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Nanotechnology Role in Cancer Diagnosis and Therapy

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Abstract

Cancer is a prominent cause of death and ill health around the world. There is still a deficiency in the efficacy of various cancer medications, despite the fact that numerous ways have been devised to minimise mortality, alleviate chronic pain, and improve the quality of life for those with cancer. For best cancer treatment, early detection and use of drugs with high specificity to minimise side effects must be taken into consideration. Conventional cancer diagnostic and therapeutic methods have become increasingly hazardous and refractory, leading to the development of new strategies, such as nanotechnology, to enhance diagnosis and reduce disease severity. Cancer detection and therapy have been revolutionised by nanotechnology. Cancerous cells can be detected and the very toxic medications delivered to them in vivo by this device. Some of the materials utilised in cancer detection are nanoshells, carbon nanotubes, quantum dots, supermagnetic nanoparticles, nanowires, nanodiamonds, dandrimers, and freshly created nanosponges. As a result, nanotechnology has been examined for the detection of extracellular biomarkers and cancer cells, as well as for in vivo imaging, because to its great sensitivity. The most recent breakthroughs in nanotechnology for cancer diagnosis and treatment are summarised in this article.

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Introduction

A major cause of death and a significant burden on world health, cancer must be detected and treated sooner in order to decrease its spread and the number of people who die from it. Nanotechnology is one of the most commonly employed strategies in cancer research nowadays. Scientific information from a wide range of areas in science and engineering may now be applied to nanoscale dimensions in a variety of ways [1]. There are numerous challenges to overcome in the detection, treatment, and diagnosis of cancer that nanotechnology can address [2]. Cancer diagnosis and treatment can benefit from a wide range of nanotechnology applications, including detection, diagnosis, drug delivery and gene therapy, drug carriage, biomarker mapping and targeted therapy [3]. Cancerous tissue targeting can be achieved with minimal side effects because of nanotechnology treatments such as the creation of nanoscale drug delivery systems [4, 5]. As a result of their both active and passive targeting capabilities, nanomaterials have been used in the treatment of cancer for many years. Liposomes, polymers, molecules and antibodies have all been used in cancer medication design, with the result that combining these nanomaterials can create a balance between improving efficacy and minimising toxicities [6]. Due to potential toxicity, more research is needed before nanomaterials may be widely used in the clinic for cancer treatment [7].

Nanotechnology's Cancer Benefits

Nanoscale devices are between one hundred and ten thousand times smaller than human cells. Biomolecules like enzymes and receptors are comparable in size to these molecules. It's estimated that haemoglobin, the oxygen-carrying molecule in red blood cells, is 5 nanometers in diameter. The majority of cells can be easily penetrated by nanoscale devices smaller than 50 nanometers, while those smaller than 20 nanometers can pass through blood vessels and exit the body as they travel through it. These devices are so small that they can easily interact with biomolecules on the cell surface and inside the cell. Because they have have the ability to access so many different parts of the body, they have the ability to detect and treat disease [8]. Nanotechnology can detect cancer-related molecules quickly and sensitively, allowing scientists to detect molecular changes even in a small percentage of cells.Nanotechnology has the potential to create completely novel and highly effective therapeutic agents [9]. Nanoscale materials for cancer treatment are unique in that they can be easily functionalized and tuned; they can deliver and/or act as the therapeutic, diagnostic, or both; and they can be delivered across traditional biological barriers in the body, such as the blood-brain barrier or dense stromal tissue of the pancreas that highly receptive to the delivery of drugs and other therapeutics [10].

Detection and Prevention of Cancer Using Nanotechnology Tools

Magnetic nanoparticles (MNPs), for example, gold nanoparticles (AuNPs), quantum dots (QDs), nanowires, silicon nanopillars, carbon nanotubes, dendrimers, graphene oxide, and polymers, can be used to detect circulating tumour cells (CTCs) in blood [11]. Using these nanomaterials, it has been shown that CTC capture devices can be improved in terms of sensitivity and specificity, which could lead to improved cancer diagnosis and prognosis.

Near Infrared (NIR) Quantum Dots

Her-2, actin, micro fibril proteins, and nuclear antigens can be measured using quantum dots, which are the nanoscale crystals of a semiconductor material such as cadmium selenide. Colorectal cancer, liver cancer, pancreatic cancer, and lymphoma can be better visualised using near-infrared fluorescence from quantum dots [12-14]. Silver-rich Ag2Te quantum dots (QDs) with a sulphur source have been developed and shown to improve spatial resolution images in the far infrared range [15].

Colloidal Gold Nanoparticles

AuNPs are used as optical probes for the detection of oral cancer at an early stage. Conjugated to antibodies or peptides, they can be used to detect specific cellular biomarkers (EGFR) with high sensitivity and affinity. In order to obtain molecular-specific information, gold nanoparticles can be used to generate useful optical signals. In a study by Rand et al., the gold nanocomposite group's clusters of liver cancer cells were found to be significantly stronger than those in the liver cancer cells alone, using X-ray imaging. By detecting tumours as small as a few micrometres in diameter, these findings have important implications for early diagnosis [16].

Nanoshells

Nanoshells are another widely used nanotechnology application. Small metal shells (typically gold) cover a silicon core with a dielectric layer of 10–300 nanometers in thickness, known as a nanoshell [17, 18]. Through UV-infrared emission and absorption arrays these nanoshells convert plasma-mediated electrical energy into light energy. Despite their large size, the lack of heavy metal toxicity in nanoshell imaging makes them desirable [19].

Polymer Therapeutics such as dendrimers, fullerenes

Dendritic polymeric nano devices can be used to detect, identify, and deliver anti-cancer therapeutics to cancer cells and contrast agents to tumour cells (i.e. Cis-platine, Methotrexate, and Taxol). As a result of their uniform uptake and long-term cell survival, the polymers do not appear to be affected by the body's multidrug resistance processes. Polymers of this size cannot cross the blood-brain barrier because they are too small to be filtered by the kidneys. There is no immune reactivity, since host cells cannot bind any foreign substances. Early detection of oral cancer may be possible thanks to a new sensor technique called Nano-Bio-Chip. More research is required to determine the efficacy of these drugs.

Nanotechnology's Applications in Cancer Treatment

Current cancer treatments face numerous difficulties, such as non-specific distribution of antitumor agents, insufficient drug concentrations reaching tumours, and limited monitoring of therapeutic responses. Complications such as multidrug resistance can arise when drugs are not delivered to their intended location [20]. Several of the current challenges in cancer therapy can be addressed with current Nanotechnology. It is possible for nanoparticles to interact with biological systems at the molecular level because they have a range of sizes from 5 nm to 200 nm. Nanoparticles can self-assemble and maintain stability and specificity, which are critical for drug encapsulation and biocompatibility, due to the composition of their materials. Developing nanosystems based on an understanding of their interactions with the biological environment, target cell population, target cell surface receptors, changes in cell receptors that occur with progression of disease, mechanism and site of drug action, drug retention, multiple drug administration, molecular mechanism and patho biology of the disease under consideration would be an effective approach in achieving efficient drug delivery [21]. Oncologists have long relied on nano-carriers like liposomes and micelles to deliver chemotherapy drugs to tumours.

Liposomes

Nanoparticles based on lipids, such as liposomes this type of colloidal structure is self-assembled into spherical, self-closing liposomes, which are made up of two layers of bilayers of lipids surrounded by an area of water. In terms of nanoparticle drug delivery, liposomes have received the most attention. Drugs associated with liposomal formulation have shown improved pharmacokinetics and pharmacodynamics [22, 23]. There are two types of liposomes: monolayer and multilayer. Hydrophilic drugs stay in the monolayer liposome, while hydrophobic ones form before the multilayer liposome, due to phospholipids' amphiphilicity [24, 25]. Exchanging acidic buffers for neutral buffers may allow some drugs to enter liposomes.

Carbon Nanotubes

It is possible to determine whether a person has a high or low risk of developing cancer by scanning their DNA with carbon nanotubes, which look for single nucleotide polymorphism (SNP). In large strands of non-amplified DNA, this method can identify multiple nucleotide polymorphic sites at relatively high throughput and low cost, and it can replace PCR. As highly competent carriers for the transport of different drug molecules into living cells, the natural forms of carbon nanotubes promote noninvasive penetration of biofilms [26]. Carbon nanotubes can be used to make cancer-fighting drugs like paclitaxel, which can be administered both in vitro and in vivo [27].

Polymeric Nano Particles

Hydrophilic polymers can be used to coat nanoparticles. Coating is an effective means of preventing macrophages from engulfing nanoparticles. Biocompatibility can be improved by increasing hydrophobicity of nanoparticles, making them more water-soluble and less susceptible to enzymatic degradation [28, 29]. A decade ago, the advent of biodegradable polymers increased exponentially the use of polymer-based drug delivery systems for cancer treatment. Drugs can be dissolved, encapsulated, or covalently attached to the polymer matrix in these polymers. Different structures, such as micelles and dendrimers, can be produced as a result of the reaction.

Conclusion and Future Directions

Molecular, biological, and genetic diagnostic techniques have recently begun to investigate cancer-associated biomarkers and their implications for the development and progression of cancer and reveal that cancer is controlled by a complex multi-factor mechanism rather than a single factor. Over the years, nanotechnology has shown great promise in the treatment of cancer. Nanomaterials have improved cancer diagnosis and treatment through their improved pharmacokinetic and pharmacodynamic properties. To detect multiple cancer-related biomarkers on a single tumour specimen quickly and accurately, nanotechnology advances, such as the use of conjugated quantum dots, may one day make it possible to detect multiple markers on a single tumour specimen simultaneously. Along with the advancement of nanoscale drug delivery systems, researchers have also looked into in vivo imaging of cancer using various types of nanoparticles for the detection of early cancer and the profiling of molecular biomarkers. Multifunctional nanoparticles could play a significant role in the development of individualised cancer treatment. Therapeutic agents and targeting moieties for multifunctional nanoparticles should be selected based on accurate biological information about the tumour and imaging materials attached to nanoparticle surfaces in an ideal world. It's possible that nanoparticles will be able to detect cancer cells, pinpoint and visualise their location in the body, kill the cancer cells with minimal side effects by sparing healthy cells, and monitor treatment outcomes in real time.

As nanotechnology advances at an accelerating pace, researchers in physics, chemistry, engineering, biology, and medicine will work to develop new and effective nanosystems for cancer diagnosis and treatment. As nanotechnology develops at a rapid pace, new and sophisticated applications for detecting and treating cancer cells, delivering drugs to specific tissues, monitoring intracellular changes, and reporting treatment outcomes are expected. A bright future awaits those who continue to work tirelessly to make the tiniest of contributions to the advancement of science and medicine.

Conflict of Interest

No potential conflict of interest

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