Review Article

A systematic review on nanoparticles: A ubiquitous approach for anti-tumour drug delivery and cancer management

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Abstract

The goal of this study was to examine current research on nanotechnology-based medication delivery. Pharmaceutical nanocarriers currently in use, such as microspheres, dendrimers, nanoparticles, micelles, polymeric nanoparticles, and others, have a wide range of useful properties, including longevity in the blood, which allows for accumulation in pathological areas with reduced vasculature; specific targeting to specific disease sites; improved intracellular penetration of nonmaterial with contrast properties, which allows for direct visualisation. Some pharmacological carriers have already entered clinical trials, while others are still in the early stages of research. Furthermore, the development of multifunctional nanocarriers with desirable qualities might greatly improve the efficacy of a variety of therapeutic and diagnostic techniques. These cutting-edge materials function at the nanoscale level and provide new and powerful imaging, diagnostic, and treatment techniques. Data from research papers published in journals, data from different publications, and other internet accessible material were used to compile various reports. A list of several medication delivery methods through NP is offered, along with its benefits and drawbacks. Nanotechnology is a breakthrough invention that has a broad range of applications in disciplines such as medicine, communications, diagnostics, and electronics.

Keywords: Nanotechnology, multifunctional nanocarriers, cancer, drug delivery, imaging agents

Introduction

Cancer faces a number of physiological challenges, including vascular endothelial pores, uneven blood supply, and heterogeneous architecture (Jain, 1989; Jain, 2001). It is critical to overcome these barriers for a drug to be effective. For medication delivery, cancer represents a massive biological problem (Baker and Choi, 2005). The mode of distribution has a big impact on cancer therapy. Patients with cancer employed a variety of anticancer medications in the past, but these treatments were proven to be ineffective and to have significant adverse effects. Nanoparticles have attracted scientists' interest owing to their multifunctional properties. The use of tailored drug delivery nanoparticles to treat cancer is the most recent medical breakthrough. Nanomaterials are at the forefront of nanotechnology's constantly evolving field. Nanoparticles'

applicability in cancer medication delivery are limitless, with new ones being developed all the time. This evaluation is based on the positive implications of these platforms for cancer diagnostics and treatments innovation. Nanoparticles are appealing for cancer therapy for a variety of reasons: they have unique pharmacokinetics, including minimal renal filtration; they have high surface-to-volume ratios, allowing modification with a variety of surface functional groups that home, internalise or stabilise; and they can be made from a variety of materials to enclose or solubilize therapeutic agents for drug delivery or to provide exclusive optical, magnetic, and elastomeric properties. The structure of a nanoparticle core, coating, and surface functional groups lends itself to modular design, allowing features and functional moieties to be swapped out or mixed. Although much of the functionality of nanoparticles has been established, including some clinically approved drug formulations and imaging agents (Harisinghani and Weissleder, 2004; Gordon et al., 2001), the merging of these into nanocarriers (nanoparticles) capable of targeting, imaging, and delivering therapeutics is an exciting area of research with great potential for cancer treatment in the

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future. Figure 1 shows a multifunctional nanoparticle with many properties, including the ability to target tumours, avoid uptake by the reticuloendothelial system (RES), protect therapeutics that can be released on demand, act as tumour responsiveness sensors, and provide image contrast to visualise disease sites and monitor disease progression (Ruoslahti, 2002). Both bio-inspired and synthetic nanoparticle functions that have been exploited in cancer treatment are discussed in this study, as well as present and future attempts to combine them into multifunctional devices (Harisinghani and Weissleder, 2004; Gordon et al., 2001).

Nanotechnology Advancement

The word "nanoscale" was coined by physicist R. P. Feynman. "There's plenty of space down the bottom," he said in a 1959 speech. But there isn't much space; putting every particle in its proper position, as some nanotechnologists envision, would need the use of magic fingers." He was one of the first to argue that the key to future technology and growth was scaling down to the nanoscale and beginning from the bottom (Feynman, 1991; Peterson, 2004).

Future of Nanoparticles in Cancer Treatment

The Greek term 'Nano' originally meant midget (Stylios et al., 2005). Nanotechnology is the control of matter at the nanometer-length scale, i.e. at the level of atoms, molecules, and

supramolecular structures, to fabricate materials, devices, and systems. These strategies have been used to enhance medication distribution and overcome some of the challenges that come with it in cancer therapy. Drug delivery in cancer has been aided by a variety of nanobiotechnologies. Because of their multifunctional behaviour, nanoparticles have piqued everyone's interest, and they have given us hope for a cure for this condition. We finally want more exact methods to eradicate cancer from our society, even if we are using better medicine delivery pathways into the body. The development of cancer therapy using nanoparticle delivery of anticancer drugs is the subject of this review. It has also considered the creation of several kinds of nanoparticles for the delivery of cancer drugs (Stylios et al., 2005).

Cancer's prevalence in our society

Cancer has become one of the most horrible illnesses in the world, with more than 10 million new cases per year (Stewart and Kleihues, 2003). Malignant tumours were responsible for around 12% of the 56 million deaths globally from all causes in 2000, according to the World Health Organization (WHO). In 2000, almost 22 million individuals throughout the globe were treated for cancer, representing a 19% rise in incidence (cases) and an 18% increase in death since 1990. Global cancer rates are expected to rise by 50% by 2020, according to

Figure 1. Multifunctional nanoparticle in schematic form. In reaction to an environmental or biological trigger, a hypothetical nanoparticle targets the tumour, detects and reports molecular markers, and administers a treatment (Lobo et al., 2021).

the International Agency for Research on Cancer (IARC), a division of the World Health Organization.

Structure and functional characteristics of nanoparticles

A nanometer is one billionth of a meter (10^{-9} m); a sheet of paper, for example, is 100,000 nanometers thick. We can see cells and molecules that we couldn't see before with standard imaging because to these nanoparticles. The capacity to detect what occurs within a cell, to witness therapeutic action, and to monitor when a cancer cell is lethally damaged are all critical for effective disease diagnosis and treatment. We have "Nano scale devices" for cancer treatment delivery. Nanoscale devices (Yih and Wei, 2005) are 102 to 104 times smaller than human cells, yet they have the same size as big macromolecules like enzymes and receptors. Nanoscale devices with a diameter of less than 50 nanometers can easily infiltrate most cells, while those with a diameter of less than 20 nanometers can even travel out of blood arteries as they circulate through the body. Nanodevices are ideal devices for delivering huge dosages of chemotherapeutic drugs or therapeutic genes into malignant cells while protecting healthy cells as tailored, targeted drug delivery vehicles. According to the National Cancer Institute, the nanoparticulate technique has been shown to be an effective tool for cancer therapy, allowing for effective and targeted drug delivery by overcoming many biological, biophysical, and biomedical barriers that the body encounters during a normal invasion, such as drug or contrast agent administration. Nanoscale constructs can be used as adaptable, targeted drug delivery vehicles that can deliver large doses of chemotherapeutic agents or therapeutic genes to malignant cells while sparing healthy cells, significantly reducing or eliminating the often undesirable side effects associated with many current cancer therapies. Certain nanotechnological approaches have been used to improve chemotherapeutic chemical delivery to cancer cells, with the objective of lowering adverse effects on healthy tissues while maintaining antitumor efficacy. Dendrimers (spherical, branching polymers), silica-coated micelles, ceramic nanoparticles, and cross linked liposomes are examples of nanoscale delivery systems that may be selectively targeted to cancer cells. This improves therapeutic selectivity for cancer cells, which may and will reduce toxicity to normal tissue (Brigger et al., 2002).

Biomedical Nanoparticles (Comes in a variety of shapes and sizes)

Despite the fact that the number of distinct kinds of nanoparticles is continually rising, the majority may be divided into two categories: Nanoparticles made of inorganic materials Nanoparticles made of organic materials. Liposomes, dendrimers, carbon nanotubes, emulsions, and other polymers are only a few of the many types of organic particles. These organic nanoparticles have previously generated promising results (Yezhelyev et al., 2006). Liposomes

have been used as drug delivery vehicles in a variety of human malignancies, including breast cancer. Dendrimers, which are employed as contrast agents in MRI, have helped to see a variety of disease processes. Organic nanovectors are excellent vehicles for drug administration and selective imaging of a variety of human malignancies when paired with pharmacological drugs and targeting compounds. The fundamental structure of most inorganic nanoparticles is identical. This consists of a central core that expresses the particle's fluorescent, optical, magnetic, and electronic capabilities, as well as a surface-protecting organic layer (Yezhelyev et al., 2006). This outer layer protects the core from deterioration in a medically hostile environment and may form electrostatic, covalent, or both electrostatic and covalent interactions with positively charged substances and biomolecules with basic functional groups like amines and thiols. Peptides, proteins, and oligonucleotides have all been successfully connected to fluorescent nanoparticles by a variety of researchers (Yezhelyev et al., 2006).

Nanoparticles with multiple functions

Nanoparticles have an advantage over bigger microparticles in that they may be delivered intravenously (i.v.). The smallest capillaries in the body have a diameter of 5–6 mm. Particles circulating in the circulation must be less than 5 mm in diameter to avoid creating clots, aggregates, in order to prevent the particles from becoming an embolism. Nanoparticles may transport hydrophilic and hydrophobic medicines, vaccinations, biological macromolecules, and proteins, among other things. They may be manufactured for long-term systemic circulation and targeted distribution to the lymphatic system, spleen, artery walls, lungs, and liver. Size, encapsulation effectiveness, zeta potential (surface charge), and release characteristics are four of the most essential features of nanoparticles.

Nanoparticles of lipids and polymers

Positively charged lipid-based nanoparticles are well-known for provoking robust immune responses when administered into the body. When these nanoparticles are tried to be employed as a medication delivery agent, this may be troublesome. Cavalcanti et al. (2005) discovered that lipid-based cationic nanoparticles (Cavalcanti et al., 2005) had improved binding and absorption at neo-angiogenic endothelial cells, which a tumour needs for nourishment and growth. The tumour endothelium and, as a result, the tumour itself may be eliminated by loading suitable cytotoxic substances onto the cationic carrier. The control of drug loading and drug release from the carrier matrix is critical for

the development of innovative anti-tumor medicines. Drug/lipid membrane structural studies may provide useful information on drug arrangement in lipid matrices. The evaluation of several matrices for a particular medication might be advantageous for quick and cost-effective drug/lipid combination optimization in pharmaceutical development. Targeted medication delivery is carried out not only to the tumour itself, but also to the neo-angiogenic blood vessels that the tumour induces to develop for its nourishment in a novel treatment method. This method is based on the discovery that cationic liposomes had better binding and uptake in tumour endothelial cells. Munich Biotech AG has acquired a number of cationic, lipid-based nanoparticulate medicines for tumour therapy in this context. A cytotoxic drug, such as Paclitaxel, is placed into the lipid matrix of the cationic carrier as the therapeutic agent. Understanding the physico-chemical constraints of drug loading and drug release from the lipid matrix is required for effective development of such pharmacological formulations. Structural investigation of drug/lipid membranes, such as using X-ray scattering methods, may provide useful information about a drug's structure in the membrane and can aid in the optimization of a lipid matrix's solubilizing potency of a certain drug. The arrangement of Paclitaxel in cationic and zwitter-ionic lipid membrane matrices was the focus of this study. When administered systemically, polymeric nanoparticles are stable and non-

phototoxic. The photo-sensitizer is released from the nanoparticle during cellular internalisation and becomes extremely phototoxic. Various cancer cell lines are killed by visible light irradiation in a cell-specific manner (Habeck and Writer, 2001).

Nanoparticles of gold with magnetic nanoparticles

Gold nanoparticles are the most widely utilised nanoparticles for diagnostics and medication administration in practise. Colloidal gold's unique chemical characteristics make it a good choice for delivering medications or gene-specific cells to specified cells. Nanobullets made of gold and silica composite nanoparticles have been tested as cancer nanobullets (Drummond et al., 1999; Jain, 2005). Magnetic nanoparticles are also being used to release anti-cancer drugs by researchers. Magnetic nanoparticles (Hilger et al., 2005) were initially proposed in cell biology in the 1990s, and their application has considerably facilitated the separation of cells or molecules such as proteins, peptides, and DNA.

By using magnetic resonance tomography to diagnose malignancies in the liver and spleen, nanoparticles were first employed as medication. One of the most difficult aspects of cancer therapy is destroying tumour cells without hurting healthy tissue. Although radiotherapy aims to

Figure 2. Systems based on nanoparticles for tumour targeting and medication administration and representation of passive and active targeting approaches. The diagram includes different types of ligands that can be conjugated with NPs for active targeting. EPR, enhanced permeability and retention; NP, nanoparticle; PEG, polyethylene glycol (Jahan et al., 2017).

concentrate irradiation on the tumour, it nonetheless causes harm to healthy tissue. The use of nanoparticles as a carrier for magnetic medication targeting is a promising cancer treatment that avoids the adverse effects of traditional chemotherapy (Alexiou et al., 2006). Hyperthermia plays a crucial function in the administration of cancer drugs. It has been shown that hyperthermia at 40–43°C enhances therapeutic agent absorption in cancer cells and allows for more precise medication administration (Habeck and Writer, 2001). The use of nanoparticles (NPs) for anticancer drug delivery (Sealy, 2006) has several notable advantages, including the ability to target specific locations in the body, the ability to reduce the overall quantity of drug used, and the ability to lower the concentration of the drug at non-target sites, resulting in fewer unpleasant side effects (Sealy, 2006).

Furthermore, several types of nanoparticles have shown some intriguing potential for reversing multidrug resistance (MDR), a critical issue in chemotherapy. The use of nanoparticles as drug delivery vehicles for anticancer medications has the potential to change cancer treatment in the future (Vlerken and Amiji, 2006). Because tumour design causes nanoparticles to gather specifically at the tumour site, their usage as drug delivery vectors causes a higher portion of the drug load to be localised to the tumour site, furthering cancer treatment and reducing damaging nonspecific chemotherapeutic side effects. Furthermore, combining these nanoparticles with imaging contrast agents creates a powerful cancer diagnosis technique (Vlerken and Amiji, 2006).

Nanoparticles made of viruses

Virus-based nanoparticles are now being extensively researched for nanobiotechnology applications (Pattenden et al., 2005; Rae et al., 2005; Singh et al., 2006; Singh et al., 2006). Viruses have long been anticipated as nanoparticle vectors for medicine delivery, vaccinations, and gene therapy (Portney and Ozkan, 2006). Viruses are now being studied as nano-containers for precise targeted applications. To achieve tumor-specific delivery, these methods generally involve chemical or genetic alteration of the viral surface. Engineered virus (nanoparticles) were created as the most recent technology for cancer therapy (Rae et al., 2005). Viruses are well-defined nanoparticles by their own nature, and various research groups are following in nature's footsteps and generating non-infectious, engineered viral nanoparticles for use as multifunctional nanoscale devices (Rae et al., 2005). The plant virus known as (CPMV) cowpea mosaic virus (CPMV and FHV are among the smallest viruses with diverse nanostructures that have been extensively investigated) has emerged as a favourite research subject because it is relatively easy to produce in large quantities and is harmless to humans and other animals. Furthermore, scientists have devised techniques for modifying the virus's coat protein to give it chemical activity, which will aid in increasing the

nanoparticles' targeting and drug delivery capabilities. Another argument for choosing CPMV particles as prospective biological nanodevices is this: M. Manchester, M.G. Finn, and their Scripps Research Institute colleagues have shown that CPMV nanoparticles can pass past the stomach's hostile environment and enter the circulation through the intestines. As a result, CPMV nanoparticles might make it easier to take anticancer medications and tumour imaging agents orally rather than injecting them. The results of this study were published in the journal *Virology*. In most investigations, researchers utilise a system that produces just the proteins that the virus requires to construct its outer shell — these proteins self-assemble to form the virus's shell. The investigators used the fully formed virus, complete with its RNA genetic material, to simulate what would happen to CPMV particles as they passed through the digestive system. Because the RNA was present, the researchers were able to use a PCR-based technique to detect a very small number of particles. In fact, after feeding infected cowpea leaves to mice, the researchers discovered that virus particles were broadly disseminated throughout the animals' bodies. The viral particle had travelled through the stomach, been absorbed into the intestines, and dispersed itself throughout the animal, according to subsequent tests employing analytical methods to identify the virus coat proteins. When the virus was injected directly into the circulation of the test animals, very identical results were obtained, supporting the theory that viral particles might travel through the intestines unharmed. *In vitro* tests also shown that modified CPMV particles are stable in acidic circumstances similar to those seen in the stomach. At the same time, our findings support the idea that tailored, synthetic plant virus particles might be effective in delivering medications and imaging contrast agents to tumours. Earlier work by the Manchester and Finn groups showed that it is possible to connect tumor-targeting molecules to the surface of modified viral nanoparticles and to load specific drug-type molecules into the virus particles' inside. A Yonsei University study team utilises a genetically altered variant of the adenovirus, which normally causes colds. The human gene involved in the generation of relaxin, a hormone linked to pregnancy, was grafted onto the adenovirus. When injected into malignant tumours, the virus replicated quickly and killed the cancer cells. This new adenovirus can only attack cancer cells and does not harm healthy cells (Singh et al., 2006).

Dr. Lobenberg of the University of Alberta has developed a medication delivery system for lung cancer treatment that uses nanoparticles in a dry powder aerosol form. *In vitro*, drug-loaded nanoparticles given as dry powders showed a concentration-dependent increase in cytotoxicity (Singh et al., 2006). This research uses nanoparticles as a medication

delivery vector to help with local lung cancer therapy. The development of inhalable nanoparticles containing bioactive compounds is an unique delivery platform that may one day allow for the targeted treatment of lung illnesses. The medicine is in powder form in the inhaler, which is similar to the device used by asthmatics, according to Loebenberg (Azarmi et al., 2006).

Nanomedicine

One of nanomedicine's main goals is to develop therapeutically effective nanodevices that can operate within the body. Nanomedicine will also have an impact on cancer therapy's key problems, such as localised medication delivery and precise targeting. Quantum dots, nanowires, nanotubes, nanocantilevers, nanopores, nanoshells, and nanoparticles are among the recently advanced nanomedicine and nanodevices that can be used to cure many forms of cancer. Nanospheres (matrix systems in which pharmaceuticals are dispersed throughout the particle) and nanocapsules (Brigger et al., 2002) are two types of nanoparticles (where the drug is enclosed in an aqueous or oily cavity bounded by a single polymeric membrane). Supramolecular assemblages of drug and functional carrier materials are often used in nanomedicines that speed up the absorption and transport of therapeutically active molecules (delivery systems) (Smith et al., 2006). The use of nanomedicines makes it simple to create dosage differentials between the illness site and the rest of the body, improving therapeutic benefit while decreasing non-specific adverse effects. The utilisation of nanometer-sized particles and systems to diagnose and treat illnesses at the molecular level is critical to meeting the federal government's stated goal of eradicating cancer as the second largest cause of death in the United States by 2015 (Mitchell, 2003).

Drug delivery in the treatment of cancer

Treatment of cancer patients with an anticancer drug delivered in interestium (Jain, 1987) will be regulated by the physiological (i.e. pressure) and physiochemical (i.e. composition, structure, and charge) properties of the interestium, as well as by the physiochemical properties of the molecules themselves (such as size, configuration, charge, and hydrophobicity). The release of therapeutic agents into tumour cells in vivo requires the resolution of the following issues: Drug resistance at the tumour level due to physiological barriers (non-cellular mechanisms), Drug resistance at the cell level (cellular mechanisms), and Distribution, biotransformation, and clearance of anticancer drugs in the body. Brigger et al. (2002) describe a method for overcoming drug resistance at the tumour level due to physiological barriers (non-cellular mechanisms).

With the goal of overcoming non-cellular and cellular-based mechanisms of resistance, as well as increasing treatment selectivity towards cancer cells while decreasing drug toxicity towards normal

tissues, a new technique to combining anticancer medicines with colloidal nanoparticles might be developed. Several medication delivery systems have been developed and tested in the battle against cancer, and these tactics are covered in this article.

Nanoparticle delivery pathways in the treatment of cancer

Nanotechnology has the great potential to make a substantial contribution to cancer prevention, detection, diagnosis, imaging, and therapy, among other areas. It has the ability to target a tumour; it also has the capability to perform imaging to confirm the presence of a tumour; it can detect pathophysiological defects in tumour cells; it can release therapeutic genes or drugs based on tumour properties; it can respond to external triggers to release the agent and certify the tumour response; and it can identify residual tumour cells. Nanoparticles are necessary because of their nanoscaled structure, yet nanoparticles (Conrad, 2006) in cancer are still larger than many anticancer medications, despite their nanoscaled nature. Because of their "big" size, they might have difficulty evading organs such as the liver, spleen, and lungs, which are constantly sweeping unwanted items from the body and eliminating them. Furthermore, they must be able to take advantage of minute changes in cell composition in order to distinguish between normal and malignant tissues. Researchers are now working on developing nanoparticles that are capable of evading the immune system and actively targeting cancers, which will be useful in the future. Active tumour targeting of nanoparticles is accomplished by attaching molecules to the outsides of nanoparticles, which are collectively referred to as ligands. In that they can recognise and bind to corresponding molecules or receptors on the surface of tumour cells, these ligands are remarkable in their ability to combat cancer. A large amount of the anticancer drug is found and enters the tumour cell when such targeting molecules are attached to a drug delivery nanoparticle, as illustrated in figure 2. Nanotechnology studies (Kawasaki et al., 2005) are not new; they have been ongoing for the past 30 years of innovation in nanotechnology. However, the novelty of nanotechnology studies has been replaced by the "smart bombs" of the twenty-first century, which are capable of delivering a wide range of new anticancer drugs directly to tumours.

Characteristics of nanoparticles used in cancer treatment for drug delivery

Nanoparticles and other nanostructures are being considered as a potentially useful tool in the treatment of cancer in the near future. Nanoparticles have been proven to be capable of

selectively delivering large quantities of antitumor medications to tumour cells in research trials, which have mostly been conducted in animal models. Toxicity levels at high concentrations seem to remain inside tumour cells for extended periods of time, resulting in more targeted antitumor effects and less toxicity than those achieved by routine administration of toxic drugs. When it comes to delivering anticancer drugs to cancer cells or tissues, researchers have shown that nanoparticles are very effective. Treatment efficacy is improved by the advancement and optimization of drug delivery strategies based on nanoparticles. This is related to the early detection of cancer cells and/or specific tumour biomarkers, as well as the improvement and optimization of drug delivery strategies based on nanoparticles.

Nanoparticles, which are used to treat cancer, are colloidal systems that are submicronic (less than one micron in size) and are often composed of polymers (biodegradable or not). Nanospheres or nanocapsules may be produced depending on the procedure that was utilised for the manufacture of the nanoparticles in the first place. Nanocapsules, in contrast to nanospheres (matrix systems in which the drug is dispersed throughout the particles), are vesicular systems in which the drug is confined to an aqueous or oily cavity enclosed by a single polymeric membrane. Nanospheres are a type of matrix system in which the drug is dispersed throughout the particles. Nanocapsules may be thought of as a kind of 'reservoir' mechanism in this context. In the right circumstances, it may be used as a drug delivery vehicle, allowing the medication to reach tumour tissues or cells at a particular concentration while protecting the drug from being inactivated prematurely during transit. The accumulation process of intravenously delivered nanoparticles at the tumour level is based on passive diffusion or convection via the leaky, hyperpermeable tumour vasculature, as shown in this study. In the case of ligand-decorated nanoparticles ('active targeting'), the uptake might also be caused by a particular identification of the nanoparticles. Various technologies such as nanotechnology, advanced polymer chemistry, and electronic engineering are being used to produce new means of medication administration that are more effective and efficient.

The current emphasis for cancer therapy development (Jain, 2005) is on targeted drug delivery in order to make therapeutic concentrations of anticancer drugs accessible at the site of action while still preserving normal tissues. Targeted medication delivery to tumours may improve the selectivity of cancer cells for destruction, minimise peripheral/systemic toxicity, and allow for dosage escalation, according to the National Cancer Institute. As a result, focused medicine delivery will be more advantageous. Micro/nanoparticle medication delivery has been shown to offer significant potential for achieving regulated and targeted therapeutic effects in recent years, and this is expected to continue. Because of their chemical structure, size, and surface

features, among other things, the carrier particles exhibit exclusive transportation and extravasation (Drummond et al., 1999) characteristics. These characteristics are critical in determining the pharmacokinetics and pharmacodynamics of medications that are administered. In order to reach cancer cells in a tumour, a blood-borne therapeutic chemical or cell must first find its way into the tumor's blood vessels and then past the vessel wall into the interstitium, where it may then migrate via the interstitium to the cancer cells. Each of these transport modes, for a molecule of a particular size, charge, and configuration, may include diffusion and convection, respectively (Jain, 2001). In the year 2002, a very interesting paper entitled "Nanoparticles Cut Tumors' Supply Lines" was published in the journal Science, in which it was stated that hungry tumours (Couzin, 2002) demand new blood vessels to give nutrients and deliver the products. Scientists have been attempting for many years to starve tumours by interfering with the formation of new blood vessels, often known as angiogenesis. It took the researchers just minutes to load and deliver to blood arteries feeding tumours in mice a small particle containing a gene that causes the cells in the vessels to self-destruct. In the realm of cancer treatment, this was the most recent triumph that demonstrated fresh hope for cancer patients who were suffering from angiogenesis (blood vessel growth). In the field of pharmacology, targeted medication delivery plays an essential role. The use of such a method is crucial in tumour treatment since the chemicals are very toxic and, if they act on cells other than tumour cells, they might cause serious side effects. Any method that allows for an increase in the ratio of the medicine that needs to be delivered to the target spot will aid in the prevention of such adverse effects from occurring (Couzin, 2002).

Nanodevices for detection and treatment

"Smart" dynamic nanoplateforms have the potential to revolutionise the way cancer is identified, treated, and suppressed, among other aspects of health care. When it comes to designing nanodevices, there are two fundamental approaches. These approaches were dubbed the top-down approach and the bottom-up approach, respectively, by scientists. In the top-down technique, materials are formed into smaller components by moulding or etching them. This method has traditionally been employed in the production of computer and electrical components. The bottom-up technique entails constructing structures atom by atom or molecule by molecule, and it has the potential to be effective in the manufacture of medical devices. The majority of animal cells have a diameter ranging from

10,000 nm to 20,000 nm. Nanoscale devices (those smaller than 100 nanometers in diameter) may migrate inside cells and the organelles within them, where they can interact with DNA and proteins, according to the findings. The technologies that have been developed as a result of nanotechnology are capable of detecting illness in extremely tiny amounts of cells or tissue. They may even be able to access and monitor cells inside a live organism, if necessary. Scientists must be able to detect molecular alterations in cancer cells even when they occur in just a tiny fraction of cells if they are to have a chance of detecting cancer in its early stages. This illustrates the notion that the fundamental instruments must be exceedingly sensitive in order to be effective. The capacity of nanostructures to penetrate and study single cells demonstrates that they may be able to satisfy this need in the future.

Nanopores

The nanopore is yet another astonishing nanodevice that has been developed. Researchers will be able to spot faults in genes that may cause cancer with the use of advanced ways of scanning the genetic code. Nanopores, according to scientists, are the microscopic holes that allow DNA to travel through one strand at a time; this will improve the accuracy of DNA sequencing by making it more efficient. Researchers can track the structure and electrical characteristics of each base or letter on DNA as it travels through a nanopore, allowing them to better understand how DNA works. Because each of these characteristics is unique to each of the four bases that make up the genetic code, researchers may utilise the passage of DNA through a nanopore to read the encoded data, including faults in the code that have been linked to cancer.

Nanotubes

The nanotube is an alternative nanodevice that will aid in the identification of DNA alterations associated with cancer. Essentially, nanotubes are carbon rods with a diameter about half that of a molecule of DNA. They are capable of not only detecting the presence of changed genes, but they may also aid scientists in determining the precise location of those alterations. Teker et al. (2004) describe carbon nanotubes (CNTs) as remarkable solid state nanomaterials because of their different electrical (Bockrath et al., 1997) and mechanical characteristics. Carbon nanotubes (CNTs) are a kind of nanotube that has been studied extensively (Ruoff and Lorents, 1995). Nanotubes' electrical capabilities, when combined with biological molecules such as proteins, have the potential to be used to create nanoscale devices for biological sensing applications. Because of its tremendous potential for medicinal and biotechnological applications, the investigation of carbon nanotube functionalization has intensified. Inorganic

alteration of carbon nanotubes generates many sites for the attachment of bioactive compounds, and the modified nanotube might be used as a biosensor or delivery system for innovative therapeutic agents. Carbon nanotubes have been shown to target tumours in the first experiment of its sort (Liu et al., 2007), according to researchers at the Center for Cancer Nanotechnology Response (CCNE-TR) at Stanford University, who conducted the research. Single-walled carbon nanotubes (SWCNTs) wrapped in poly (ethylene glycol), or PEG, have been shown to be efficient tumour targets in live animals, according to research.

Quantum Dots (QDs)

Quantum dots (Ruoff and Lorents, 1995) are special owing to the vast possibilities they provide in a broad range of medical applications. In the field of medical imaging, a QD is a fluorescent nanoparticle that can be used as a sensitive probe for screening cancer markers in fluids, as a specific label for organizing tissue biopsies, and as a high resolution contrast agent for medical imaging, which is capable of detecting even the tiniest tumours. In addition, these particles have the unique property of being sensitively detected on a broad variety of length scales, from macroscale imaging to atomic resolution utilising electron microscopy, among other applications. The drug delivery particles are delivered into the bloodstream until they detect the cancer cells, to which the antibodies bind. This is accomplished by using Quantum dots (QDs). The infrared light beaming on the suspected cancer spot diffuses the tissues and causes the quantum dots to emit photons, which allows the cancer to be detected. The photons identify the location of the cancer cell and also cause the production of Taxol (an anticancer medication), which may subsequently be used to target and kill the cancer cells. Quantum dots are small crystals that emit a bright glow when exposed to ultraviolet light. Crystals are classified according to their size, which influences the wavelength or colour of the light. Latex beads loaded with these crystals may be designed to attach to certain DNA sequences with high specificity. Using different-sized quantum dots combined in a single bead, scientists may create probes that emit light in a variety of hues and intensities, according to their preferences. When the crystals are activated by ultraviolet light, each bead emits light that acts as a spectral bar code, allowing each bead to recognise a specific section of DNA. The wide range of quantum dots available will allow scientists to generate a plethora of unique labels that will be able to identify many sections of DNA at the same time. In the identification of cancer, which is caused by the accumulation of many distinct alterations inside a cell, this will be very useful. A further advantage of quantum dots is that they can be used in the

body, thereby avoiding the need for invasive procedures such as biopsy. Nanotechnology may potentially be useful in the development of methods for destroying cancer cells without causing damage to healthy, adjacent cells. According to researchers, they want to use nanotechnology to develop therapeutic compounds that target particular cells and release the toxic substance they contain in a controlled and time-released way (Ruoff and Lorents, 1995).

Nanoshells

In the case of nanoshells, the core is a nonconducting nanoparticle (Hirsch and colleagues, 2003), which is covered by a thin metal shell, the thickness of which is adjustable in order to precisely control the plasmon resonance. Proteins that exclusively bind to tumour cells may be attached to the surface of nanoparticles, resulting in tumor-seeking nanoparticles. Low-power extracorporeally applied laser light shown at the patient produces a response signal from injected nanoshells clustered around a tumour by adjusting the shells to strongly absorb 820 nm NIR light, where optical transmission through body tissue is optimum and harmless. The response signal is produced by adjusting the shells to strongly absorb 820 nm NIR light, where optical transmission through body tissue is optimum and harmless. As the strength of the laser is increased to a still-moderately-low exposure level, the nanoshells are heated just enough to kill the tumour while causing no damage to healthy tissue. Human breast cancer cells treated with nanoshells in vitro experience photothermally induced morbidity after being exposed to NIR light at a power of 35 W/cm². Cells that do not contain nanoshells show no signs of deterioration in viability. Similarly, in vivo investigations conducted under magnetic resonance guidance indicate that exposure to low-dose (4 W/cm²) NIR light in solid tumours treated with nanoshells results in a temperature rise of 37.46.6°C within 4-6 minutes in solid tumours treated with nanoshells. A coagulation pattern, cell shrinkage, and loss of nuclear staining are all seen in the tissue, suggesting permanent heat injury. Controls that were not treated with nanoshells had substantially lower temperatures and seemed to be unharmed. Nanoshells are likewise made up of tiny beads that have been coated with gold. Changing the thickness of the layers that make up the nanoshells allows researchers to create these beads to absorb various wavelengths of light by adjusting the layers' thickness. The most lucrative nanoshells are those that absorb near-infrared light, which can readily penetrate through several centimetres of human flesh and is thus very important in medical applications. The absorption of light by the nanoshells results in a tremendous amount of heat, which is fatal to living cells (Hirsch et al., 2003).

Researchers have the option of attaching the nanoshells to antibodies that are specifically designed to target cancer cells. Using light-absorbing nanoshells to generate heat in laboratory settings, researchers were able to effectively eliminate tumour cells while keeping nearby cells unaffected by the heat. When it comes to achieving tumor-targeted medication delivery, nanoparticle systems must address both technological and biological issues that have an impact on how they are distributed.

Dendrimers

Extremely branched and monodisperse macromolecules (Klajnert and Bryszewska, 2001), often known as "hyperbranched molecules" or "Dendrimers," were initially found in the early 1980s by D. Tomalia and co-researchers (Klajnert and Bryszewska, 2001; Tomalia et al., 1985). Dendrimers are a novel class of polymeric compounds that have just emerged. They have the ability to bring together treatment, as well as detection and diagnosis, in one package. Dendrimers have a significant amount of surface area because of their structure, which allows researchers to attach medicinal medicines or other physiologically active molecules to them and study their behaviour. It is possible to use a single dendrimer to transport three different molecules: one to identify cancer cells, one to eliminate cancer cells, and one to recognise signs of cell death in a single dendrimer system. Scientists are attempting to alter dendrimers such that their contents are delivered only in the presence of particular trigger molecules that are linked to the development of cancer. Following the administration of the medicine, the dendrimers are also capable of determining whether or not they have successfully killed their targets. The physical and chemical properties of these materials are greatly influenced by the structure of the materials. Dendrimers are particularly well suited for a wide variety of biological and industrial applications because of their unique characteristics. Dendrimers are being considered for use in cancer therapy, according to current thinking. Dendrimers have the potential to function as carriers, also known as vectors, for gene therapy. Vectors are used to introduce genes into the nucleus by passing them across the cell membrane. At the moment, liposomes and genetically altered viruses are the most often employed methods for accomplishing this goal. Due to the exceptional properties of dendrimers (Gillies and Fréchet, 2005), such as their high degree of branching, multivalency, globular architecture, and well-defined molecular weight, they are particularly well suited for drug delivery applications. One of the most recent advancements has been made in the application of biocompatible dendrimers to cancer treatment. These include their use as delivery systems for powerful anticancer drugs such as cisplatin and doxorubicin, and as

agents for both boron neutron capture therapy and photodynamic therapy. In spite of the increased work necessary for the stepwise synthesis of big dendrimers, the fact that these molecules hold additional advantages over their linear polymer analogues in terms of being useful in practical terms becomes apparent.

Hydrogel

The use of hydrogels in medication delivery is one of the most recent developments in the field. A variety of biomedical applications, including drug delivery systems, biosensors, contact lenses, catheters, and wound dressings, may be achieved via the use of hydrogels (Moon and colleagues, 2006). It is possible to create three-dimensional hydrogels out of hydrophilic polymeric networks that can absorb vast volumes of water or biological fluids. The networks are composed of homopolymers or copolymers and are insoluble owing to the presence of chemical crosslinks (tie-points, junctions) or physical crosslinks, such as entanglements or crystallites, which prevent the networks from breaking down. It is the thermodynamic compatibility of hydrogels with water that permits them to expand when exposed to watery solutions. They are used to regulate drug release in reservoir-based controlled release systems, as well as carriers in swellable and swelling-controlled release devices, among other applications. Biodegradable hydrogels are now being investigated as a cancer therapy option by scientists (Moon et al., 2006).

Herbal nanoparticles for cancer treatment in the future

Today, herbal therapy is being practised all over the globe in order to avoid adverse effects. As previously stated (Balachandran and Govindarajan, 2005), the science of Ayurveda is claimed to be an additional step in the treatment of cancers. There are numerous herbs, such as Aswagandha, Amla, Basil, Rakta vrntaka (Tomato), Neem, Turmeric, and others, that have anti-cancerous properties. These herbs include When it comes to protecting cells from the damaging effects of oxidative stress, antioxidants play a significant role. Lycopene, a carotenoid, has recently received a great deal of scientific interest due to its antioxidant properties. They have shown that they play a very essential function in cancer therapy. Recent experimental findings have shown that lycopene is effective in the prevention of various cancers, most notably prostate cancer, over the course of many years (Giovannucci, 2002). Tomatoes are an excellent source of lycopene (Stahl et al., 2006). The antioxidant capabilities of lycopene (*Lycopersicon esculentum*) were discovered for the first time in the 1970s (Sies et al., 1995). Given the relatively high amounts of lycopene found in the tissues of many people, as well as the probable involvement of oxidative stress in the development or spread of malignancies, it has been hypothesised that lycopene may have an anticancer effect. Furthermore, certain epidemiologic studies have suggested that individuals who

consume a high amount of lycopene, specifically from tomato products, have a lower risk of prostate cancer than those who do not (Giovannucci, 1999; Salata, 2004). In the future, the notion of herbal nanoparticles for cancer treatment delivery may also attract some potential research organisations, which will likely result in the production of findings that are both interesting and noteworthy.

Nanomaterials

In order to change the therapeutic impact, appropriateness, and dosage of a medicine, drug delivery technologies were developed to distribute or regulate the quantity, pace, and occasionally location of a drug in the body. The majority of pharmaceutical companies are focusing their efforts on drug delivery applications. The most well-known pharmaceutical companies have internal research projects on medication delivery that are focused on formulations or dispersions that include components with nanoscale diameters in their composition. With a current total universal investment in nanotechnology of € 5 billion, the worldwide market is expected to reach more than € 1 trillion by 2011-2015, according to estimates. Nano and micro techniques are included in the most recent innovative solutions and new models for shortening the time it takes to discover and develop new drugs, as well as potentially lowering the costs associated with drug development.

Conclusion

It is undeniable that nanotechnology will be a medical benefit in the diagnosis, treatment, and prevention of cancer sickness. It will fundamentally alter the way cancer is diagnosed, treated, and prevented in order to achieve the objective of eliminating cancer. Despite the fact that the vast majority of the approaches listed are promising and correspond well with current therapeutic methods, there are still safety risks related with the introduction of nanoparticles into the human body, according to the National Institutes of Health. Some of the goods will need extra research before they can be authorized. When it comes to cancer therapy, the most advantageous approaches to medication delivery will be those that combine diagnostics with treatment. These will enable for more customized cancer care and will provide a more integrated approach for cancer diagnosis and follow-up, which is critical in the management of cancer patients. In order to enhance nanoparticles for cancer therapy, several technological advancements are required in the future. Future efforts will be directed on identifying the mechanism of action and site of action of the vector, as

well as determining the vector's overall eligibility for treating cancers at all stages in preclinical models of various types. Additional research is being conducted with the goal of broadening the variety of medications that may be used to unleash innovative nanoparticle vectors. Certainly, this will enable for the development of innovative cancer therapy options in the future.

Conflict of interest: None

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