target organ or binds to particular cells. Several imaging agents can be used to visualize cellular activity, one of which is the radiotracer, a substance that contains a radioactive atom, or isotope. The imaging device detects the imaging agent and produces images that show how it is distributed in the body. The ultimate goal of molecular imaging is to provide real-time, non-invasive monitoring of all internal metabolic activities. Some examples of modalities being used for noninvasive molecular imaging, (i) positron emission tomography (PET), (ii) molecular magnetic resonance imaging (mMRI), (iii) single-photon emission computed tomography (SPECT), (iv) ultrasound (US), (v) photoacoustic imaging (PAI), (vi) and optical imaging (OI)

7.2 Positron Emission Tomography (PET)?

“Positron emission tomography (PET) is a nuclear medicine imaging technique that involves the use of an imaging device (PET scanner) and a radiotracer that is injected into the patient’s bloodstream to produces a three-dimensional image or picture of functional processes in the body. As soon as radiotracers build up in the tissues and organs of the human body, they naturally decay, releasing small particles known as positrons that interact with the body's electrons. These positrons annihilate with nearby electrons, releasing two 511 keV photons that are 180 degrees apart and pointed in opposite directions” [13]. This reaction is known as annihilation, and it results in the production of energy in the form of a pair of photons. Following the detection of these photons by a scanner, which can gauge the density of positron annihilations in a particular region, three-dimensional images of the distribution of the radiotracers in the area of the body under investigation are produced. The density of the original molecule can be determined in that region after sufficient interactions and annihilations have taken place. Hot spots, so named because they look more intense than the surrounding tissue, are regions where a lot of radiotracers builds up and are associated with high levels of chemical activity or metabolism Cold patches are regions with reduced metabolic activity because they appear less intense [13].

7.3 Magnetic Resonance Imaging (MRI) in Cancer Theranostics

“Magnetic resonance imaging (MRI) is a medical imaging technique used in radiology to form pictures of the anatomy and the physiological processes of the body, however, with a more detailed analysis of contrast enhancement kinetics or the use of contrast agents that are more molecularly targeted or both, MRI can be used to measure physiologic and molecular properties” [13]. Strong magnetic fields, magnetic field gradients, and radio waves are used in MRI scanners to provide images of the body's organs. MRI differs from CT and PET scans in that it does not utilize X-rays or ionizing radiation. When viewing soft tissue images, such as those of the brain or abdomen, an MRI offers superior contrast. Humans and other biological entities inherently contain a lot of hydrogen atoms, especially in water and fat. Because of this, the majority of MRI scans effectively map the body's water and fat distribution. The nuclear spin energy transition is stimulated by radio wave pulses, and the polarization in space is localized by magnetic field gradients. Based on the relaxation characteristics of the hydrogen atoms within the tissues, distinct contrasts between them can be produced by altering the pulse sequence's parameters.

7.4 Single-photon Emission Computed Tomography (SPECT)

“Single-photon emission computed tomography (SPECT) can be defined as a nuclear medicine quantitative functional imaging modality used by oncologists to monitor tumor response. In malignancies, SPECT can monitor biological and metabolic changes brought on by therapy; these changes typically occur before morphological changes. A radioisotope that emits gamma waves (a radionuclide) is injected into the patient's bloodstream, and by rotating the

gamma camera around the patient, a three-dimensional image of the radiotracer's distribution can be obtained. This image can then be analyzed using filtered back projection or other tomographic techniques" [14]. By capturing rays immediately after radioactive emission and viewing several probes with varying energies, SPECT enables the simultaneous analysis of multiple molecular or cellular activities. Typically, a single-photon radiochemistry setup in a laboratory is used to generate SPECT radiopharmaceuticals. Due to its widespread availability and inexpensive cost, SPECT imaging is frequently employed in clinical settings for the diagnosis and therapy evaluation. The use of SPECT enables the assessment of early subclinical therapeutic response, post-treatment evaluation of a particular therapy, and the identification of recurrent or relapsing malignancies. It does not, however, have adequate spatial (i.e., determining the precise location of the particle) or temporal (i.e., determining if the contrast agent signal occurred at this millisecond or that millisecond) resolution. There are also safety concerns with administering radioisotopes to the subject, particularly during serial examinations, because of the radioactivity of the contrast agent [15].

7.5 Photoacoustic Imaging of Cancer

"Photoacoustic imaging (PA) is a non-invasive biomedical imaging modality that produces ultrasonic waves by irradiating the material with pulsed laser energy and reconstructs the image of light energy absorption distribution in the tissue. It is a hybrid imaging technique that uses a laser to expose the tissue of interest and detects optically induced ultrasound signals" [16,17]. "In addition to minimal acoustic distortion and attenuation of tissues, PA diagnosis relies on the heightened optical absorption of tumors and the relatively high optical transparency of normal tissues when employed for cancer diagnosis" [18,19].

Photoacoustic technology analyzes the conversion of electromagnetic energy into acoustic pressure waves. The tissue is exposed to a nanosecond pulsed laser, which produces an ultrasonic wave as a result of optical absorption and the tissue's rapid thermal (or thermoelastic) expansion [18]. "When a tissue is subjected to a pulsed near-infrared laser, the tissue's components, including hemoglobin, lipid, water, collagen, etc., absorb light and expand due to thermoelasticity, producing ultrasonic waves (photoacoustic effect). Thus, these laser-induced ultrasonic signals can be detected by an ultrasound transducer, allowing for photoacoustic (or optoacoustic) imaging. Irradiating tissue at each of these bio-absorbers' prominent absorption wavelengths will allow you to target that particular absorber specifically. In order to examine the tissue composition based on endogenous contrast, several photoacoustic images that can be spectrally resolved can be obtained utilizing a tunable laser operating at the pertinent wavelengths of interest" [17].

7.6 Ultrasound for Cancer Diagnosis

"An ultrasound (also known as ultrasonography, sonography, or sonogram) is a non-surgical procedure that helps doctors look for tumors in certain areas of the body that don't show well on x-rays. An ultrasound machine creates images called sonograms by giving off high-frequency sound waves that go through the body. As the sound waves bounces off organs and tissues, they create echoes. The machine turns these echoes into real-time pictures that show organ structure and movement and even blood flow through blood vessels" [4].

7.6.1 Ways ultrasound imaging can be applied in cancer diagnosis

1.) "Morphological diagnosis of visceral lesions and general anatomical examination of organs: According to changes in tissues and morphological alterations of diseased anatomy related to the image, ultrasound diagnosis can produce tomographic images of various organs" [20].
2.) The physiological properties of particular organs and tissues are studied functionally to determine how they affect changes in ultrasound pictures or Doppler ultrasound spectrum: Doppler ultrasonography and echocardiography can be used to identify respiratory diaphragm activity, double power systolic and diastolic function, blood flow and blood flow measurement, gallbladder enlargement, and gastric function discharge [20].
3.) Additionally, it can be used to guide ultrasonic needle punctures, administer therapeutic medications, and remove effusion, bleeding, and abscesses using laser, microwave, and other techniques [20].

8. CONCLUSION AND FUTURE PROSPECTIVES

Cancer theranostics is an emerging field of science with great prospective to contribute to the world of cancer research and diagnosis, it is a discipline that has offered better and earlier detection of cancer or tumor cells/lumps, it has also better improved the visualizing of the result of diagnosis and test being carried out making the work of doctor and health care specialist easier. Cancer theranostics symbolizes the shift from traditional medicine to customized care, allowing for the creation of treatments that are as unique as the patient, ensuring that the correct drug is given to the right patient at the right time. Theranostics for cancer has a number of benefits, including better tumor-specific drug delivery, fewer deadly effects on healthy tissues, and improved detection. When therapeutic intervention can be tailored, it can help prevent superfluous therapies from being administered to a patient for whom they are not appropriate and guarantee that the planned therapy will have an impact on the targeted therapy area. Cancer theranostics can move the diagnosis of the disease from the lab to the patient's point-of-care, enabling quicker diagnosis and preventing situations like lab back-ups. Patients will benefit from receiving care more quickly. The underlying scientific concepts to validate each for use in clinical routine are the same, despite the significant differences in the characteristics and applications of DNA biomarkers, DNA tumor biomarkers, and general biomarkers. A crucial benefit of theranostics is that it encourages patient-centered care and more specialized treatment. A partnership between nanotechnology and theranostics would open up countless possibilities for the future of cancer detection and research.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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