Application of nanotechnology in Cancer Treatment- An Overview

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ABSTRACT:

Nowadays, everyone lives in a large or small city. With the advancement of luxuries in life, there is also an increase in lifestyle-related disorders. Cancer is one of the leading causes of mortality and is the result of unhealthy practices in daily life. Although extensive techniques are in use for diagnosis as well as treatment with the intention of reducing the death rate, chronic pain, and improving the quality of life, a combination of cancer therapy and nanotechnology proves to be an effective solution for this dire situation. Nanotechnology, along with diverse conventional therapeutic techniques, imparts eminent outcomes. Alteration with diverse varieties of nanoparticles like gold nanoparticles, quantum dots, nanobiochips, etc. in the drug delivery process, chemotherapy, and photo imaging techniques is either completed or going through clinical trials, and their preliminary results are quite promising. Cancer is one of the deadliest diseases worldwide in present times, with its incidence on a tremendous rise. It is caused by uncontrolled cell growth. Cancer therapies have advanced substantially, but there is a need for improvement in specificity and a fear of systemic toxicity. Early detection is critical to improving patients' prognosis and quality of life, and recent advancements in technology, especially in dealing with biomaterials, have aided in that surge. Nanotechnology possesses the key to solving many of the downsides of traditional pharmaceutical formulations.

Indeed, significant progress has been made in using customized nanomaterials for cancer diagnosis and treatment with high specificity, sensitivity, and efficacy. Nanotechnology is the integration of nanoscience into medicine through the use of nanoparticles. The advent of nanoscience in cancer diagnosis and treatment will help clinicians better assess and manage patients and improve the healthcare system and services. This review article gives an account of the clinical applications of nanoscience in the modern management of cancer, the different modalities of nanotechnology used, and the limitations and possible side effects of this new tool.

Keywords:
Nanotechnology, Treatment, Nanocarriers

INTRODUCTION

Cancer is one of the most serious fatal diseases in today's world and kills millions of people every year. It is one of the major health concerns of the 21st century, which does not have any boundaries and can affect any organ of people from any place[1]. The need for advanced technology to play an important role in cancer treatment is clearly evident in the statistics indicating that cancer incidence, prevalence, and mortality remain at exceedingly high levels. Cancer is one of the leading causes of deaths worldwide with an estimated 7.6 million individuals lost each year and accounting for 13% of all deaths. Cancer related mortality is expected to rise to 13.1 million by 2030. Cancer is not a single disease but a collection of diseases with each organ or system developing a definite set of diseases. Many cases of cancer could be avoided, with some estimates indicating that about 30% of cancer deaths are associated with smoking or other lifestyle factors or dietary practices that could potentially be avoided by changes in human behavior[2]. "Nanomedicine" is the science and technology used to diagnose, treat, and prevent diseases. It is also used for pain management and to safeguard and improve people's health through Nano sized molecules, biotechnology, genetic engineering, complex mechanical systems, and nanorobots. Nanoscale devices are a thousand times more microscopic than human cells, being comparable to biomolecules like enzymes and their respective receptors in size. Because of this property, Nano sized devices can interact with receptors on the cell walls as well as within the cells. By obtaining entry into different parts of the body, they can help pick up the disease as well as allow delivery of treatment to areas of the body that one can never imagine being accessible. Human physiology comprises multiple biological Nano machines. Biological processes that can lead to cancer also occur at the nanoscale. Nanotechnology offers scientists the opportunity to experiment on macromolecules in real time and at the earliest stage of disease, even when very few cells are affected. This helps in the early and accurate detection of cancer[3].

ADVANTAGES OF NANOTECHNOLOGY

Cancer treatment based on nanomaterials shows advantages over using free drugs, particularly for targeted delivery. Compared to free drugs, targeted delivery exhibits reduced toxicity, decreased degradation, increased half-life, and enhanced capacity[4]

Table: Advantage and disadvantages of nanocarriers in treatment of cancer

Types of carriers	Advantages	Disadvantages
Liposomes	Biocompatible Longer duration of circulation Amphiphilic	May trigger immune response
Carbon nanoparticles	Multiple functions Chemical modification Water soluble and biocompatible Efficient loading	Toxicity
Polymeric micelles	Efficient carrier system for hydrophilic drugs Biodegradable-self assembling and biocompatible Potential targeting Functional modification	Occasional cytotoxicity Need of surface modifications
Dendrimers	Uniformity in size, shape and branch length Tuned pharmacokinetics and biodistribution Increased surface area, increased loading Targeting is achieved	Complex synthetic route
Metallic nanoparticles Gold nanoshells	Uniformity in size, shape and branch length Tuned pharmacokinetics and biodistribution Increased surface area, increased loading Targeting is achieved	Toxicity

Nanotechnology Tools Used in Cancer Treatment

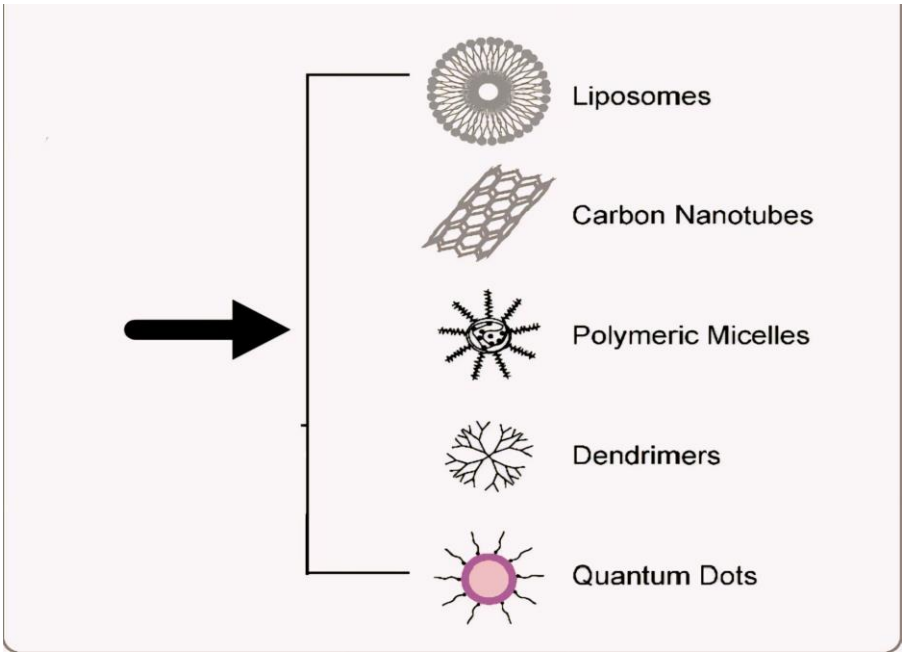

Fig: Application of nanoparticle in Cancer treatment

Polymeric Nanoparticles

Polymeric nanoparticles (PNPs) are well-defined as "colloidal macromolecules" with a specific structural architecture formed by different monomers. The drug is either entrapped or attached to the NPsexterior, creating a nanosphere or a nanocapsule to achieve regulated drug release in the target. Initially, PNPs were made up of non-biodegradable polymers such as polyacrylamide, polymethylmethacrylate (PMMA), and polystyrene. However, the accumulation of these led to toxicity due to the difficulty of eliminating them from the system. Bio-degradable polymers such as polylactic acid, poly(amino acids), chitosan, alginate, and albumin are now being used and are known to reduce toxicity and enhance drug release and biocompatibility. Proven research has shown that coating PNPs with polysorbates and using polysorbates has surfactant effects. Exterior coating enhances NPs' interactions with the endothelial cell membrane of the blood-brain barrier (BBB)[5].

Liposomal nanoparticles

Liposomes are self-assembling spherical particles with a membrane composed of phospholipid bilayers. The size of liposomes can range from 25 nm to 10 μm, depending on the preparation method. They have been studied as candidates for drug delivery for the last 50 years since being first discovered by Bangham. Drug delivery systems based on unmodified liposomes are limited by their short blood circulation time. This is mainly due to the fast clearance of liposomes by macrophages of the reticuloendothelial system (RES). The second generation of polymer-coated liposomes can dramatically increase blood circulation times from several minutes up to 3 days[6].

Dendrimers

The dendrimers are nanocarriers that have a spherical polymer core with regularly spaced branches. As the dendritic macromolecule diameter increases, the tendency to tilt towards a spherical structure increases. There are usually two ways to synthesize dendrimers: a divergent method in which the dendrimers can grow outward from the central nucleus, and a convergence method in which the dendrimers grow inward from the edges and end up in the central nucleus. Various momolecules, including polyacrylamide, polpolyglycerol succinicid, polylysine, polyglycerin, poly2, 2bis (hydroxymethyl) propionic acid, and melamelamine, are commonly used to form dendrimers. These dendritic macromolecules exhibit different chemical structures and properties, such as alkalinity, hydrogen bond capacitance, and charge, which can be regulated by growing dendritic macromolecules or changing the groups on the surface of dendritic macromolecules. In general, ditic drug conjugates are formed by the covalent binding of antitumor drugs to dendritic peripheral groups. Thus, several drug molecules can attach to each dendritic momolecule, and the release of these therapeutic molecules is controlled in part by the nature of the attachment. The physicochemical and biological properties of the polymer, including the size, charge, multi-ligand groups, lipid bilayer interactions, cytotoxicity, internalization, plasma retention time, biological distribution, and filtration of dendritic macromolecules, have made dendrimers potential nanoscale carriers. Several studies have further shown that cancer cells with a high expression of folate receptors could form foils from dendritic molecules bound to folate.

An added advantage of dendrimers is their ability to bind to DNA, as seen with the DNA-polyamide clustering DNA-poly(amidoamine) (DNAPAMAM), making them highly effective at killing cancer cells that express the folate receptor[7]. Depending on their unique structure, dendrimers exert specific functions, such as adjustable branches, outstanding solubility, and excellent bioavailability[14].

Quantum dots

Quantum dots Quantum dots (QDs) are nano-sized crystals capable of transporting electrons. Under UV light, QD can emit light of different colors with very high energy. QDs have an inactive site on their surface where specific antibodies can easily conjugate. Quantum dots are already used in drug delivery and treatment for lung cancer and can help clear up bacterial infections. In addition, conjugated QDs have been shown to inhibit P-glycoprotein gene expression in lung cancer cells by inducing miR-185 and miR-34b. miR-185 and miR-34b are potential targets for the treatment of lung cancer. Besides many benefits, QD also contains heavy metals such as cadmium, which are carcinogenic[8].

Metal nanoparticles

In recent years, metal oxide nanoparticles have grabbed significant attention in biomedical fields, in particular developing napovaccine scaffolds. Due to their tendency to penetrate a wide range of cells, these nanoparticles have also played an interesting role in cancer therapy. Metal oxide nanoparticles have unique physical (e.g., fluorescent enhancement and plasmonic resonance) and chemical (e.g., catalytic activity) properties, making them appropriate agents as drug carriers. Metal nanoparticles have a larger surface area, a higher surface area-to-volume ratio, and characteristic physicochemical properties (such as high toxicity against cancer cells due to structural properties and inducing reactive oxygen species, as well as photothermal and hyperthermia effects), which make them potential platforms for cancer therapy. Metallic nanoshells, which usually contain metals such as gold (Au) or titanium (Ti), have been employed to control the gradual release of chemotherapeutic agents in tumor tissues[9].

LIPOSOMES

Liposomes are bilayer spherical vesicles composed of phospholipids and cholesterol that, in water, create at least one lipid bilayer surrounding an aqueous core, which may encapsulate both hydrophilic drugs and hydrophobic compounds immersed in the lamellae by Van der Waals forces[10]. Liposomes seem to be an almost ideal drug-carrier system, since their morphology is similar to that of cellular membranes and because of their ability to incorporate various substances. They are valued for their biological and technological advantages as optimal delivery systems for biologically active substances, both in vitro and in vivo, and are considered to be the most successful drug-carrier system known to date. During the last two decades, notable progress has been made, and several biomedical applications of liposomes are either in clinical trials or are about to be put on the market, while others have already been approved for public use[11].

CARBON NANOTUBES

Carbon nanotubes in nanomedicine: in an exceedingly victorious therapy, therapeutic agents have to pass a series of biological barriers together with internal organ and urinary organ clearance, enzy molysis, and chemical reactions, as well as cellular uptake and lysosomal degradation. In the case of antineoplastic medicine, the potency is often additionally low due to its poor solubility, low stability, and high toxicity for traditional tissues and cells. In spite of these difficulties, nanomaterial carriers are ready to improve the biodistribution and prolonged blood circulation of medical specialty drugs that considerably increase the pharmaceutical effectiveness and reduce the usage dose. They're notably promising candidates for early diagnosis of tumor cells. Many categories of nanomaterials, together with nerve fiber and supramolecular polymers, CNT- and graphene-based materials, nanoparticles, and gold nanostructures, have shown tremendous ability to acknowledge and destroy cancer cells in vivo[12].

POLYMERIC MICELLES

Polymeric micelles are recognized as ‘‘well-formed auto-assemblies” that are developed in a liquid matrix, which is comprised of amphiphilic macromolecules. Such amphiphilic macromolecules are generally made up of di- or tri-block copolymers having both solvophilic and solvophobic blocks. Generally, the size of polymeric micelles ranges from 10 to 100 nm. In the polymeric micelles, the hydrophobic core gets covered by the hydrophilic chain to avoid direct contact. Polymeric micelles exhibit outstanding characteristics, such as enhanced tumor targeting, which makes them an ideal delivery system with increased translational efficiency. Presently, a few polymeric micelles are under clinical assessment; however, most of them are still under pre-clinical evaluation[13].

Conclusion

This review paper provides a study of various cancer treatments using different types of nanoparticles. The nanoparticles mainly play an important role in the medicinal field. Nanotechnology allows targeted drug delivery to affected organs with minimal systemic toxicities due to their specificities. However, as with other therapeutic options, nanotechnology is not completely devoid of toxicities and comes with a few challenges with its use, including systemic and certain organ toxicities, hence causing setbacks in its clinical applications. Given the limitations of nanotechnology, more advancements must be made to improve drug delivery, maximize their efficacy, and keep the disadvantages to a minimum. By improving the interactions between the physicochemical properties of the nanomaterials employed, safer and more efficacious derivatives for diagnosis and treatment can be made available for cancer management.

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