Review Article

Cancer nanotechnology: A review

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ABSTRACT

Cancer is a highly complex disease. The challenges encountered in cancer detection and management include delayed detection, invasive investigation methods such as biopsy, comorbidity due to non-specific systemic distribution, inadequate drug concentration, and inability to monitor therapeutic responses. Through this article, we would like to throw some light on the use of nanotechnology and nanoparticles in the early detection and management of cancer, their advantages, limitations, and the various recent advancements in the field of nanomedicine and their use for the treatment of cancer.

KEY WORDS: Gold nanoparticles, Gold nanorods, Liposomes, Photothermal therapy, Quantum dots

INTRODUCTION

"Nano" is derived from the Greek word for "dwarf." The term "nanotechnology," coined in 1974, refers to the science of manipulating matter, measured in the billionths of meters or nanometers, roughly the size of two or three atoms.

Nanomedicine is a subfield of nanotechnology. It is often defined as the repair, construction, and control of human biological systems using devices built on nanotechnology standards. Basically, nanomedicine is the medical application of nanotechnology.[1]

Cancer is the abnormal, uncontrolled, and uncoordinated proliferation of cells. Cancer is a highly complex disease to understand. The most common cancer treatments are limited to chemotherapy, radiation, and surgery. The current challenges seen in cancer therapies today include lack of early disease detection, non-specific systemic distribution, inadequate drug concentrations reaching the tumor, and inability to monitor therapeutic responses. Current clinical diagnostic techniques typically involve invasive biopsy.[2] Further, histopathological diagnosis is based on morphological and structural changes at cellular or tissue level, which may not be obvious for early stage tumors.[19]

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Nanotechnology brings at least two major attractive features to existing techniques. Synthetic nanoscale materials are inherently small, with at least one dimension in the 1–100 nm range, so they can cross-biological barriers including the blood–brain barrier, transit out blood vessel walls, or the cell membrane by different uptake mechanisms. They can, therefore, interact with a wide panel of biological entities (e.g., from proteins to cells). Furthermore, nanoparticles (NPs) exhibit tuneable physical (e.g., electrical, magnetic, optical, and mechanical), chemical (e.g., reactivity and melting point), or biological properties that are dramatically different from the same materials in larger scale forms due to modified quantum mechanical properties.[3,4]

NPs offer great promise to improve therapeutic effectiveness and safety profile in cancer treatment through site specificity, their ability to limit multidrug resistance and efficient delivery of anticancer agents. A wide variety of NP-based systems those are available for cancer detection, diagnosis, and treatment includes liposomes, polymeric micelles, nanosystems, nanoshells, fullerene-based derivatives, carbon nanotubes, dendrimers, nanopores, quantum dots (QDs), gold NPs (AuNPs), solid lipid NPs, nanowires, and paramagnetic NPs.[5]

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DIAGNOSIS OF CANCER USING NANOTECHNOLOGY

One of the most important factors in effective cancer treatment is the detection of cancerous tumor cells in an early and perhaps curable stage. Thus, the detection time frame has an enormous effect on a patient's prognosis. Nanotechnology brings new hope to the arena of cancer detection research, due to NPs unique physical and chemical properties, giving them the potential to be used as a synthetic scaffold for imaging probes in the detection and monitoring of cancer. NPs surface properties are tunable, meaning injectable solutions of them can be made without using toxic organic solvents to attach water-insoluble anticancer agents. This, along with NPs ability to do passive or active tumor targeting, makes them an excellent platform to use for diagnostic imaging and treatment. Thus, nanotechnology-based imaging modalities have made a significant entry into cancer research with their potential of highly sensitive probes for cancer detection.[6]

AuNPs

Due to their photo-optical distinctiveness and biocompatibility, AuNPs have proven to be powerful tools in various nanomedical applications such as in diagnostic imaging, biosensing, and binary cancer therapeutic techniques.[15]

Au-based NPs are the perfect raw materials for robust, rapid diagnostic testing to detect cancer. The minute quantities required make it inexpensive, while its stability, sensitivity, and reproducibility as well as high-quality supplies give manufacture guarantee due to which it is already commercially available.[10]

AuNPs over an inexpensive and significant route to targeting only cancerous cells, leaving healthy cells untouched without doing any harm.[10] The unique light absorption and emission and scattering properties of AuNPs have made them the most studied entities during recent years in cancer diagnostics.[10] Biomarkers related to cancer cells and optical contrast agents provide excellent signal sources from cancer tissues to detect them from complex environment.[10] Most of the larger AuNPs make them promising probes for cancer detection based on imaging because of their scattering properties.[10]

Surface Plasmon Resonance (SPR) Scattering and Absorption of Anti-epidermal Growth Factor Receptor (EGFR) Antibody-conjugated AuNPs

SPR is a phenomenon occurring at the metal surface when a beam of light is incident on the surface of the molecules at a particular angle and distance (typically in case of gold [Au] and silver [Ag] metals or spherical NPs). It is well known that size and thickness of materials play an important role at the metal surface; the SPR phenomenon results in a gradual reduction in intensity of the reflected light. By measuring the appropriate exquisite sensitivity of SPR to the refractive index of the surrounding medium on to the metal surface, it is possible to measure accurately the adsorption and scattering of molecules on the metal surface and their targeted specific ligands.[7]

Colloidal AuNPs are found in dispersed and aggregated forms within the cell cytoplasm and provide anatomic labeling information, but their uptake is non-specific for malignant cells. The anti-EGFR antibody-conjugated AuNPs specifically and homogeneously bind to the surface of the cancer type cells with 600% greater affinity than to the non-cancerous cells. This specific and homogeneous binding is found to give a relatively sharper SPR absorption band with a red-shifted maximum compared to that observed when added to the non-cancerous cells. These results suggest that SPR scattering imaging or SPR absorption spectroscopy generated from antibody-conjugated AuNPs can be useful in molecular biosensor techniques for the diagnosis and investigation of oral epithelial living cancer cells *in vivo* and *in vitro*.[8,9]

Surface-enhanced Raman Spectroscopy (SERS)

Kah *et al.* (2007) demonstrated the use of AuNPs in SERS to enhance the Raman spectroscopy signal for the analysis of cancer-related chemical changes in saliva. SERS spectra of saliva were obtained and shown to be differentiable between those acquired from normal individuals and those from oral cancer patients, thus showing promise of a simple SERS-based saliva assay for early diagnosis of oral cancer.[1]

The use of saliva as a diagnostic fluid would offer a few advantages over previous sera-based counterparts in that saliva is easily accessible, painlessly acquired, and presents lower risk of infection compared to serum.[1]

QDs

QDs usually consist of an inorganic transition metal core/shell system usually made up of cadmium selenide, cadmium telluride, indium phosphide, and indium arsenide as core elements inside a shell, usually zinc sulfide.[18] These inorganic-organic composite NPs are extremely efficient agents for cancer detection *in vivo* due to their small size, which offers them unhindered access to the systemic circulation, and at the same time, their ability to conjugate targeting molecules that direct specific accumulation in neoplastic sites.[20]

Depending on size and the core/shell system, QDs have the ability to emit light across the visible and infrared wavelength spectrum. Thus, one can choose a suitable color of light emission. The main advantage of the QDs

is that with a single light source, the variously sized QDs can be excited while preserving the narrow emission of each individual particle/wavelength. Moreover, QDs have the ability to incorporate different markers simultaneously (multiplexing), enabling numerous targets to be imaged in a single experiment.[20]

A recent advancement in QDs technology is the use of QDs for near-infrared (NIR) imaging (700–1000 nm wavelength range) as an imaging probe. The main advantage of NIR QDs over its counterpart, visible QDs, is that it increases the depth of tissue penetration, allowing for more accurate and sensitive detection of photons *in vivo*. In addition, NIR QDs evade the problem of autofluorescence associated with optical imaging because of the naturally occurring compounds present in animal tissue.[10]

Biosensors

Cell-based biosensors work on the principle that multiple biochemical pathways are followed to translate the molecular code on the oncogenes into a malignant tissue. A living cell can be integrated in a microsystem as the primary transduction mechanism. The cells would detect the key biochemical signals and can amplify it. This can be detected by either monitoring physical parameters (such as electrical activity, structural changes), or chemical parameters (production of "messenger" molecules).[19]

Biosensors are composed of:

1. The biological marker (in short: biomarkers) that needs to be detected,
2. The interface, a scaffold typically using high-affinity ligands that provide specificity
3. The transducer - the sensing part of the device - which is sensitive to the presence of the biomolecule to be detected
4. The environment - resulting analog signals need then to be digitized, preprocessed, and analyzed.[2]

Sensor test chips containing thousands of nanowires, able to detect proteins and other biomarkers left behind by cancer cells, could enable the detection and diagnosis of cancer in the early stages from a few drops of a patient's blood.[5,20]

The lab-on-chip technology holds the promise of replacing the elaborate techniques with miniaturized, integrated, automated, disposable microfluidic cassettes, inexpensive diagnostic devices with preloaded, freeze-dried reagents, and used in conjunction with a handheld instrument, which would promote early screening and diagnostics during dental visits or routine medical examinations.[1]

The detection of oral precancer (dysplastic) and cancer cells within the chip will take advantage of membrane-associated cell proteins that are singularly expressed on the cell membranes of dysplastic and cancer cells and of the unique gene transcription profiles of cancer cells.[1]

Cancer Biomarker Discovery in Saliva by Mass Spectrometry

To date, diagnosis of cancer has been based on biopsies and histological examinations and often becomes difficult to get repeated sampling from patients for confirmation. Consequently, it is important for clinical researchers to look at multiple body fluids and different molecular techniques to identify biomarkers. One such body fluid is saliva, which is easily and non-invasively collected and contains thousands of potential protein biomarkers. Moreover, recent advances in the sensitivity and specificity of mass spectrometry-based proteomics hold great promise to identify potential biomarkers in saliva.[8]

Saliva can be used not only as a diagnostic medium to detect putative biomarkers directly related to a disease (e.g., oral cancer) but it can also be used to identify proteins such as CA 125 detected in higher abundance in patients with ovarian cancer as post-treatment follow-up.[8] Similarly, high concentrations of c-erbB-2 and epidermal growth factor have also been detected in saliva as a post-operative follow-up for breast cancer.[11]

Magnetic NPs

Magnetic NPs are able to target cancerous cells and have potential use in cancer therapeutics. It is due to superparamagnetic iron oxides, typically Fe_2O_3 and Fe_3O_4, which do not retain their magnetic property when removed from the magnetic field. Their paramagnetic characteristics have made them good candidate for the destruction of tumors *in vivo* through hypothermia.[20]

Magnetic NPs used in biomedical applications mainly have an inorganic NP core and in most cases are coated by a suitable coating material. Suitable coatings not only increase the stability and solubility of the nanoformulation but also can be used to incorporate a targeting moiety to increase the imaging sensitivity and to do real-time monitoring. Enhanced proton relaxation is one of the most added value properties that make magnetic NPs one of the best contrast agents for biomedical applications of magnetic resonance imaging. The most widely used NPs of this kind are the supermagnetic iron oxide NPs.[12]

Gold Nanorods

Two-photon imaging (TPI) is a powerful technique for the early diagnosis of epithelial cancers because it permits non-invasive imaging of subcellular features potentially hundreds of micrometers deep into tissue.[14]

The two-photon luminescence intensity from gold-nanorod-labeled cancer cells is three orders of magnitude brighter than the two-photon autofluorescence emission intensity from unlabeled cancer cells at 760 nm excitation light. Their strong signal, resistance to photobleaching, chemical stability, ease of synthesis, simplicity of conjugation chemistry, and biocompatibility make gold nanorods an attractive contrast agent for TPI of epithelial cancer.[13]

Nanoshells

Nanoshells are a novel class of optically tunable NPs that consist of a dielectric core of silica[20] surrounded by a thin gold shell. Based on the relative dimensions of the shell thickness and core radius, nanoshells may be designed to scatter and/or absorb light over a broad spectral range including the NIR, a wavelength region that provides maximal penetration of light through tissue. The ability to control both wavelength-dependent scattering and absorption of nanoshells offers the opportunity to design nanoshells which provide, in single NPs, both diagnostic and therapeutic capabilities.[12]

Immunotargeted nanoshells are engineered to both scatter light in the NIR enabling optical molecular cancer imaging and to absorb light, allowing selective destruction of targeted carcinoma cells through photothermal therapy.[12]

Nanoelectromechanical Systems (NEMS)

Nanotechnology-based NEMS biosensors that exhibit exquisite sensitivity and specificity for analyte detection, down to single molecule level, are being developed. They convert (bio) chemical to electrical signal. These are extremely useful in the diagnosis of oral cancer.[4,20]

Various functions can be carried out by devices based on micro/submicron technologies using silicon or engineered polymers. The existence of advanced and low-cost semiconductor and microchip manufacturing technologies has provided scientists and researchers to develop micron-sized sensors systems known as microelectromechanical systems (MEMS)/NEMS.[19]

Bio-MEMS have been used as a diagnostic tool in cancer therapy, by incorporation of novel functional or novel-shaped nanomaterials and biomolecular markers. This makes it possible to study the fundamental biological mechanisms that dictate health and disease. Based on the cell molecular machinery and signal transduction mechanisms, nanomedicines can be synthesized which can act as artificial cells and help in targeted molecular drug delivery combined with therapeutic imaging.[14]

Carbon Nanotubes

Carbon nanotubes consist of carbon atoms exclusively arranged in a series of condensed benzene rings rolled-up into tubular architecture. Tumor-targeting carbon nanotubes have been synthesized covalently attaching multiple copies of tumor-specific monoclonal antibodies, radiation ion chelates, and various fluorescent probes. The surface of carbon nanotubes can be modified with proteins for cellular uptake. Then, they are heated on absorbing NIR light wave. When exposed to NIR light, carbon nanotubes quickly release excess energy as heat (~70°C) which can kill cancerous cells. Another advantage of carbon tube is that they help in detection of altered gene ,which helps is diagnosis of cancer.

Nanopore

These contain tiny hole that allows DNA to pass through one strand at a time making DNA sequencing more efficient. This will help researchers to detect errors in genes that contribute to cancer.[15]

TREATMENT OF CANCER USING NANOTECHNOLOGY

Once cancer has been diagnosed, treating the disease mostly relies on surgery, radiotherapy, and chemotherapy, separately or in combination.[2] Nanotechnology is probably the only method that can be used for site-specific action without causing side effects by killing the normal cells.[1] Nanotechnology represents a great hope to improve cancer treatments by acting at least at two main levels:

a. Conferring new properties to a pharmaceutical agent (increased stability, modified pharmacokinetics, and decreased toxicity)[2]
b. Targeting the agent directly to the tumor.[2]

The first strategy provides a means to revisit selected new molecular entities which failed in the development process due to poor pharmaceutical properties. The goal is thus to increase the therapeutic index of known drugs.[2] A major bottleneck of chemotherapy (e.g., systemic injection and oral administration) is the relative lack of specificity, thus along with tumor cells, it also affects the normal tissues, triggering undesirable side-effects. The use of drug delivery systems (DDSs), composed of a nanocarrier and its therapeutics, dramatically changes the physicochemical properties of the drug as well as its biodistribution.[2] This is particularly relevant in the case of very active drugs whose interest in the clinics is limited by their toxicity on vital organs (heart, kidneys, and bone marrow), but it may also provide new delivery options for existing drugs which are about to be off patent.[2] The opportunity offered by nanotechnology is to take advantage of the leaky

neovasculature of the tumor (i.e., passive targeting), and possibly also of high-affinity ligands to target the tumor with a DDS (i.e., active targeting) and deliver the drug locally, minimizing side effects.[2]

Photodynamic Therapy (PDT)

One of the major advances in minimally invasive therapies for cancer is PDT. First discovered in the early 1900s, it is now an approved cancer treatment for various superficial malignancies including basal cell carcinoma, oral, esophageal, and lung cancers.[1] QDs can be used in PDT as photosensitizers, which can mediate targeted cellular destruction. They can bind to antibody present on surface target cell and when stimulated by ultraviolet light, will release reactive oxygen species (ROS). This is lethal to target cells.[16]

Photothermal Therapy

A less invasive experimental technique that holds great promise for the treatment of cancer and related disease conditions is photothermal therapy. It combines two key components: (a) A light source, specifically lasers with a spectral range of 650–900 nm for deep tissue penetration and (b) optical absorbing AuNPs, which transform the optical irradiation into heat on a picosecond timescale, thereby inducing photothermal ablation.[1]

Gold Nanoshells

Hirsch *et al.* (2003) reported that gold nanoshells that were labeled with antibodies specific to oncoprotein were injected and bound to the target carcinoma cells. Subsequent NIR illumination resulted in local heating because of strong absorption by the nanoshells and subsequent destruction of the tumor cells.[1]

In another step forward, gold nanoshells were conjugated with ligands for specific accumulation in oral squamous carcinoma cell lines (HSC 313 and HOC 3 Clone 8). Furthermore, these kinds of nanoshells have been used for targeted delivery and therapy of many cancers including breast and prostate cancers.[18]

Enhanced Permeability and Retention (EPR) Effect

Some nanoparticles have the ability to accumulate in tumor vasculature, known as EPR, thus increasing accumulation of the payload to the tumor site. Passive targeting, in this case, takes advantage of the rapid vascularization of hyperpermeable cells. This results in leaky, defective vessels and impaired lymphatic drainage.[18]

Nanoparticles sized at 10–100 nm have the ability to accumulate within tumors because of their ineffective lymphatic drainage. Thus, consideration of the size and surface properties of NPs is vital, particularly for passive targeting. Particles must be <100 nm to avoid uptake by the reticuloendothelial system and their surface should be hydrophilic to avoid rapid clearance by macrophages. Furthermore, both active and passive targeting can be exploited simultaneously to obtain maximum efficacy.[17]

Liposomes

Nanocarriers encounter numerous barriers en route to their target such as mucosal barriers and non-specific uptake. One way to overcome these limitations is to program the nanocarriers so they actively bind to specific cells after extravasation. This binding may be achieved by attaching targeting agents such as ligands molecules that bind to specific receptors on the cell surface to the surface of the nanocarrier by a variety of conjugation chemistries.[19]

Liposomes are small artificial spherical vesicles composed of non-toxic phospholipids and cholesterol, which self-associate into bilayers to encapsulate drugs, genes, and other biomolecules on aqueous interior. Liposomes are within the size range of 25 nm to 10 µm, depending on their preparation method. Various therapeutic agent-loaded liposomes are being extensively tested as targeted delivery for fighting against cancer. Liposomes of certain sizes, typically <400 nm, can rapidly penetrate tumor sites from the blood, but are kept in the bloodstream by the endothelial wall in healthy tissue vasculature.[20]

Doxorubicin is an anticancer drug from the family of anthracyclines that inhibit the synthesis of nucleic acids within cancer cells. Its drawbacks include cardiotoxicity and myelosuppression.[2] Doxil, which is doxorubicin formulated in nanoliposome, has shown significant improvements over its counterpart, free doxorubicin.[18] The cardiotoxicity of liposomal doxorubicin is decreased thanks to the DDS which reduces the peak cardiac level of the drug.[2]

Polylactic-co-glycolic Acid (PLGA) NPs/Nanocells

Polymeric NPs may provide the most promising nanovectors for drug transportation. Among them, biodegradable ones are of particular interest since they can be metabolized and removed from the body. An interesting example is the case of PLGA in which the relative amount of polylactic acid and polyglycolic acid can provide PLGA polymers with tuneable biodegradable properties. Adding polyethylene glycol to the DDSs surface offers a hydrophilic "stealth" coating.[2] Paclitaxel (Taxol®, Bristol-Myers Squibb) belongs to the taxane drug family like Docetaxel (Taxotere®, Sanofi Aventis). Paclitaxel promotes cell death by increasing the polymerization of tubulin, hence, provoking the disruption of cell division's dynamics. This microtubule-stabilizing agent is, however, poorly soluble in aqueous solutions so its

formulation includes Cremophor EL (polyethoxylated castor oil) and ethanol. The former being cytotoxic and exhibiting side effects, new formulations were sought. Among them are different sizes of biodegradable NPs made of PLGA. Current formulations include a 130 nm albumin-bound particle form of paclitaxel (Abraxane®, Abraxis Bioscience), administered without the use of other excipients. Abraxane® targets tumors through the endothelial gp60 receptor and the albumin-binding protein overexpressed in a majority of tumors: The secreted protein acidic and rich in cysteine and was shown to be twice as effective as Taxol®.[2,18]

Dendrimers

Dendrimers are a unique group of NPs that are highly suitable for effective delivery of drugs, particularly for cancer treatment. Dendrimers can be synthesized by controlled, repeated polymerization reactions to engineer a desired shape and size. The main advantage of dendrimers is their exclusive branching point that is available for conjugation to multiple entities including targeting proteins, treatment moieties, and even apoptosis factor ligands. Chemotherapy drugs, when incorporated into the core of the dendrimer, do not affect healthy cells. The dendrimer can be engineered so that when it gets into the target tumor cell, it can change its conformation, allowing the incorporated moiety to be released to the tumor site, efficiently suppressing tumor growth. The size, tenability, and multifunctional capability to enhance multiple drug interactions to deliver a chemotherapeutic agent to the specific tumor site make dendrimers an excellent nanocarrier for tumor targeting and therapy.[18]

Quintana *et al.* synthesized an ethylenediamine core polyamidoamine dendrimer of generation five that was covalently attached to folic acid, fluorescein, and methotrexate. This complex provided targeting, imaging, and intracellular drug delivery capabilities with 100-fold decreased cytotoxicity over free methotrexate.[18]

Scientists and researchers have fashioned dendrimers into an effective and sophisticated anticancer therapy machines carrying five important chemical tools:

- A molecule designed to bind cancerous cells and tumors
- Fluorescence on locating genetic mutations
- To assist in imaging tumor shape using X-rays
- Carrying therapeutic agents released on demand, and
- Signaling when cancerous cells are finally dead.[20]

Nanocapsules

It is now possible to engineer tiny containers the size of a virus to deliver drugs and other materials with almost 100% efficiency to targeted cells in the bloodstream. According to a new Cornell study, the technique could 1 day be used to deliver vaccines, drugs, or genetic material to treat cancer and blood and immunological disorders. Drug targeting by NPs or nanocapsules offers the following enormous advantages as examples: Reduces dosage, ensures the pharmaceutical effects, and minimizes side effects; and protects drugs against degradation and enhances drug stability. Tiny machines, known as nanoassemblers, should be controlled by computer to perform specialized jobs. The nanoassemblers could be smaller than a cell nucleus so that they could fit into places that are hard to reach by hand or with other technologies.[18]

Carbon Nanotubes

Single-walled carbon nanotubes (SWNTs) are a recent and innovative technological advancement in the world of chemistry that could be one of the best ways to fight cancer. SWNTs have been shown to shuttle various cargoes across the cellular membrane without cytotoxicity. The cancer cells can be distinguished from healthy cells by locating alterations on them that are not on healthy cells. Coating functionalized SWNTs with peptides and other cell-binding ligands such as monoclonal antibodies allow them to target-specific cancerous cells.[19] Treatment using functionalized SWNTs can begin after they make their way inside the tumor. No effects will be seen until the patient is placed inside a radiofrequency or NIR region field. These two types of radiation were chosen for their ability to pass through the body without damaging body tissue.[19] Radiofrequency waves have the tendency to penetrate further into the body. Once inside the field SWNTs can effectively convert radiofrequency energy or NIR into heat. They absorb the arriving waves of radiation, giving them energy and in turn causing them to vibrate.[19] The vibrational movement causes heat to be produced and thermal properties to activate. Vibration of the lattice structure releases phonons, which transfer the heat energy throughout the length of the nanotube. Heat is then dispersed inside the tumor from the entire surface area of the SWNTs causing overheating, protein denaturation, and eventually malignant cell death.[19]

Brachysil™

Nanomaterials for brachytherapy, such as Brachysil™ (Sivida, Boston, and Perth, Australia), deliver 32P and are currently being tested in a clinical trial. A DDS that can cross the blood–brain barrier is a vision of the future with this technology. Nanovectors for gene therapy to correct disease at molecular level are at the development stage.[1,4]

AuNPs and QDS

Various killing mechanisms of cancer cells by AuNPs have been proposed. The one most commonly

discussed, that has become an extensive area of research, is based on the formation of a bubble around the overheated AuNPs in a liquid environment followed by generation of acoustic and shock waves and protein inactivation. In particular, gold nanoclusters attached to a cell membrane can lead to dramatic increase in bubble formation efficiency, resulting in more severe cancer cell damage at a laser strength that is safer for normal tissue. For environments with a lack of sufficient amount of liquid for efficient bubble generation, such as bones or dense solid tumors, other killing mechanisms are being sought. For instance, one is a "gold atom bullet" that moves from the explosion zone with kinetic energy sufficiently large to mechanically damage the surrounding cellular structure. Another is the melting of cell walls by hot AuNPs and subsequent destruction of the cell by gold nanoclusters.[20]

QD probes can target and accumulate in tumors both by their EPR effect and by recognition of cancer cell surface biomarkers. Chemotherapeutic agents bound to QD probes that will recognize and bind to cancer cells may offer a new strategy for molecular cancer therapy by avoiding systemic toxicity.[1]

QDs can be used as photosensitizers which can mediate targeted cellular destruction. They can bind to antibody present on surface of target cell and when stimulated by UV light will release ROS and this will be lethal to target cell. This therapy can be used to fight with malignant cells.[4,19]

ADVANTAGES OF NPs

The use of NPs has not only revolutionized the field of medicine but also has helped in accurate, precise treatment of diseases, and drug delivery. It is relatively easy and non-invasive method for detection and management of cancer. It provides increased contrast for diagnosis of cancer. Multiple molecular elements can be target simultaneously for imaging. It helps in detection of cancer at an early stage, thereby improving the prognosis. The NPs are relatively non-toxic. It exhibits targeted malignant tissue destruction.[19]

DISADVANTAGES OF NPs

Cancer targeting is highly dependent on surface chemistry of the target cell. Biocompatibility is a major issue in use of NPs. The safety of use of NPs cannot be determined. The cost of manufacture of NPs is very high, and it is not easily available globally.[19]

RECENT ADVANCES

Cancer Nanovaccines

Vaccine as a form of nanovaccine in the treatment of cancer is still under development. The first type, prophylactic vaccines, triggers humoral and cellular immunity and is administered into healthy individuals to prevent them from getting cancer. The human papillomavirus vaccine is an example of a prophylactic vaccine. For those who already have cancer, there is a second type of vaccine called cancer nanovaccines.[19]

Nanorobots

The ultimate tool of nanomedicine is the medical nanorobot - a robot the size of a bacterium, composed of many thousands of molecule size mechanical parts perhaps resembling macroscale gears, bearings, and ratchets, possibly composed of a strong diamond-like material. A nanorobot that would travel through the bloodstream must be smaller than the red cells in our blood - tiny enough to squeeze through even the narrowest capillaries in the human body.[20,3]

Related nanorobots could be programmed to quickly recognize and digest even the tiniest aggregates of early cancer cells. Medical nanorobots could also be used to perform surgery on individual cells. In one proposed procedure, a cell repair nanorobot called a "chromallocyte," controlled by a physician, would extract all existing chromosomes from a diseased cell and insert fresh new ones in their place. This process is called chromosome replacement therapy.[20]

CONCLUSION

Nanobiotechnology has strong potential to revolutionize the diagnosis and treatment of deadly diseases like cancer. Nanomedicine will allow a more personalized treatment for many diseases, exploiting the in-depth understanding of disease on a molecular level. The multimodal NPs have the potential to be used as diagnostic as well as therapeutic agents in cancer.[20]

Nanotechnology applications in cancer detection and treatment have the potential to replace highly invasive conventional cancer detection and treatment, which often includes biopsies, irradiation, and painful therapies. The ability to diagnose malignant disease at the earliest opportunity allows treatment options to be planned as early as possible and hence directly affects the morbidity and mortality of cancer.[1]

Imagine a future where NPs can help detect cancer before it even has a chance to manifest and selectively destroy cancer cells while leaving the normal cells unharmed. Cancer, in such a circumstance, could become a highly manageable condition.[19]

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