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A Review on Nanoparticles and Targeted Drug Delivery System for Cancer Therapy

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ABSTRACT:

The side effects of radiation and chemotherapy can significantly limit how effective cancer treatment is. This abstract explores the potential of targeted delivery systems based on nanoparticles to revolutionize cancer therapy. We discuss the following outcomes of developing nanoparticles that can recognize and adhere to cancer cells: Enhanced Administration of Drugs: Nanoparticles have the ability to directly target tumors with powerful therapeutic payloads, thereby reducing systemic toxicity and improving treatment outcomes. Improved Focus: Nanoparticles can more accurately target indicators by altering the surface of cancer cells with the least amount of damage to healthy organs. Getting Past Resistance: Multi-drug resistance is a major barrier to traditional cancer treatment, but nanoparticle-based treatments may be able to help. The last section of the paper highlights the current research being done to convert this exciting technology into practical uses and current challenges faced by industry.

Key words: Nanoparticle, Cancer, Tumour, treatment

INTRODUCTION :

Human cancer is the most lethal disease in the world. According to estimates, 6% of people worldwide suffered from cancer in 2019. There are four immunotherapy techniques. Immune therapy, hormone treatment, surgery, and chemotherapy. It is applied to cancer treatment. Unfortunately, low therapeutic faces, low oral bioavailability, and high destructiveness. These days, cancer is the leading cause of mortality worldwide and one of the most prevalent diseases. Globally, there is projected to be 1.9 million new cases of cancer in 2022. Recently, the multidisciplinary area of nanotechnology has emerged, encompassing the engineering of materials and systems at the nanoscale. [1,2] Radiation therapy and chemotherapy are currently the most popular cancer therapies. Conventional treatments have undergone significant advancements; nonetheless, their non-specific mechanisms of action pose a challenge in precisely targeting tumor cells, resulting in the destruction of cancerous cells while simultaneously posing a risk to healthy ones. One area of nanotechnology that has enabled the development of drug delivery systems for nanoparticles is "nanomedicine," or the application of nanotechnology to medicine and healthcare. [3,4]

Furthermore, a complete understanding of these nanoparticles' pharmacologic and toxicologic properties as well as an impartial and comprehensive evaluation of the advantages and disadvantages for human health are expected prior to these materials being used in clinical settings. New insights into the application of innovative nanomaterials for cancer treatment have been made possible by a multifunctional platform built on gold nanoparticles. This platform enables the integration of imaging and therapy, as well as the implementation of multiple receptor targeting. The main method by which NPs enter target cells is called endocytosis, and it involves two different processes: phagocytosis and pinocytosis. While pinocytosis is a universal process that can be classified into three types, it is the principal mode of capture employed by phagocytic cells, including neutrophils, dendritic cells, and macrophages. On the other hand, micropinocytosis, Cathrin/caveolae-independent endocytosis, and Cathrin-or caveolae-mediated endocytosis, is a process that occurs in all cells. [5,6]

CANCER AND ITS EPIDEMIOLOGY

One big obstacle to living a long life is cancer. According to World Health Organization (WHO) forecasts from 2019, cancer is currently the main cause of death in most nations before the age of 70. As a result, cancer is now considered a major worldwide public health issue that requires quick attention. The World Health Organization has revised its list of the top 10 causes of disease burden based on disability adjusted life year. [7]

NANOPARTICLES

Scientific definitions define nanoparticles (NPs) as particles with a single dimension smaller than 100 nm and unique properties not seen in bulk samples of the same material. Whether a nanoparticle is classified as 0D, 1D, 2D, or 3D depends on its overall shape. The basic composition of nanoparticles is complicated and consists of the surface layer, shell layer, and core (the major component of the NP, usually referred to as the NP itself). These materials' exceptional qualities—such as their high surface-to-volume ratio, dissimilarity, sub-micron size, and enhanced targeting system—have made them more significant in transdisciplinary fields. [8]

One of the biggest challenges is figuring out which targeting agent, if any, is optimal for successfully and selectively delivering nanoparticle systems to malignant tissue. Therefore, the effectiveness of these tactics hinges on the ligands' or the targeted drugs' capacity to bind to the tumor cell surface in a way that activates receptor endocytosis. [9] Nanoparticles can target tumors by binding interactions, sometimes known as active targeting, or by precise molecular targeting or a physical screening mechanism based on size (often referred to as passive targeting). Using localized physical forces, such as magnetic fields, to focus and confine magnetic particles to certain body regions is one of the other targeting strategies. [10]

CHARACTERISTICS OF NANOPARTICLES

The most efficient method for a nanoparticle to systematically administer a medication is through the reticuloendothelial system, which frequently removes unmodified common medications from the body based on their size and ability to stay in the bloodstream for an extended period of time to reach the target cells and constitutively deliver a drug to the target region. The reticulo endothelial system regularly removes unmodified conventional drugs from the body, depending on their size and composition. characteristics of the NPs' surface that are being used to administer the drug. [11]

KEY PROPERTIES OF ANTICANCER NANOPARTICLES

The reticulo-endothelial system regularly removes unmodified conventional drugs from the body, depending on their size and composition. the nanoparticles' surfaces. Given their higher surface-to-volume ratios compared to larger particles, controlling the surface characteristics of nanoparticles is crucial to comprehending their behavior in human tissue. beneficial carriers of antibodies, DNA, peptides, imaging agents, or other substances to certain body areas for a range of diseases, including cancer detection and diagnostics. Gold nanoparticles may be readily made, are not harmful, and can Using this approach, molecules of biological relevance might be linked to and tracked by one medication molecule in a cell or another biological sample visible to the laser light that was utilized to view the particles wavelength that barely slightly harms as a delivery vehicle for drugs targeted at tumours to living organisms. [13,14]

Types of Smart Nanocarriers

The nanoscale drug carriers are the key component of smart nanoparticles. For a smart nanoparticle to be deemed optimal, it needs to meet a number of essential criteria. These include a material or structure that responds to stimuli, a stable nanoscale size, a surface charge that can be adjusted, a high encapsulation capacity, biocompatibility, degradability, low toxicity, and so forth.

Polymeric Nanoparticles

For biological applications, the unique properties of polymeric nanoparticles are essential, encouraging new kinds of cooperation between biologists, chemists, engineers, and medical specialists. The discovery of polymeric nanoparticles has spurred a revolution in medicine and led to important biotechnological developments in biomaterials, drug delivery, tissue engineering, and medical device manufacturing as shown in figure 1.

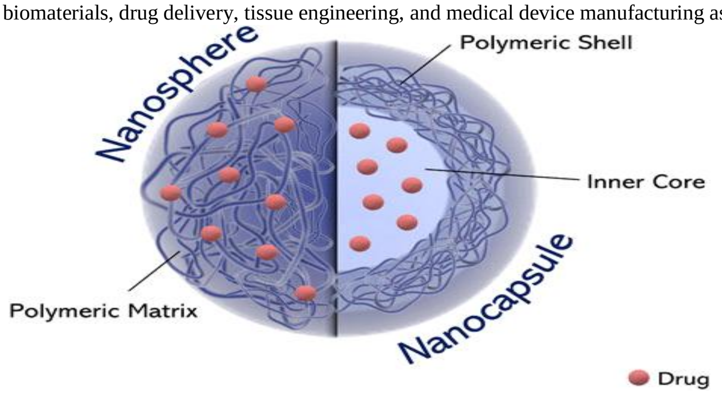

Figure 1: Polymeric Nanoparticles

Gold nanoparticles

A variety of bulk elements, including gold, silver, copper, iron, platinum, cobalt, and others, have been utilized to make nanoparticles due to the ongoing breakthroughs in nanotechnology and medical research. These elements are produced by biological or physicochemical processes (see figure 2). Since gold nanoparticles are easy to make, have a large specific surface area, surface plasmon resonance, stable characteristics, surface chemistry, and multi-functionalization, it is believed that they offer great potential for both medicine delivery and cancer diagnosis. [15]

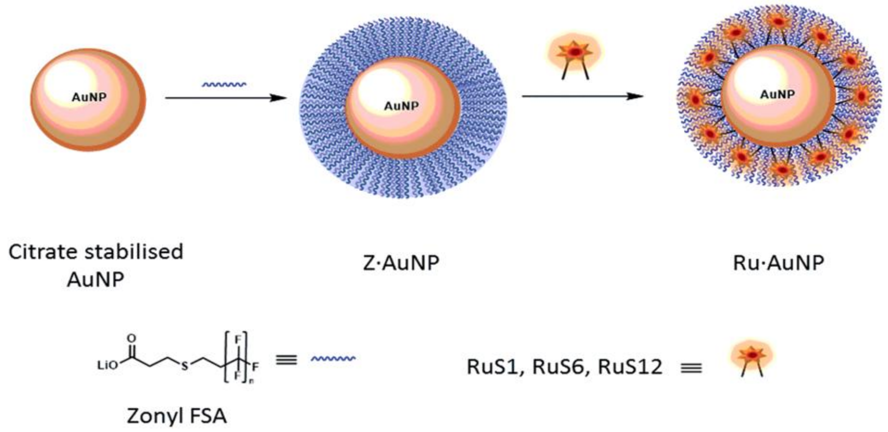

Figure 2: Gold nanoparticles

Silver Nanoparticle

Nanoparticles are solid colloidal particles that are smaller than 100 nm. Their extraordinary size and ability to trap electrons gives them unique optical and physiochemical properties, unlike their powder, plate, or sheet forms. AgNPs can be produced using simple, low-cost, one-step procedures based on green chemistry principles and utilizing renewable resources and naturally biodegradable ingredients such polysaccharides, biopolymers, vitamins, plant extracts (PEs), and microorganisms as shown in figure 3. [16]

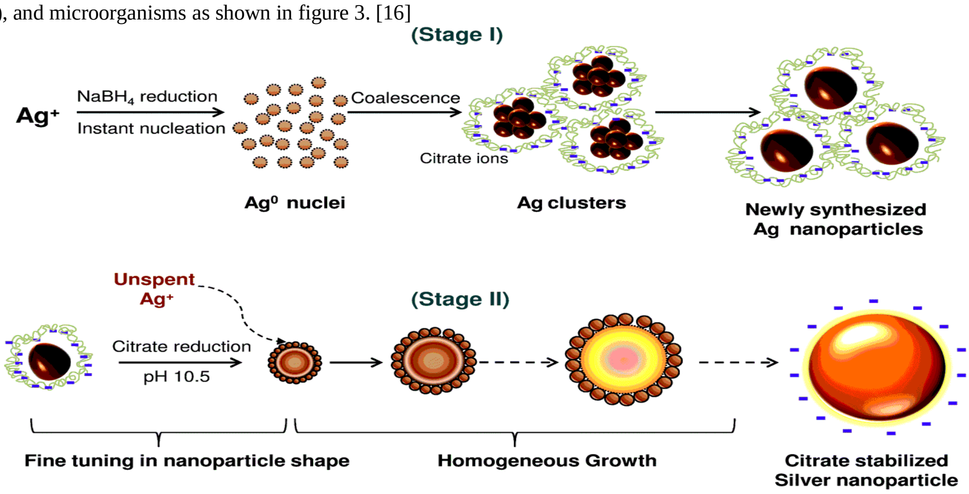

Figure 3: Silver Nanoparticle

Iron oxide Nanoparticles

Though sometimes overlooked as a part of the nanotechnology revolution, parenteral iron (i.e., iron oxide nanoparticles) therapy for iron deficiency anemia (IDA) dates back to the early 20th century. The early Fe formulations were associated with toxicities because of the rapid release of bioactive Fe as illustrated in figure 4. Currently, all approved intravenous iron formulations are either iron oxide-carbohydrate complexes or colloids, which are based on small, spheroidal nanoparticles of both. [17]

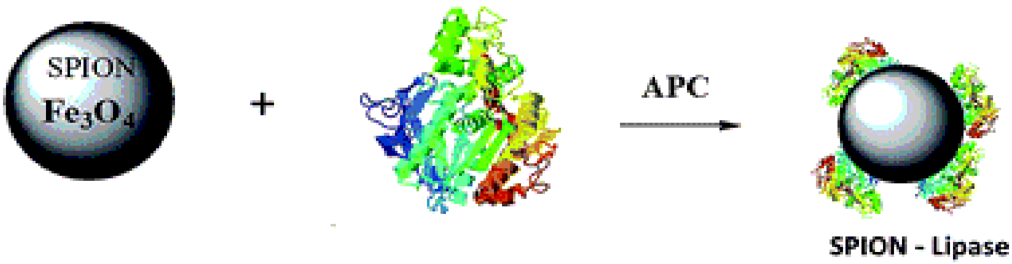

Figure 4: Iron oxide Nanoparticles

DRUG DELIVERY SYSTEMS FOR CANCER TREATMENT

Using DDS is one technique to avoid the negative effects of chemotherapy for the treatment of cancer. The preceding section provided an overview of the several types of natural polymers. To build a drug delivery system, any of these can be employed to encapsulate therapeutic chemicals in drug carriers. The DDS's characteristics are influenced by its architecture, componentry, and surface characteristics. Various natural ingredients may be chosen according to the desired therapeutic result. In certain situations, several natural components may be used to make the DDS. Several types of naturally occurring polymer-based nanoparticles meant for targeted cancer treatment are covered in this section. [18]

Mode of Action of Immunotherapeutic in Cancer

It is vital to comprehend the molecular components of cancer immunotherapy prior to employing nanoparticles in cancer treatment. One essential element of the cancer-immunity cycle is the removal of tumour cells. that serves as the foundation for research on cancer immunotherapy. The necrosis or death of cancer cells results in the production of tumour antigens. APCs bind to these antigens, which are then presented on the major histocompatibility complex (MHC). Immature T cells prime in lymph nodes in response to the complexity of dendritic cells and cancer antigens, and then activated TCLs (cytotoxic T lymphocytes specific to tumors) infiltrate the tumor site. TCLs interact with MHC and T cell receptors to recognize tumor cells. [19]

Nanotechnology-Based Active Drug Targeting

Through active targeting, medications and other therapeutic substances are given straight to the tumor cells. In order to facilitate active targeting, chemotherapy-loaded nanocarriers have been engineered to directly interact with or identify tumor cells. Finding overexpressed genes and biomarkers based on various pathophysiological changes in cancer cells is the foundation of active targeting. Nanoparticles can be surface-decorated with ligands that work through ligand receptor binding or antigen-antibody interaction, which tumor cells can easily recognize. [20]

Novel prospects in nanomedicine for enhanced tumour treatment

Strategies for active targeting: Despite the fact that "passive targeting" of nanoparticles results in increased preferred accumulation in malignancies, there is still a significant amount of non-specific uptake of circulating nanoparticles in healthy tissues as shown in figure 5. Thus, a recent area of research involves altering nanoparticles with targeting moieties that identify and bind to receptors overexpressed on tumors or the endothelium surrounding them in order to enhance localization and accumulation in tumors. [21]

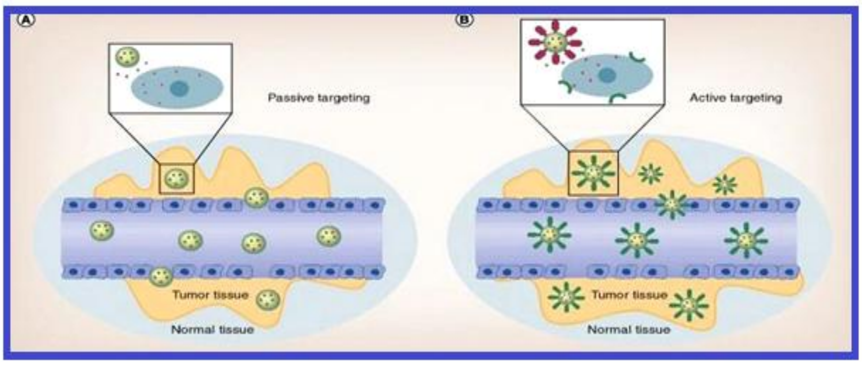

Figure 5: Active & Passive Targeting of Drug

Controlled drug delivery

The advancement of nanotechnology has made nanoparticles a feasible alternative for controlled drug delivery systems. Generally speaking, particles with a dimension of 10–1000 nm are called nanoparticles. When used as a DDS, nanoparticles can extend the half-life and improve the solubility of the drug, increasing the efficacy of the hydrophobic treatment and administering it in a consistent or controlled way. Furthermore, stimuli-responsive nanoparticles can help control the biodistribution of the drugs and lessen their toxicity (See Figure 6). [22]

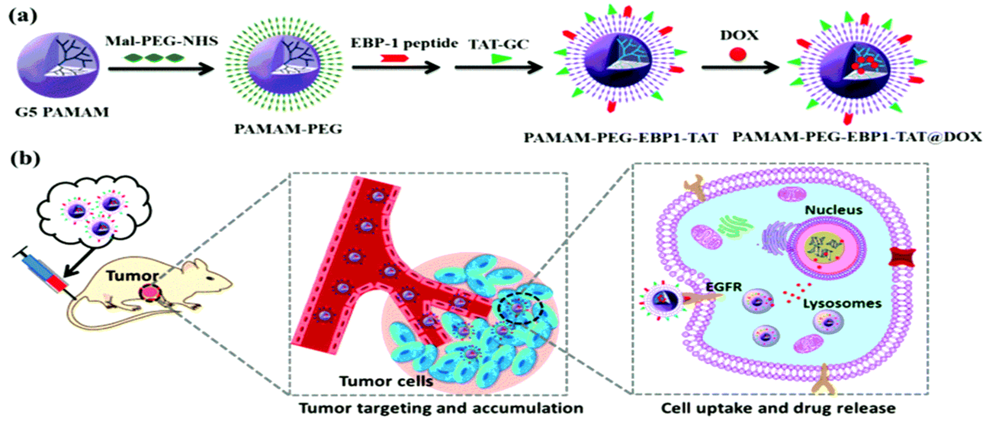

Figure 6: Controlled Drug Delivery of Drug

Overcoming Challenges in Cancer Treatment with Nanoparticles

Challenges that can be divided into biological, technological, and study-design related.

1. The biological challenges involve several issues such as inadequate delivery channels, reducing biodistribution, degradation, and toxicity.
2. Technological challenges of NPs include **s**cale-up synthesis, equal optimization, and performance projections are some of the technological problems facing NPs. These play a critical role in ensuring NP's clinical success.
3. Study-design challenges like issues with study design, such as study size, purpose, and when to administer NP treatments have a considerable influence on clinical trials. Most of the research uses "cell and animal models," which might not provide results in human trials that are understandable. [23]

CONCLUSION

A tailored drug delivery technique offered by nanoparticles has the potential to completely transform cancer treatment. The following summarizes the key concepts:
Enhanced Targeting: Nanoparticles can be made to particularly target cancer cells through surface modifications that recognize markers on tumor cells. This reduces harm to healthy tissues, one of the main side effects of traditional chemotherapy. Better Drug Delivery: Medicinal drugs can be delivered by nanoparticles with a higher payload than with conventional methods. This could improve the therapy's efficacy. Overcoming Resistance: One prevalent issue in the treatment of cancer is multi-drug resistance, which nanoparticles may be able to aid with, Multifunctional Potential: Some nanoparticles can be engineered to be "smart," reacting to stimuli from the outside or the inside to release their payload at the tumour location or combine imaging and medicine. All things considered, targeted systems based on nanoparticles mark a major advancement in the fight against cancer. To overcome existing obstacles and advance this potent technique in the treatment of cancer, more research is essential.

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CONFLICT OF INTERESTED

The authors declare no conflicts of interest

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