Nanotechnology and its Role in Cancer Treatment and Diagnosis

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Abstract. Globally, cancer is one of the leading causes of death and is extremely difficult to treat and diagnose. The numerous types and variations of the disease make it a complex illness to tackle. Often, a patient diagnosed with cancer will face a drastic reduction in quality of life, if not death. One of the biggest challenges regarding cancer is early detection and toxic therapies. Over the past few years, the two factors have been improved upon by the employment of nanotechnology via innovations in tumor imaging and reducing toxicity in drug delivery. Various nanocarriers and materials such as liposomes and nanotubes have shown improvement in target specificity and enhanced imaging. They preserve healthy tissue cells to a greater degree and can aid in accurately detecting cancer before metastasis. In this paper, there will be (i) an overview of various nanoparticles and their advantages, (ii) how nanocarriers are applied in cancer diagnosis and treatment, (iii) the developmental path of nanotechnology methods, and (iv) future prospects of nanotechnology development.

Keywords: Nanotechnology, Cancer Treatment, Nanoparticles.

1. Introduction

An increasing proportion of the world's population is suffering from cancer. It can be described as an illness in which there is uncontrolled cell division that often spread to various parts of the body, ultimately causing death. Currently, treatment includes surgical removal of cancerous tumors, chemotherapy drugs, radiation therapy, and a few other means. These methods are inherently damaging to surrounding healthy tissue and result in a large trade-off between killing malignant cells and harming normal ones. Therefore, it is crucial that, in order to reduce the mortality rate and improve treatment, cancer must be detected at an early stage, treatments damage healthy tissue cells as little as possible, and drug delivery or therapies target tumors in a specific manner. With these factors prioritized, the use of nanoparticles as carriers for various molecules has shown promising results for advancing the prognosis of cancer patients. Nanoparticles have a high surface area-to-volume ratio, allowing them to carry various materials to a specific delivery site. They are also engineered to last longer in circulation in vivo, prolonging treatment effects. In terms of diagnostics, nanotechnology enhances imaging methods such as MRI or PET scans, and it also recognizes biomarkers. This way, cancer can be detected before any tissue damage occurs.

On the other hand, with therapies, nanoparticles are being used as carriers for drugs, genetic material, and other large molecules that play a role in apoptosis. Because of more precise targeting than traditional methods, delivery with nanoparticles can reduce the side effects of medication as well. A combination of nanomaterials such as liposomes, molecules, antibodies, and polymers can be used to maximize efficacy. Depending on the size, shape, and surface characteristics, some nanoparticles may be more suitable for certain tasks than others. However, different particles also have various drawbacks. Some can be potentially toxic and are still under development. With the rapidly developing area of study, nanoparticles have evolved an extensive amount, but there is still much to expand upon. As a new direction of cancer theranostics research nanotechnology holds a very promising future. This paper will review the background of various nanoparticles and their applications of them in cancer diagnosis and therapy, and then highlight their developmental history to understand the role they will play in the future of the disease.

2. Types of Nanoparticles in Cancer Therapy

Many types of nanoparticles have been developed to aid in cancer theranostics. Their functions vary from diagnosis to therapy. This paper will highlight the major types, some of which are shown in Figure 1 below.

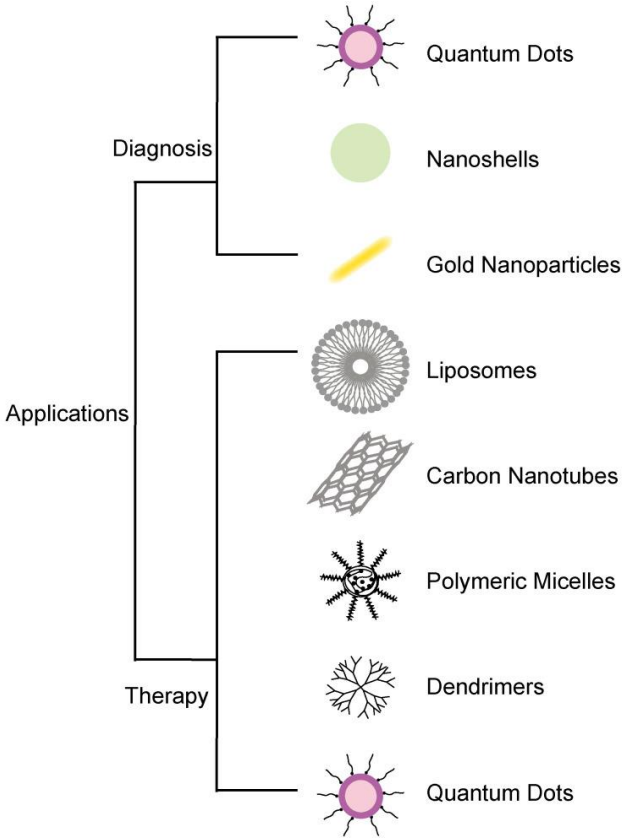

Figure 1. Classification of NPs according to the application and chemical properties, (Adapted from Jin 2020)

2.1. Liposomes

Liposomes are a widely studied nanocarrier to deliver traditional anti-tumor drugs. In general, liposomes operate on the basis of their high penetrations and retention rate regarding the network of blood vessels around a tumor. This enhances the accumulation of drug-carrying liposomes at the tumor and reduces the side effects of the treatment.[1]

Liposomes are especially effective due to their resemblance both chemically and structurally to human cell membranes. They're primarily constructed of phospholipids and cholesterol, which are highly biocompatible and biodegradable. With the hydrophilic heads facing the outer water environment and the hydrophobic tails forming the internal assembly of the membrane, liposomes are amphiphilic. The formation of the bilayer results in a balloon-like structure of the liposome. It can safely encapsulate molecules on the inside and protect drugs from the extracellular environment, ensuring effective and safe delivery. Not only that, but because their structure contains qualities that are both attractive and resistant to water, it gives them the advantage of being able to deliver a variety of both hydrophobic and hydrophilic drugs.

There are various ways for liposomes to deliver drugs. One of the most common is stimulus-responsive liposomes.[1] They are triggered by external or internal physical, chemical, or biological stimuli, and change structures when exposed to them. The biological difference between healthy cells and cancerous tissue causes a controlled release of cancer drugs and improves their utilization. Stimuli can also be classified into two different categories: endogenous and exogenous. Endogenous stimuli come from factors in the tumor itself. For example, high levels of glutathione (GSH) can disrupt the

membranes of liposomes by degrading the disulfide bonds that hold it together. [1]When the liposomes break down, the drugs it encapsulated are released. On the other hand, exogenous stimuli are the opposite. For instance, the encapsulation of a liposome, light or radiation exposure, etc. can trigger structural changes in liposomes and also release drugs.[1]

Liposome manufacturing also plays a significant factor in the stability and pharmacokinetics of the nanoparticle. The most common method of synthesizing these carriers is the Bangham method or thin-film hydration technique.[1] The lipid is dissolved in an organic solvent, which is then evaporated, and the remaining lipid film is dispersed in an aqueous medium. The intended drug for delivery can be incorporated in the aqueous medium if it is hydrophilic, or the lipid film if it is hydrophobic.

2.2. Colloidal Gold Nanoparticles

Colloidal Gold is another nanoparticle that offers unique advantages in cancer diagnostics. It is a suspension that has sub-micron gold nanoparticles (AuNPs) within a solvent - most often water. The element, with its high atomic number, have certain optical, thermal, and electronic properties that are beneficial when incorporated into cancer technologies.[2] Not only that, but these properties can be adjusted by changing the particle's size, shape, surface chemistry, or aggregation site.[2]

One of the most outstanding properties of gold nanoparticles is its interaction with light. Based on the particle's size, dimension, and environment, light rays or electric fields cause the gold's electrons to oscillate with the frequency of visible light.[3] These oscillations are called surface plasmons and depending on the gold nanoparticle's size, absorption of light occurs for various colors of the spectrum. Therefore, with simple tailoring of AuNP size, they can be designed to absorb differing colors for various applications.[2]

Briefly, gold nanoparticles are being used in cancer theranostics in a variety of ways. In photodynamic therapy, AuNPs are adjusted to absorbed infrared wavelengths, which in turn cause the particles to produce heat.[3] When light is applied to tumors with gold nanoparticles, they heat up rapidly and destroy the cancerous cells.[3] AuNPs are also being used in diagnostics to detect cancer biomarkers, or more commonly, in lateral flow immunoassays such as pregnancy tests. Similar to other nanoparticles, AuNPs are also used for drug delivery, with a high surface area-to-volume ratio.

2.3. Quantum Dots

Quantum Dots (QDs) are another type of emerging nanoparticle that is currently being studied for application in cancer diagnosis, imaging, and treatment. In essence, quantum dots are man-made nanoscale crystals, about 2-10 nanometers in size, that have the ability to transport electrons. They are made of a range of chemicals, such as Cadmium, Selenium, Silver, etc, and covered in a variety of biomaterials.[4] They emit light of various colors when UV rays hit them because they are made of semiconducting nanoparticles. When the size of the nanoparticle shrinks, the frequency of light created also becomes more restricted.

QDs were theorized around thirty years ago and created just about 20 years ago. Scientists hypothesized that quantum effects would start being prevalent if the particles of semiconductors were made small enough.[4] It is then when the energy of electrons and holes is limited as it exists in the particles. Therefore, because certain amounts of energy correlate to certain wavelengths of light, the optical properties of quantum dots can be adjusted by changing their size. They can emit and absorb whatever wavelength of light is applicable for the certain situation they are being used for.

Although research regarding quantum dots is still fairly new, these nanoparticles have already shown many advantages. Their optical and chemical properties make them contenders mainly in the area of tumor imaging, cancer detection, and biomarker detection. The brightness of quantum dot-based nanoprobes makes them highly sensitive, which is crucial for molecular imaging of cancer cells and even potential targeted therapy. This also makes them useful for deep-tissue imaging, especially when they are attached with cancer-specific antibodies, peptides, or ligands.[4] Compared to

traditional fluorescent organic dyes, they offer many more benefits. For example, when exposed to light for longer than one hour, the excitation that quantum dots produce is much more stable and constant than traditional colors. Not only that, but their fluorescence lifetime is longer and more intense. Another advantage is that they are more resistant to photobleaching. Lastly, quantum dots are noncytotoxic, so they are suitable for a variety of therapeutic applications as well.

3. Applications of Nanotechnology in Cancer

3.1. Diagnosis

Currently, cancer is diagnosed in patients using a variety of imaging techniques. Some of those include positron emission tomography (PET), magnetic resonance imaging (MRI), computed tomography (CT), X-ray, or ultrasound. However, these methods are limited to the fact that abnormalities can only be detected once there is a visible change in the tissue. This can be problematic because it gives time for the cancerous cells to proliferate and metastasize. Not only that, but imaging scans cannot differentiate between malignant and benign tumors, so additional measures must be taken to correctly diagnose cancer. Most of the time, surgical measures are taken, further risking the patient's health. In short, the techniques that are widely being used have major shortcomings when it comes to detecting cancer at an early stage, and identifying the type and stage of the disease.

Due to this, nanoparticles have been a very attractive tool in diagnosing cancer. This is in part due to the fact that their surface area to volume ratio is exceptionally high, so their surfaces can be densely covered with small molecules like antibodies, peptides, etc. Their ability to carry many materials allows for many advantages.

First, nanoparticles can detect cancer biomarkers in a more efficient, cost-effective, and convenient way. Biomarkers are molecules that can be found in bodily tissues or fluids and indicate that a certain cancer is present in the body. They can be proteins, carbohydrates, or the genetic material of cancer cells. Early detection of the disease can be accomplished through the identification of certain cancer biomarker levels. The detection of biomarkers is made more efficient by nanoparticles, as they provide specific targeting, and can target multiple factors simultaneously.[5] Nanoparticles have the ability to carry an array of binding ligands, such as antibodies or small molecules, that will recognize and bind to specific cancer cells. For example, in recent studies, gold nanoparticle systems were developed to target cancer metastasis and angiogenesis. They carried the Arg-Gly-Asp (RGD) peptide motif, which is recognized by cancer cell surface receptors. High penetration and accumulation was recorded in 4 T1 mammary tumors.

Recognizing biomarkers and identifying the correct stage of cancer is also vital for doctors to determine what dosing regimens will be the most effective, thereby allowing them to precisely administer novel therapies without over-diagnosing. New nanotechnology is being developed at Standford in which cancer cell death induced by therapy can be visualized through molecular markers - a method that exposes cancer cells and molecules that cannot be detected through normal imaging.[5] The Target-Enabled in Situ Ligand Assembly (TESLA) system forms in the human body after being injected with IV molecular precursors, which contain atoms that form larger nanoparticles. However, these particles are only formed after being cleaved by enzymes that cancer cells produce during apoptosis. The larger nanoparticles carry imaging contrasts and can aid PET, MRI, and other scanning methods to monitor how the tumor is responding to therapies.[5]

However, biomarker identification is not the only way nanoparticles revolutionize current techniques. Another way that they are being used is in enhancing imaging and screening methods, such as MRI or CT scans. Nanoparticles, with their ability to carry multiple small molecules, can carry particles that result in higher resolution imaging. Many different materials are currently being tested and prove to be very efficient. For example, MRI imaging for the detection of lung cancer in the early stages has been made possible. Immune superparamagnetic iron oxide nanoparticles (SPIONs) target cancer cell lines and the SPIONs have shown high specificity with no side effects.[6]

Some institutions even take advantage of the nanoparticle's high surface area by designing it to

have multiple functions. One group at Emory University had been working to develop particles that can both enhance imaging and deliver drugs for pancreatic and ovarian cancer patients. They used gold nanoparticles to enhance the scattering of light during endoscopic techniques for colonoscopies, and deliver small-molecule drugs. The magnetic iron cores diagnose the patient through MRI scans, and the particle also has the ability to traverse the fibrotic stromal tissues that protect the tumors - an area that has been traditionally hard to deliver drugs to.[6]

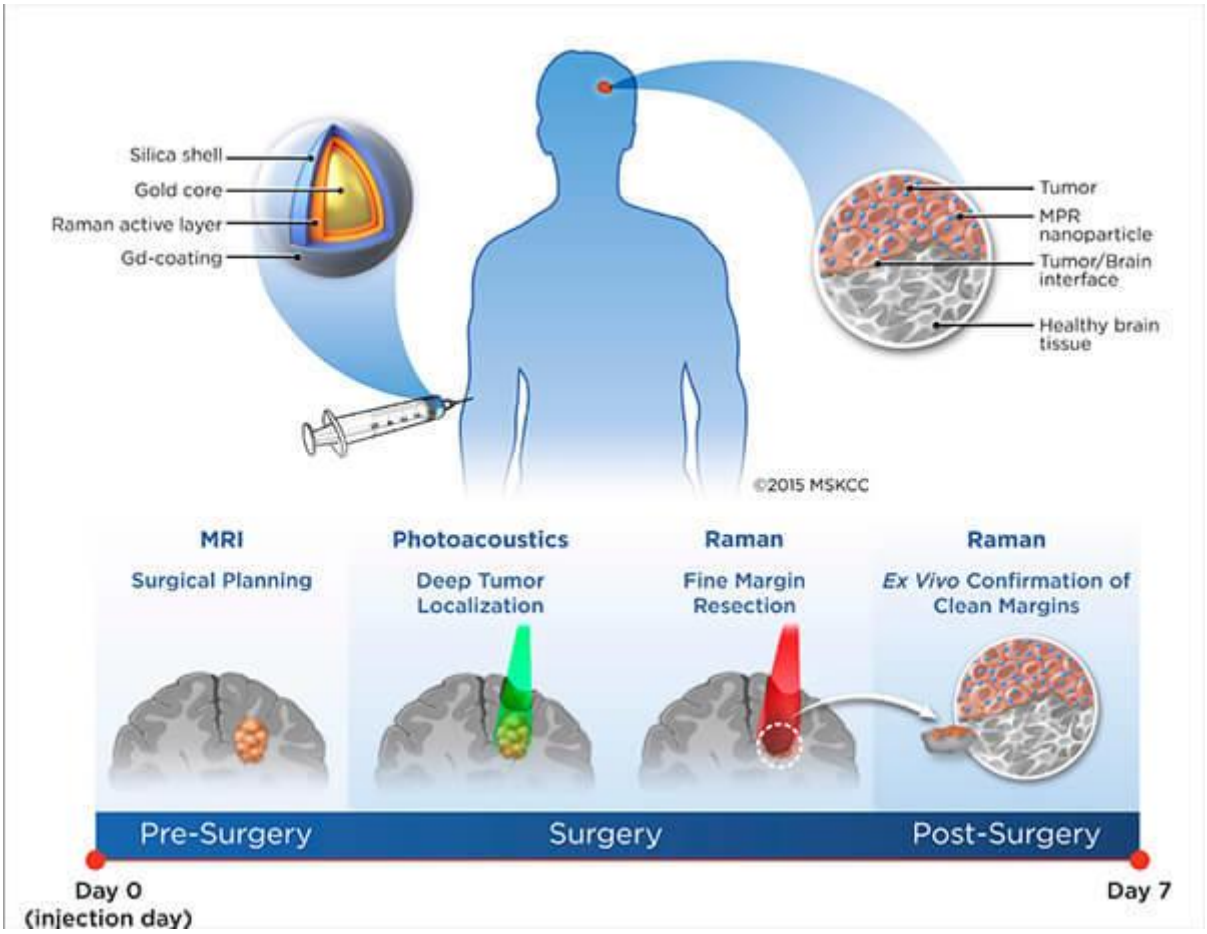

Figure 2. Principle of a triple-modality MRI-photoacoustic-Raman nanoparticle for clinical use (Adapted from National Cancer Institute 2017)

3.2. Drug Delivery

Drug Delivery is also a major way that nanoparticles are currently being used. Currently, conventional therapy has many limitations. First, methods such as chemotherapy and radiation treatment do not specifically target cancer cells. Coupled with the fact that this treatment is inherently toxic because it uses chemicals to kill fast-growing cells, it can cause drastic side effects that damage the patient's quality of life. Common side effects include loss of hair, low blood counts, nausea, weakness, and many more. The same holds true for radiation therapy. The high-energy particles and waves can destroy cancer cells and shrink tumors, but they also cause implications for other parts of the body, such as the immune system. Finally, a frequent approach in cancer treatment is invasive surgery to remove cancerous tissue or tumors. This obviously puts the patient at further risk, having to undergo a major procedure. Not only that but surgery often cannot guarantee that all of the cancerous cells are removed, so there is still a chance that the disease will return.

Nanoparticles offer a way to overcome the disadvantage of traditional medicine. They have shown many advantages in cancer therapy, such as precise targeting of tumors, combating drug resistance, and having good pharmacokinetics.[5] They also have shown promising results in areas that are traditionally hard to treat, such as the brain, due to the blood-brain barrier.[7]

The nanoparticle system has the ability to enhance current chemotherapy treatments. They improve the solubility of certain hydrophobic chemicals and also increase their stability. Not only that, but the particles improve drug distribution by extending the circulation time.[7] In addition, they could greatly reduce the risks and side effects that come with chemotherapy. Through the enhanced permeability and retention (EPR) effect, tumor sites offer increased vascular permeability, allowing nanoparticles carrying chemotherapeutic drugs to deliver straight to the specific area. In fact, the pressure difference in the solid tumor prefers the accumulation of molecules from 10nm to 200nm, and studies have shown that drug retention is much higher when carried by nanoparticles.[6]

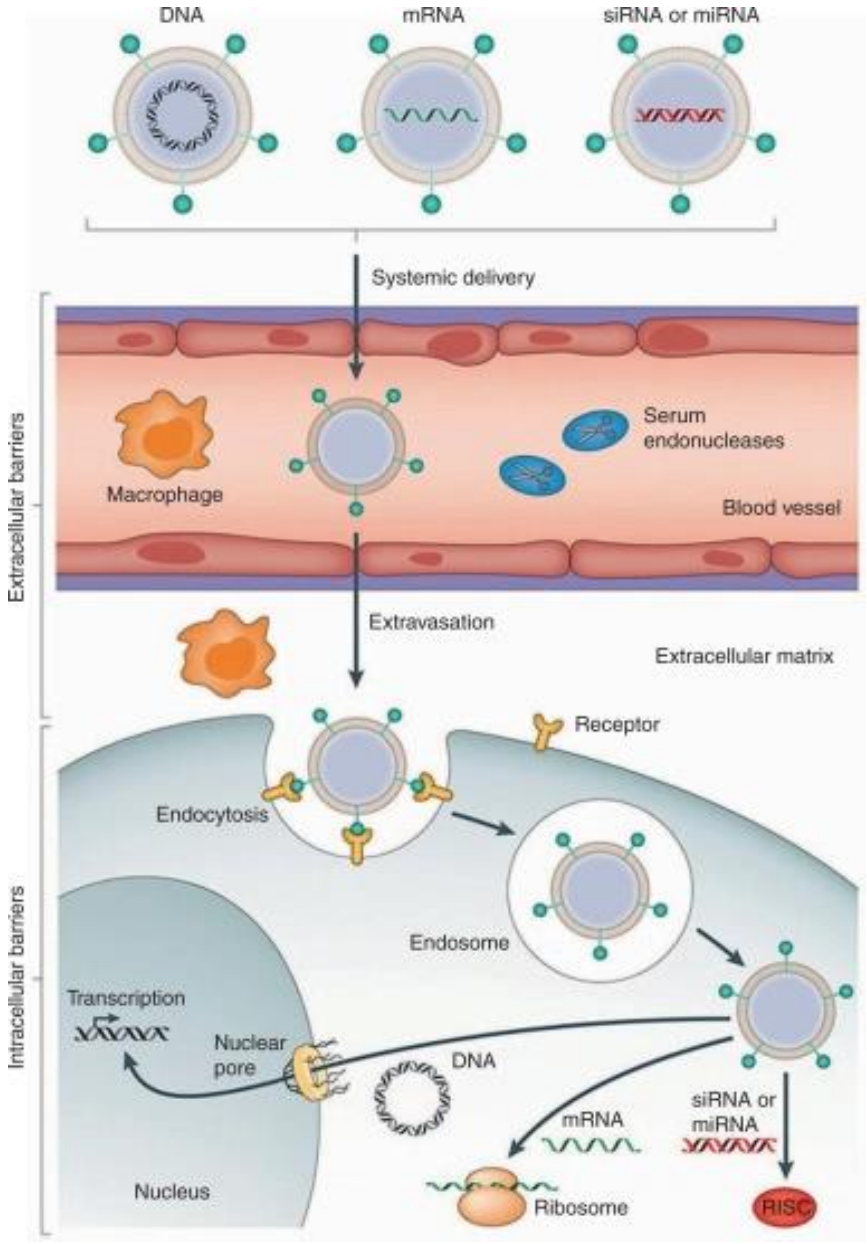

Figure 3. Schematization of nanoparticle-based gene therapy in vivo (Adapted from 2014 Nature Publishing Group)

Another type of therapy being delivered by nanoparticles is gene therapy. Gene therapy is a treatment method in which normal or healthy genes are transplanted into cells in place of defective ones to correct disorders or diseases. Not only that but gene therapy is turned to target "undruggable" cancer proteins. Two main factors lead to successful gene therapy. First, the genes must be delivered efficiently and safely to target cells, and second, the modified cells or modifying agents must be monitored using noninvasive imaging.[8] Gene delivery and expression can therefore be tracked. Gene therapeutics is a relatively new approach in itself, so it faces many challenges. The genetic

materials/nucleic acids such as microRNAs (miRNAs) and small interfering RNAs (siRNAs) are highly sensitive to degradation and unstable in circulation.[7] With delivery through nanoparticles, they are more stable and released in a controlled manner, prolonging the effects. This is because the nucleic acids must be delivered to cell nuclei, where they produce the intended proteins. Nanoparticles must transfer an amount that reaches the level and duration of gene expression enough to correct defects and allow expression of the gene without toxic side effects.

There are many nanocariers that have shown promising results in delivering gene therapy. The first is gene-loaded polymeric nanocarriers (PNCs), which are biodegradable, biocompatible, and highly novel polymeric systems. They improve pharmacokinetics and respond to permeation and retention at the tumor site, and also play a crucial role due to how easily they are synthesized and their flexible properties.[8] Another type of carrier are the lipid-based nanocarriers, which are also efficient vectors in delivering genes. They are used to encapsulate RNA, and are created by a combination of a lipid solution and plasmid DNA. They are extremely appealing due to their physical stability and biocompatibility. They're positively charged, making them easily captured by the negatively charged cell membranes. In terms of inorganic nanocarriers, gold nanoparticles are widely being studied due to their surface chemistry and easy molecular imaging. The particle surfaces hold positively charged molecules like peptides, amino acids, or oligonucleotides.[8]

Often in conjunction with chemotherapy or gene therapy, cancer patients will receive radiation to further limit the growth of cancer cells. This is done so by damaging their DNA and inducing cellular death by altering the DNA directly or by creating charged atoms that will. Similar to chemotherapy, there is a tradeoff between safety and efficacy, and the treatment must be given in regulated levels to avoid excess harm to surrounding tissues. Not only that, but certain cancers have been found to be resistant to radiotherapy, such as pancreatic cancer and glioblastoma.

Scientists are now turning toward nanoparticles to potentially augment and enhance radiotherapy. Nanoparticles are extremely attractive due to their physical properties. As an example, gold nanoparticles show photothermal and surface plasmon resonance effects.[9] Nanoparticles and X-rays interact due to their similar properties at an atomic level, so they can enhance the photoelectric and Compton effects of traditional radiation therapy. Essentially, they can increase the efficacy while the dose of radiation is held constant. Not only that, but nanoparticles in interact with high energy waves such as the waves triggering the particle to release drugs, which can allow them to deliver at the local tumor site or sensitize the tumor to radiation.

Alternatively, another type of radiation therapy, photodynamic therapy (PDT) relies on external electromagnetic radiation.It is mainly effective for superficial tumors and relies on local photosensitizers. Photosensitizers are activated by a source of light and proceed to generate reactive oxygen species (ROS) that are damaging to cell structures and therefore kill them. The nanoparticle that is commonly used is made of hafnium of lanthanide-doped core and is injected into the patient.[9] Once injected, external X-rays irradiate them while they're at the tumor site, and their cores emit visible light photons. When the photons are emitted, they further activate a local photosensitizer or one that is bound to the nanoparticle itself, and ROS is produced for cancer cell destruction. There are many benefits to this method: PDT can be locally delivered to tumors in deep tissue, it serves as an alternate option for cancers that are radiotherapy resistant, and it also reduces the toxicity such as light sensitivity that comes with conventional PDT.[9]

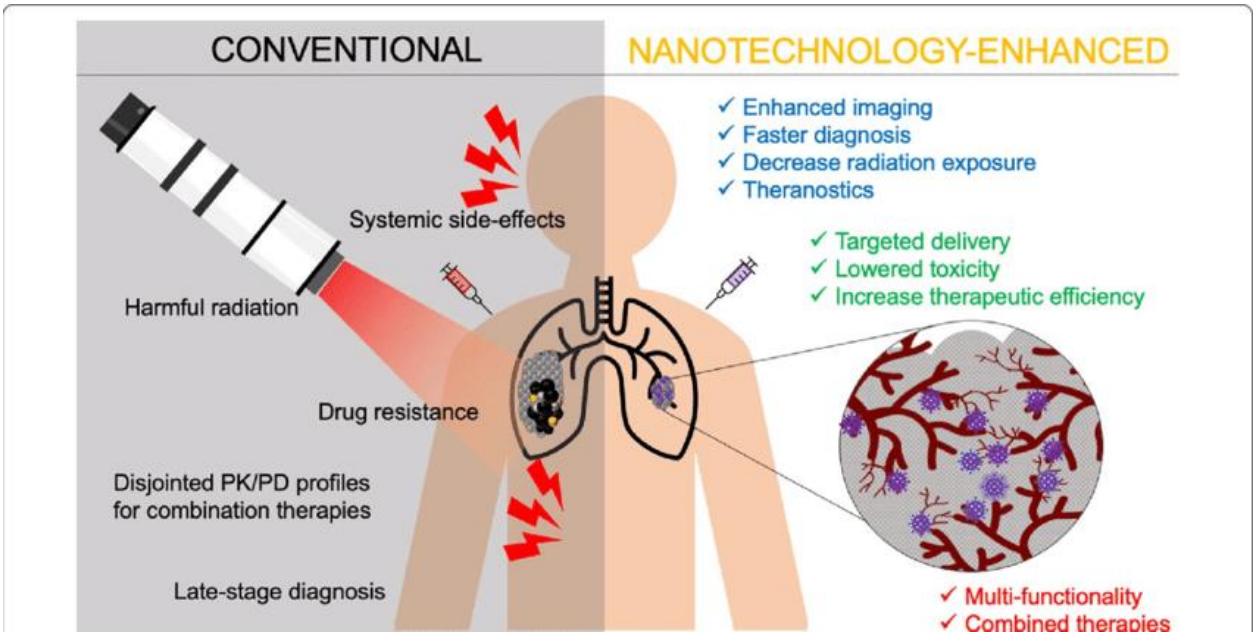

Figure 4. Advantages of nanotechnology in radiotherapy (Adapted from Kwon 2021)

4. History of Nanotechnology in Cancer Theranostics

Nanotechnology, especially nanomedicine, is still a relatively new area of study with vast potential.With the small size that allows them to stay in circulating blood without being filtered out and their hollow insides that allow for carrying various drugs, nanoparticles operate on the basis of the Enhanced Permeability and Retention Effect as described in 1986 by Yasuhiro Matsumura and Hiroshi Maeda.

Reflecting on the history of nanotechnology, the development of methods in which nanoparticles are employed in cancer treatment can be divided into three distinct generations. The nature of these, as well as examples that are currently available or are in clinical trials, will be discussed below.

4.1. First Generation

The first generation of nanotechnology being used for cancer is generally characterized by liposomes. As described earlier, liposomes are constructed of curved bilayers and cholesterol. The nature of liposomes is fairly simple. They are biodegradable, non-toxic, biocompatible, and have non-immunogenic components, making them very attractive for nanotherapy and medicine.

In the early 1990s, the cytotoxic cancer drug doxorubicin was formulated and launched using liposomal nanotechnology to enhance its effects. Named Doxil, it was the first FDA-approved nano-drug. In essence, it is a form of chemotherapy that has a layer of protective coating around it so the body's immune system will not target it, allowing it to remain in the body longer. Due to this, Doxil has more time to reach the cancerous tissue and can then slowly release the medicine that inhibits DNA synthesis in malignant cells.[10] The performance of Doxil in humans was significantly better than free doxorubicin without the liposomal layer.[10]

However, there are still some disadvantages of using liposomes as drug-delivering nanoparticles. Not only are they rather expensive to manufacture, there is often leakage of the encapsulated drugs, and it has a shorter half-life than when compared to other nanoparticles. In addition, the phospholipids that construct the liposomes sometimes undergo hydrolysis-like reactions that break them apart.[11]

4.2. Second Generation

The second generation of nanotechnologies being used in cancer treatment is essentially the phase of discovery and research that dives deeper into a variety of nanoparticles, and their abilities to carry many different molecules in addition to drugs, such as genetic material. Some of the nanoparticles

that were focused on include albumin-bound paclitaxel (Abraxane) and paclitaxel polymer micelles (GenexOL-PM).

Abraxane is a drug that essentially reformulated paclitaxel, a chemotherapy that is used to treat lung, ovarian, and breat cancer. Paclitaxel prevents cell division by interfering in mitosis. It stops the cell cycle during the G0/G1 and G2/M phases, and then induces apoptosis.[12] Furthermore, it can kill cancer cells by stimulating tumor necrosis factor receptors on macrophages, thereby promoting the release of cytokines that target the tumor.

In Abraxane, the paclitaxel molecules are attached to a albumin molecules, which is a protein synthesized by the liver. Together, they are administered and have a different pharmacokinetic profile than paclitaxel by itself. In fact, Abraxane had a 53% higher volume of distribution than the paclitaxel injection alone. Similar to other nanoparticle-formulated drugs, it can reduce side effects and stay in human body circulation longer.[12]

Despite the benefits, there are still many issues that these nanoparticles face when carrying drugs. Humans still experience many side effects, such as nausea, vomiting, myelosuppression, leukocyte decline, and many more. This prompted researchers to continue making innovations, eventually leading to the third generation of nanotechnology.

4.3. Third Generation of Nanotechnology

With the rather recent development of microelectronic technology in the 1980s, a rise in nanotechnology has been occurring, leading to the newest area of research in which nanorobots are being created. In hopes of revolutionizing current clinical medicine and therapy, nanorobots are designed for many functions, such as targeting, drug delivery, recognition of cancerous cells, and various other mechanisms to aid in cancer theranostics.[12]

Nanobots are tiny machines that are programmed to carry out certain functions in the human body.Currently, nanobots can be programmed to recognize numerous different types of cancer cells and even possess the ability to attack them with precision and selectivity. This is a great advantage over chemotherapy drugs, which are toxic to healthy cells. In addition to destroying cancer cells, nanobots have also been designed to make repairs to genetic and cellular material. They are able to find damaged tissue in the body and initiate a regenerative process with DNA components to form new tissues.

Recently researchers at Arizona State University have successfully harnessed the potential of nanobots by programming them to shrink tumors by cutting off their blood supply.[12] Each nanorobot was a flat, rectangular sheet of DNA, with a size of approximately 90 nanometers by 60 nanometers with thrombin and a DNA aptamer attached to the surface.[13] Thrombin is a blood-clotting enzyme, and the DNA aptamer specifically targets nucleolin, a protein found on the surface of tumor cells.

5. Future Perspectives

Nanotechnology is used in medicine is still a rather new area of research. Many of the current or more recent developments are still under clinical trial or in their early stages. Nonetheless, this new technology is still regarded as the future of medicine. Aside from the potential of better treating one of the globe's leading causes of death, nanotechnology can be used all throughout the human body to perform various other tasks.

Looking at the future, nanotechnology seems to make many promises. First, it can allow doctors to employ more personalized therapeutic treatments. Nanomedicines are currently being developed to have multi-component systems, such as theranostics, which incorporates aspects of both diagnostics and therapy. As a result, the nano-system would be capable of diagnosis of cancer, delivery of drugs, and then monitoring the effects of those drugs. This also combats the issues of overprescribing medicine or not detecting cancer early enough. In addition, diseases like cancer don't have adequate treatments considering the range of patient backgrounds, ages, and stages of the disease.

If nanobots are effectively used and drug effects can be visualized, they can be dosed in amounts that create a maximum effect for that individual.

Researchers are currently also developing new materials for nanoparticles in addition to innovating the structure and function of existing ones. Emerging nanomaterials include block copolymer micelles, polymers, carbon nanotubes, dendrimers, and carbon nanotubes. They're designed to deliver drugs more efficiently. However, for these nanoparticles, toxicity is a primary concern so developments are still occurring to make them less toxic before use in medical applications.

Lastly, nanorobots also play a big role in the future of nanotechnology in medicine. Because of how new this area of research is, many aspects are still unclear. However, scientists are working toward using nanorobots as artificial blood replacement fluids for cardiovascular disease, speeding up the process of hemostasis in life-threatening situations, and even as a disease-fighting robot.[12] Engineers at the University of California San Diego have developed nanorobots powered by ultrasound that can traverse the human bloodstream and remove bacteria.

6. Conclusion

Nanotechnology is emerging as a new modality for combating one of the most prominent incurable diseases. Cancer, which reduces the quality of life and often causes death, is an area where nanotechnology is being used. In recent years, the engineering of nanoparticles, which have the ability to carry large molecules in a precise manner, has revolutionized to combat tumors. They serve in multiple areas, such as diagnostics, treatment and therapy, and drug delivery. Detection can occur at an earlier stage, and conventional treatments that are toxic to healthy cells can be delivered in a manner that reduces common side effects. Not only that but new methods of treating cancer are also being explored and made possible thanks to nanotechnology. Gene therapy and repair, for example, have developed immensely over the past few years.

The future of medicine, with nanotechnology, holds massive potential. Being able to operate and conduct processes on a nanoscale allows scientists and doctors to target the root of many diseases, not just cancer. Permanent neurological diseases could be reversed, and many incurable illnesses will have new treatment options.

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