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NANOTECHNOLOGY FOR CANCER TREATMENT

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Abstract:

Nanotechnology has applications in practically every department of science, including physics, biology, chemistry, medicine, and engineering. One of the most potential applications of nanotechnology is in medical technology. Designing multifunctional nanoparticles capable of targeting cancer cells, delivering and releasing medications in a controlled manner, and detecting cancer cells with high specificity and sensitivity are just a few examples of how nanotechnology might be used to treat cancer. Chemotherapy and radiation are well-known cancer therapies, but they have various drawbacks, such as a lack of early illness identification and non-local medication distribution. Because the exact medication concentration reaches not just the tumour site but is disseminated throughout the body, these therapies have a limited capacity to cure and monitor the drug's effect in the human body. To some extent, nanotechnology has allowed us to circumvent these restrictions.

Introduction:

CANCER:

Cancer is anticipated to rank as the main cause of mortality and the single most critical obstacle to expanding life expectancy in every country of the globe in the twenty-first century. Cancer is the primary or second major cause of death before the age of 70 years in 91 of 172 countries, according to WHO estimates from 2015, and it ranks third or fourth in another 22 nations. [1] Every day, people all across the world are confronted with a slew of new and difficult environmental issues. Air, water, and soil pollution take millions of years to recover from. The worldwide burden of cancer continues to rise, owing to the ageing and growing of the global population, as well as an increase in the adoption of cancer-causing habits, notably smoking, in emerging nations. Many economically developing nations have high rates of female breast, lung, and colo-rectal cancers, in addition to a disproportionately high burden of malignancies caused by infections. [2] Cervical cancer, female breast cancer, liver cancer, Kaposi's sarcoma, and nonHodgkin lymphoma appear to be the most common cancer forms in places with a low Human Development Index[3].

NANOTECHNOLOGY :

Nanotechnology is having a beneficial influence on almost every field, including healthcare. Nanomedicine, or the use of nanotechnology to healthcare, necessitates the collaboration of several disciplines, including biology, chemistry, physics, chemical and mechanical engineering, material science, and clinical medicine. [4] Nanoparticles are defined as: The Encyclopedia of Pharmaceutical Technology defines nanoparticles for pharmaceutical uses as solid colloidal particles with a size range of 1 to 1000 nm (1 μ m). They are made up of macromolecular materials and can be utilised as drug carriers to dissolve, entrap, or encapsulate the active principle (drug or biologically active ingredient), or to which the active principle is adsorbed or attached. [5] Nanoscopic therapeutic systems with therapeutic agents, molecular

targeting, and diagnostic imaging capabilities are developing as the next generation of multifunctional nanomedicine for improving drug treatment therapeutic outcomes. Polymeric micelles, which are self-assembled nanoparticles made from amphiphilic block copolymers, have a unique core-shell architecture in which the hydrophobic core acts as a natural carrier environment for hydrophobic drugs and the hydrophilic shell allows for particle stabilisation in aqueous solution. [6] American Bio Science, Inc.'s Abraxane (paclitaxel protein-bound particles for injectable solution) (albumin-bound) was authorised by the FDA. [7] Every 21 days, Doxil was given as a 60-90 minute intravenous infusion. [8] DaunoXome [9] and diagnostic Feridex [10]

Targeted delivery of nanocarriers to tumors:

A large number of anti-cancer therapeutic medicines have been developed as a result of extraordinary developments in molecular medicine and biotechnology. A blood-borne therapeutic chemical, particle, or cell must enter the tumor's blood vessels, pass the vessel wall into the interstitium, and then travel across the interstitium to reach cancer cells. Unfortunately, tumours frequently form in such a way that each of these phases is hampered. [11] The fluorescence intensity recorded by intravital fluorescence microscopy was used to calculate microvascular permeability. In the molecular weight range of 25,000 to 160,000, the value of permeability changed by around 2-fold. Because of the numerous holes in the vessel wall, tumour vessels appear to be less permselective than normal vessels. Diffusion across these pores appears to be limiting macromolecule transport. Observations of transvascular transport of sterically stabilised liposomes with diameters of 100-600 nm were used to determine the pores' cutoff size. We discovered that tumour arteries in our model were permeable to liposomes with a diameter of up to 400 microns, implying that the pores' cutoff size is between 400 and 600 microns. [12] The interstitial compartment of neoplastic tissues differs greatly from the interstitial compartment of most normal tissues. In comparison to most normal tissues, the tumour interstitial compartment has a large interstitial space, high collagen concentration, low proteoglycan and hyaluronate concentrations, high interstitial fluid pressure and flow, absence of anatomically well-defined functioning lymphatic network, high effective interstitial diffusion coefficient of macromolecules, large hydraulic conductivity, and large interstitial convection. [13] One of the few tumor-specific properties that is becoming a gold standard in anticancer medication delivery is the increased permeability and retention (EPR) impact in solid tumours. Biocompatible macromolecules (or macromolecular medicines and lipids) show the strongest EPR impact. Furthermore, it appears that even the targeting of minute particles like liposomes to the tumour is predicated on this process. [14] Although the first generation of liposomes were limited by low drug encapsulation efficiencies and rapid clearance by the reticuloendothelial system, advancements in technology have resulted in more stable and long-circulating liposomes with increased tumour deposition, which may provide clinical benefits in some cases. Immunoliposomes, which are antibody fragments attached to long-circulating liposomes for targeted drug delivery, are the next generation of nanoparticle-based drug delivery systems. [15] We'll go through some of the most important breakthrough nanotechnology platforms for cancer therapeutic applications.

Challenges in cancer therapy:

Surgery, chemotherapy, radiation, hormonal therapy, and targeted therapy are among the multimodal therapies used to treat cancer. Chemotherapy can kill tumour cells and reduce tumour size, however failure to treat certain individuals results in recurrence and death. [16] The biosocial data of 90 children with acute lymphoblastic leukaemia was gathered, as well as a visual analogue scale assessment of gastrointestinal side effects of treatment. When it comes to nausea and vomiting, ginger lozenges are more effective than acupuncture. The group of 13-15 year olds responds most to acupuncture for nausea relief. [17] Chemotherapy-induced side effects have an impact on cancer patients' quality of life and treatment effectiveness. Current attempts to addressing chemotherapy side effects are ineffective and may result in a slew of negative consequences. As a result, novel and effective medications derived from natural harmless substances are needed to address chemotherapy-induced adverse effects. [18] Chemotherapy and radiation based on cytotoxicity are still the most used cancer therapies. Chemotherapeutic drugs are routinely used systemically, resulting in severe side effects such as cisplatin-induced nephrotoxicity, doxorubicin (DOX)-induced cardiotoxicity, and bleomycin-induced lung fibrosis. The adverse effects of radiotherapy are clinically expressed in particular and organ-related tissues, for example, irradiation-induced fibrosis, atrophy, and neuronal and vascular damage are common late side effects. Loss of homeostatic regulation

of reactive oxygen species (ROS), onset of inflammation, and DNA damaging and mutagenesis effects are the key processes that underpin the causes of cancer therapeutic side effects. [19]

Nanotechnology for cancer treatment :

Controlled release polymer technologies have had a significant influence on virtually every discipline of medicine over the last four decades, including cardiology[20], ophthalmology[21], endocrinology[22], orthopedics[23], and pain management [24]. Atridox, Lupron Depot, Gliadel, Zoladex, Trelstar Depot, and Sandostatin LAR are a few examples of these systems used in clinical practise today. The yearly global market for controlled release polymer systems, which includes more than just medication delivery, is currently projected to be worth \$60 billion, with over 100 million individuals using these systems each year. When a natural or synthetic polymer interacts with a medicine in such a way that the drug is contained inside the polymer system for eventual release in a preset manner, this is referred to as "controlled release." Polymeric drug delivery vehicles can be engineered as nanoparticles that release encapsulated pharmaceuticals by surface or bulk erosion, diffusion, or swelling, then diffusion in a time or condition-dependent way. The active agent's release might be constant over time, cyclic over time, or triggered by environmental or other external events like as changes in pH, temperature, or the presence of an analyte like glucose [25].

Targeting:

Drug delivery by nanoparticles can be active or passive. Passive delivery refers to the passive diffusion or convection of NP into the tumorinterstitium and cells through leaky tumour capillary fenestrations.

Monoclonal antibodies, the discovery of specific receptors that are either overexpressed or expressed only in specific tissues, and the development of conjugation techniques to attach antibodies or ligands to drug delivery systems have all contributed to the possibility of targeted delivery of therapeutic agents to specific tissues. Targeted distribution increases the medicinal agent's bioavailability at its location of action while lowering adverse effects. Furthermore, utilising the epoxy-activation approach established in our research, nanoparticles synthesised with PLGA may be attached to cell- or tissue-specific ligands. [26]

Active targeting :

Drug delivery to a specific place based on molecular recognition is known as active targeting. Couple a ligand to an NP, for example, so that the ligand may interact with its receptor at the target cell location. A particular antibody combined with an NP will attach to a specific antigenic target cell site in the same way. The binding of folate to pegylated particles for engagement with the folate receptor is an example of active targeting. Many cancer cells have an overabundance of folate receptors on their surfaces, and the NP folate attached protein has a greater binding affinity than free folate [27].

Passive targating :

Passive targeting entails the convection or passive diffusion of nanocarriers into the tumorinterstitium and cells through leaky tumour capillary fenestrations. The movement of molecules inside fluids is referred to as convection. When the net filtration rate is zero, convection must be the dominant method of transport for most big molecules across large pores. Low molecular weight substances, such as oxygen, are carried primarily through diffusion, which is defined as the act of transporting molecules across the cell membrane according to a concentration gradient without the use of cellular energy. Despite this, due to interstitial hypertension, convection across the tumorinterstitium is limited, leaving diffusion as the primary mechanism of drug delivery. [28]

Nanoparticles with medical applications:

In terms of size, shape, and substance, nanoparticles for drug delivery come in a variety of architectural styles. Drug loading capacity, particle and drug stability, drug release rates, and targeted delivery capabilities are all different features of each particle. Reviewing the multiple NP structures is beyond the scope of this essay. However, a quick glance reveals the range of options accessible.

Liposomes :

These are closed vesicles formed when dry phospholipids are hydrated above their transition temperature. Liposomes are divided into three categories based on the number of bilayers and their size. Multilamellar vesicles are made up of several lipid bilayers separated by aqueous gaps. These objects are small, ranging in size from a few hundred to thousands of nanometers in diameter. Small unilamellar vesicles (SUVs) and large unilamellar vesicles (LUVs), on the other hand, are made up of a single bilayer that surrounds the entrapped aqueous area. SUVs have a diameter of less than 100 nm, and LUVs have a diameter of

more than 100 nm. Depending on the physicochemical properties of the medication, it can be entrapped in the aqueous space or intercalated into the lipid bilayer of liposomes. Targeting ligands and polymers can be used to modify the liposome surface. [29]

Dendrimers:

Dendrimers are highly branched macromolecules with exact size and form control, making them a unique class of polymers. Convergent or divergent stepgrowth polymerization is used to make dendrimers from monomers. Dendrimers are promising drug carrier possibilities because of their well-defined structure, size monodispersity, surface functionalization capabilities, and stability. Complexation or encapsulation can be used to integrate drug compounds into dendrimers. Dendrimers are being studied for medication and gene delivery, as penicillin carriers, and as anticancer agents. Polyamidoamine (PAMAM) [30], melamine [31], poly(L-glutamic acid) (PG), polyethyleneimine (PEI) [32], poly(propylene imine), and poly(ethylene glycol) (PEG) [33] are some of the polymers often employed in drug delivery research.

Polymeric micelles:

Various amphiphilic block copolymers, which may self-associate to form micelles in aqueous solution and have been widely researched as drug transporters, have recently received a lot of interest. Polymeric micelles offer various benefits over traditional surfactant micelles, including improved thermodynamic stability in physiological solution, as seen by their low critical micellar concentration, which keeps polymeric micelles stable in vivo and avoids fast dissociation. Micelles have a nanometer-scale size distribution and are distinguished by their distinct core-shell design, which separates hydrophobic portions from the watery exterior. Micellar systems are effective for delivering water-insoluble medications throughout the body. Drugs may be partitioned in the hydrophobic core of micelles, and the outer hydrophilic layer creates a stable dispersion in aqueous fluids that can subsequently be given intravenously[34].

Nanoshells (NS) :

These are also a relatively new innovation. NS are very little gold-coated beads. The thickness of the layers that make up the NS may be adjusted to have the beads absorb certain wavelengths of light. Nanoshells that absorb near-infrared light, which may readily penetrate several centimetres into human tissues, are the most helpful. The absorption of light by nanoshells generates a tremendous amount of heat, which is fatal to cells. Antibodies that identify cancer cells can be coupled to nanoshells. The heat created by the light-absorbing nanoshells efficiently destroyed tumour cells in laboratory experiments while leaving neighbouring cells unharmed[35].

Conclusions:

Nanoparticle technology and research for cancer chemotherapy delivery will continue to advance in the future. The quest for new tumour targets, ligands, targeting techniques, and particle stabilisation will increase our capacity to optimise tumour delivery while reducing damage to normal tissues. While this discussion has focused on cancer therapeutic drug delivery, nanoparticles have a wide range of applications, including imaging and sensing, diagnostics, targeting, radiation, and the transfer of genetic material. Other publications in this journal will examine these nanoparticle technology tactics in relation to urological concerns.

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