A Review on the Recent Advancements on Nanoparticles Drug Delivery Approaches in Anti-Cancer Treatment

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A project submitted to the School of Pharmacy in partial fulfillment the requirements for the degree of
Bachelor of Pharmacy (Hons.)

School of Pharmacy
BRAC University
March 2023

Declaration

It is declared that here that,

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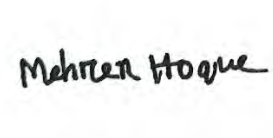

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Approval

The thesis titled "A Review on the Recent Advancements on Nanoparticles Drug Delivery Approaches in Anti-Cancer Treatment" submitted by Syeda Mehren Hoque (19146079), of Spring 2019, has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Pharmacy.

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Ethics Statement

No human or animal tests are involved in this study.

Abstract

Nanoparticle drug delivery systems show a more promising approach and convenient treatment than conventional therapy to treat cancer. A broad range of nanoparticles, including as Inorganic Nanoparticle, Liposomes Nanoparticle, and Polymers Nanoparticle, have been employed for determining and improving new cancer therapeutics. Each of them can treat cancer effectively and give less toxicity than other cancer treatments. Another approach of Theranostic nanoparticles that can show both therapeutic and diagnostic purposes for cancer therapy has expanded dramatically. This dual technique is critical because it assist in the identification of tumor tissue, nanoparticle biodistribution, therapy effectiveness and potency, and treatment progress and efficacy. This review focuses on recent advancements in several types of nanoparticle drug delivery systems that have a significant impact on cancer treatment.

Keywords: Nanoparticle, Liposome, Polymer, Theranostic, Inorganic, Conventional therapy, Biodistribution.

Dedications

Dedicated to my parents who could do anything for our happiness and to my beloved siblings and my friends.

Acknowledgement

For all the people who keep showing their constant encouragement and endless support throughout my project works, here are my acknowledgements.

First of all, I would like to express my gratefulness to my supervisor Farzana Islam, Lecturer, School of Pharmacy, BRAC University, for helping me completing this thesis. Her continuous guidance, instructions, support and motivation throughout the project work, makes it possible to complete the research paper on time. I am really thankful for her valuable inputs and knowledge which makes my work better.

I proudly acknowledge the guidance of professor Dr. Eva Rahman Kabir, Chairperson, School of Pharmacy, BRAC University and expresses my gratitude for her contribution and guidance towards every student whenever needed.

I would like to acknowledge my family and friends who keep motivating me in every sector of life. Undoubtedly without their support, motivation, prayers and affection I would not do this much. Lastly, I would like to thank all the people who helped me whenever I needed and always keep supporting me.

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List of Acronyms

DDS: Drug Delivery System

NP: Nanoparticle

TNPs: Theranostic Nanoparticles

ILP: Immunoliposome

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Chapter 1

Introduction

Drug delivery system (DDS) is a concept that allows a therapeutic material to be presented into the human cells and enhances its effectivity and safeties by regulating the rate, duration as well as targeted release of drugs (Jain, 2020). DDS has been employed in both clinical and pre-clinical situations to provide therapeutic substances for disease therapy. Conventional DDS is administered orally or via injection. Despite several advantages, such as simplicity of administration and patient acceptance, conventional DDS has significant limitations and drawbacks (Dang & Guan, 2020). One of them is decreased efficacy and selectivity, which means that radiation and chemotherapy might destroy tumor cells but result in collateral harm to normal cells as well as vary in therapeutic efficacy from individual to individual (Derakhshandeh et al., 2018). The controllable DDS was established in 1976, and the development of this unique concept grabbed the focus of all research teams to it. It was named a "magic bullet" by scientists (Sur et al., 2019). Controllable DDSs would be ideal transporters for chemotherapeutic drugs, assist them to the specific location of tumor and increasing concentration of drug in tumor tissues while minimizing harm to healthy cells. Furthermore, regulated DDSs protect drugs from breakdown and elimination, which is advantageous both protein transport and the advancement of novel therapeutic drugs such as gene therapy and RNA interference. They might assist in DNA and siRNA escape reticuloendothelial or other tissues, as well as degradation of enzyme. Nanoparticles are now playing an important role in integrating diverse areas including as technology, biological, chemistry, or physics, and they are also influencing contemporary pharmacological developments as imaging agents or DDSs. Current treatment packaged in nanoparticles or targeted administration of therapeutic pharmaceuticals to the human's affected tissues is a common technique for administering therapy treatments in cancer (Moradi et al., 2020).

1.1 Introduction to Nanoparticle Drug Delivery

Over the past couple of decades, a diverse range of nanoparticles have been produced and evaluated for their potential as diagnostic and therapeutic techniques. At the moment, medical science is heavily focused on in vivo molecular imaging. When nanoparticles are designed to behave as molecular imaging agents, they can identify the existence of cancer specificity of genetic alterations or perhaps the properties of tumor cells. Some nanoparticles, referred to as bioactivatable

nanoparticles and they operate as flexible reporters of in vivo conditions and modify their characteristics in accordance with circumstances or activities within the body. This allows them to provide spatial as well as temporal data about illness development and treatment action. This knowledge may be utilized to choose a treatment plan or alter a therapy method (Raj et al., 2021). NPs may enhance the solubility and stability of encapsulated cargos, improve membranes transportation, and lengthen circulatory periods. For these reasons, substantial study has been conducted on NP improve safety and efficacy, with significant improvements in vitro and in small animal models. Some early NP versions were unable to conquer biological obstacles to distribution, while more current NP ideas have incorporated complex architectures, bio-responsive moieties, and targeting compounds for improving drug delivery. NPs could thus be utilized to change specific mechanisms, improve the effectivity of the therapy against certain molecules. In more complex systems, such as nanocarrier-mediated combination therapies, specific steps of cell cycle can be targeted, or drug blocking processes can be defeated (Mitchell et al., 2021).

1.2 History of Nanoparticles

Nanotechnology was developed between the 1960s and 1970s as a blend of basic chemistry, biology, and technologies with sub-stance change at the nanoscale level from 1 to100nm. Nano-dimensional materials are microscopic particles which are widely used including targeting DDS, increased bio - compatibility, biodegradability, and controlled delivery of drugs, all of which have a substantial impact on the nanomedicine frontier (Thakuria & Kataria, 2021). Nanomedicine has been studied since 1990, following the invention of high-tech equipment such as ultramicroscopes, and the electron microscope. These tools assist to work and observe the nanoparticles. Peter Paul developed the first nanoparticle in the 1960s (Sur et al., 2019).

1.3 Properties of Nanoparticles

Nanoparticles are employed as pharmaceutical drug carriers for both diagnostic and therapeutic purposes. These nanoparticles, which include polymeric, nano-emulsions, liposomes, and solid NPs, have a great impact on clinical applications. Both chemical and physical characteristics, drug loading efficacy, release of drugs, as well as significantly, the carrier's low or no toxicity all influence their therapeutic application (Najahi-Missaoui et al., 2021). Controlling drug release inside a body, protecting pharmaceutical compound, being tinier than cells, attempting to cross

biological barriers to transport the drug to the desired location, maximizing drug duration in blood flow, and specific drug delivery at the target position are all examples of drug delivery methods, and biocompatibility is one of their distinctive attributes that can improve the efficacy of therapeutic drugs (Aghebati-Maleki et al., 2020). NPs size is an important property for DDS. It maintains the dispersion, bioavailability, biological systems, toxic effects of cells, and drug targeting of nano system. NPs are routinely adjusted in size to minimize penetration into bloodstream while remaining small enough to evade reticuloendothelial system macrophage and prevent NPs from being eliminated from the system. Also, the tinier the size of the NPs, the higher the drug capacity and the possibility for therapeutic targeting. Numerous studies on stimulus-triggering by nanoparticles or the tumor microenvironment have been conducted in order to modify the sizes of nanomedicines based mostly on size effect. Particles as small as 12 nanometers can reach the cancer cells more easily than larger nanoparticles. (Raj et al., 2021).

1.4 Nanoparticle based Drug Delivery in Cancer Treatment

As nanotechnology advances, nanoparticles may become a promising tool for controlled DDS. Nanoparticles are tiny particles with the size from 10-100 nanometer. When employed as a DDS, nanoparticles can enhance therapeutic efficacy by prolonging drug half-life, increasing solubility level for some hydrophobic drugs, as well as release of drugs in a regulated or sustained manner. Stimuli-responsive NPs may potentially aid in toxicity reduction and drug biodistribution management (Dang and Guan (2020). The drug delivery mechanism is accomplished by NPs in two ways and they are active and passive targeting. Systems are directed toward a specified location depending on physical anatomical circumstances in the passive targeting procedure. NPs lower than 100 nanometers can move easily via the capillary of the reticuloendothelial system and enter hepatitis and spleen macrophage. People who suffering from both splenic and hepatic problems can be treated properly utilizing current understanding. The drug initially enters and accumulates in the macrophage, indicating its efficacy. Macrophages act as a protective system in the treatment of splenic and hepatic disorders (Aghebati-Maleki et al., 2020). Active targeting incorporates binding components such as antibody and peptide to receptor structures generated in the targeted location using a drug delivery mechanism. The drug-delivery combination generated by passive targeting circulating in the bloodstream and therefore is aimed directly to the specified location by affinity or binding, which is influenced by variables such as temperature, pH, molecule position, and structure.

The primary targets in the body are cell membrane receptors, lipid components of cell membranes, and antigens or proteins onto cell surface membrane. The majority of nanoparticle drug delivery methods are now aimed at cancer prevention and cure (Patra et al., 2018).

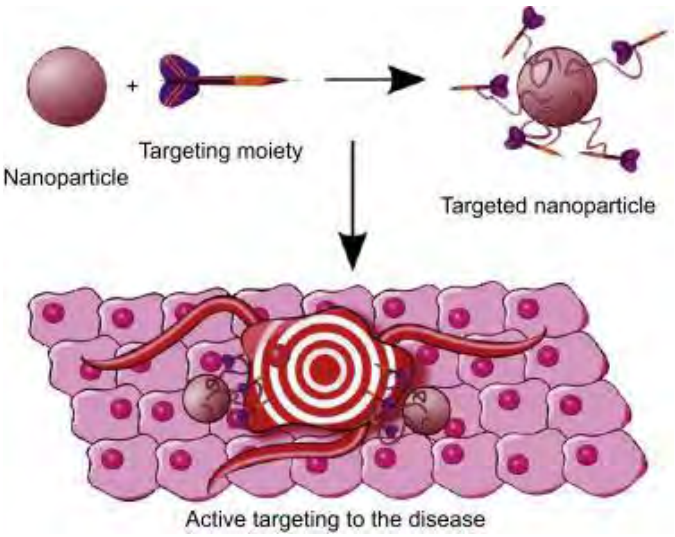

Figure 1: Schematically represented active targeting mechanism of nanoparticles (Paul & Sharma, 2019).

1.5 Types of Nanoparticles

DDS discovered and used liposomes as drug and protein carriers for the first time in the 1960s. Since then, an increasing number of materials have been manufactured into nanoparticles and employed as DDSs. Polymeric and liposomal materials represent a significant part of all authorized nanoparticle materials (Dang & Guan, 2020). Recently, the theranostic nanoparticle is another approach which becomes more crucial in research. Theranostic nanoparticles can aid in disease diagnosis, report location, identify disease stage, and provide information on therapy response. Furthermore, these nanoparticles may transport a drug molecule for the tumor, delivering the therapeutic agent at the needed concentrations by molecular or environmental factors (Patra et al., 2018). This review paper will look at the most recent breakthroughs in nanoparticle drug delivery methods in cancer treatment.

1.5.1 Liposomes

Liposomes, which are sphere vesicles formed from a naturally occurring phospholipid, significantly observed nanoparticles used in enhanced DDS. They are made up of several lipid bilayers separated

by aquatic gaps. Because of their amphipathic character in aqueous settings, which allows them to entrap both hydrophilic (polar) and hydrophobic (nonpolar) molecules, they are well established for a number of pharmacological and biological uses (Olusanya et al., 2018). Liposomes are biodegradable and biocompatible, and their lipids content can be controlled. Liposomes can also be changed in a variety of ways to optimize their efficacy as drug delivery vehicles. To create bioconjugates for certain cell and tissue types, liposomes can be customized with protein and small molecules. Because of the broad spectrum of medicines and tiny molecules that liposomes may be employed in cooperation with other agents to monitor tissue or cells while also delivering drugs or cellular monitoring and drug delivery (Almeida et al., 2020). Active liposome targeting system may increase the liposome selectivity which interacted with sick cell, culminating in receptor-mediated endocytosis of the NPs and its cargo into specific cellular targets. Based on cancer cells' improved capacity for permeability and retention, several liposome nanoparticle are authorized for passive targeting based DDS. Because passive targeting cannot differentiate between normal and damaged tissues, cell-specific targeting-based liposomes are developed to increase anti-tumor substance aggregation and localization in diseased cells. Targeting of Liposome might be increased by the addition of specific molecular moieties, resulting in more effective drug delivery with less adverse reactions (Nsairat et al., 2022). The desirable specific target DDS is comparable to a multistage rocket. It needs to be cancer and tumor cell specific, or perhaps even gene specific. To start, environmentally sensitive liposomal drugs collect and release drugs in tumor settings. Furthermore, the changed liposomes may bind to a particular receptor with cancer cells preferentially. Finally, in peculiar environment of cancer cells, liposomes that are entirely absorbed by cancerous cells release drugs swiftly. Meanwhile, liposomal drugs in the systemic circulation prolong circulating times as well as detect tumors that are unable to be removed surgical or identified without subjecting the full body to an unbearable higher loading drug (He & Tang, 2018).

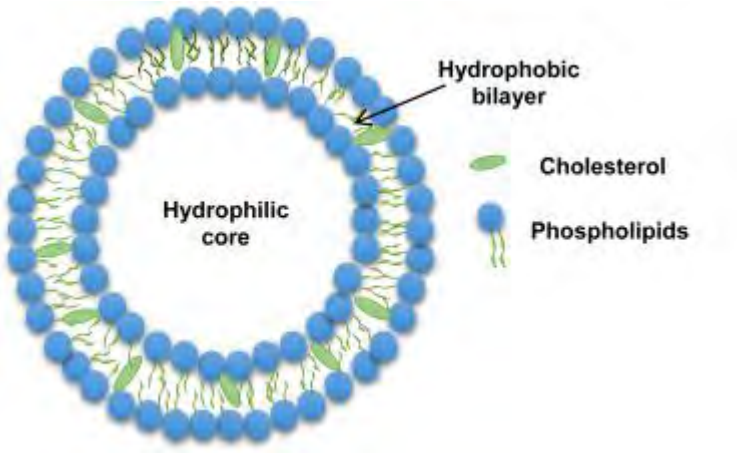

Figure 2: Schematically represented liposomes (Nsairat et al., 2022).

1.5.2 Polymer

Due to their distinct pharmacokinetic, circulating time, biocompatibility, or biodegradability, polymers are attractive drug delivery techniques. They can reduce cytotoxic nature after chemotherapeutic drug administration, improve therapeutic drug solubility, and delay tumor development (Salari et al., 2022). Polymeric nanoparticles may appear as nanospheres or nano capsules, depending on the manufacturing process. Nanospheres seem to be polymeric shell systems that contain the drug inside an aqueous or oily core, while nano capsules appear to be polymeric shell structures that contain the drug within an aquatic and greasy center. Again, physical qualities of nanoparticles, including shape, size, stability, drug-release features, and surface properties, all can impact how they behave in complex biological systems (Gagliardi et al., 2021). Polymeric nanoparticles also seem to be tiny particles with sizes ranging from 1 to 1000 nm that can be packed with active compounds and trapped in the polymer core or surface-adsorbed onto it. Polymeric nanoparticles have caught the attention of scientists and researchers in recent decades due to their remarkable features coming from their small size. As drug carriers, polymeric nanoparticles can protect pharmaceuticals and other physiologically active compounds from the environment while simultaneously enhancing bioavailability and therapeutic index (Zielinska et al., 2020). Adsorbed, encapsulated, or conjugated anticancer drug is adsorbed, encapsulated, or converted within or onto the surfaces of the Polymer nanoparticles. A targeted delivery method employs drug-loaded polymer nanoparticles to deliver anticancer medicines to specific areas. Current improvements of targeted drug delivery system are based on rational polymer design. Polymer nanoparticles may

deliver only the necessary dose of anticancer drug to the tumor location over time. It should be encouraged to apply specific genes in the development of active tumor-targeting strategies by using polymer NPs to evaluate tumor growth, development, and clinical outcomes (Masood, 2016).

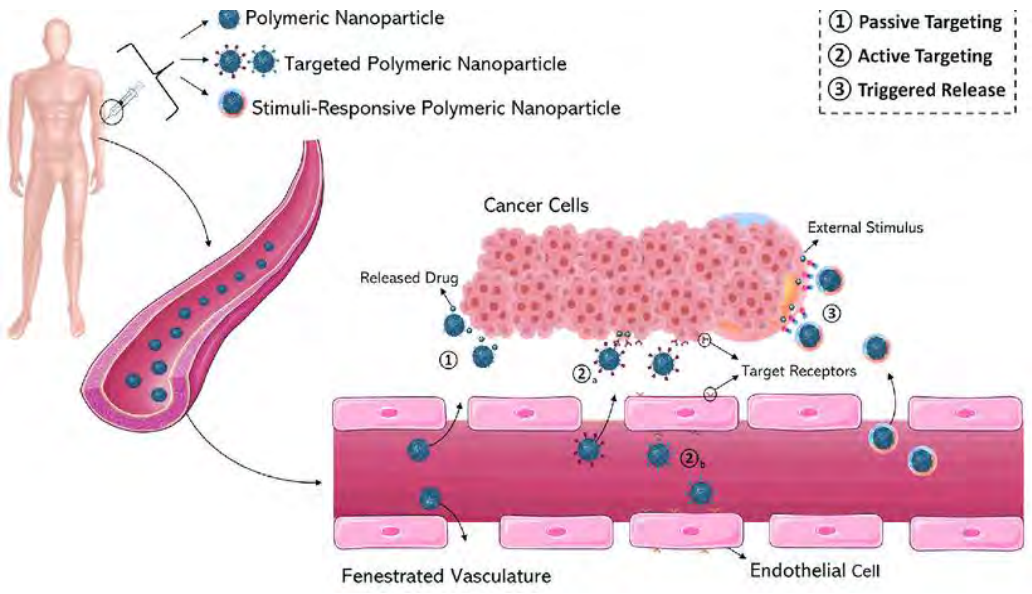

Figure 3: Schematic illustration of different drug targeting strategies. (1) Extravasation-based passive targeting of nanocarriers across tumor tissue's fenestrated vasculature. Using ligand-modified nanocarriers, active targeting of tumor endothelium (2a) and cancer cells (2b). Nanomedicines that are stimuli-responsive and can release an anticancer drug in response to internal or external triggers (Gagliardi et al., 2021).

1.5.3 Theranostic Nanoparticles

Many multifunctional, nano-theranostic techniques which incorporate therapy, imaging, and malignancy targeted activities in a particular system are progressed to eliminate the limitations of standard medications. Theranostic nanoparticles, which combine treatments and diagnostics on the same platform, have been developed and may be able to deliver more such as optimal therapeutic personalized treatment periods, doses, etc. by using imaging technologies for monitoring both adaptation and heterogeneity in cancer (Anani et al., 2021). Cancer detection and treatment have improved in recent years as a result of nanoparticles' physicochemical qualities and the capacity to

modify the surfaces of nanoparticles for selective targeting. Theranostic nanoparticles are often generated by combining one or even more inorganic components, organic components, and minimum one of each with specific physiochemical properties such as imaging and electrical properties, temperature and magnetic properties, and Ultra violet shielding capabilities (Carrese et al., 2022). Lately, Gold and Iron oxide-based NPs have become particularly popular as nanotheranostic agents in canter treatment medication approaches, with these NPs combining drug transport, imaging, and therapy. TNPs could be employed to lessen the requirement for frequent and unpleasant dose while enhancing overall pleasure (Mendes et al., 2018). Nanoparticles, magnetic nanoparticles, gold nanoparticles, silica nanoparticles, and quantum dots have already been used for developing nanoparticle-based theranostic drugs. These NPs formulations provide a few image probes that can detect cancer in its early stages. However, their metallic or inorganic makeup increases the risks of poisoning, immunogenicity, and delayed elimination, necessitating a careful clinical evaluation (Indoria et al., 2020).

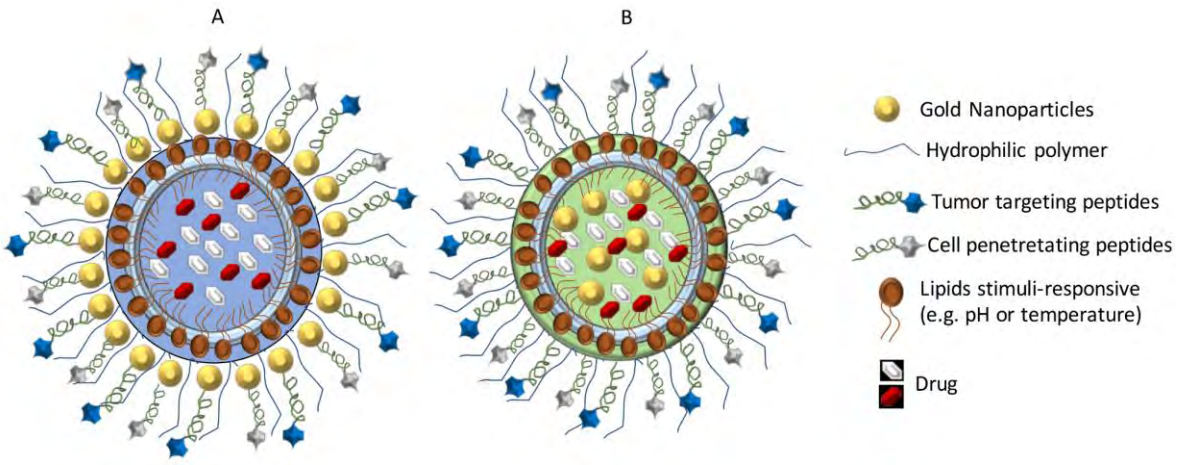

Figure 4: Two concepts of TNPs with properties having tiny size with 100 nanometer, active targeting, and stimuli-responsive targeting: (a) Electrostatically connected Gold NPs on the NPs surface; and (b) Gold NPs having lipophilic properties enclosed in NPs (Mendes et al., 2018).

1.5.4 Inorganic Nanoparticles

Iron, Gold and Silica based NPs are Inorganic elements which might assist to produce NPs for a wide spectrum of imaging and drug-delivery purposes. Because they are precisely formulated, these inorganic Nanoparticles can be manufactured in a different size, shapes, as well as geometry. So, Gold NPs, extensively explored Nanoparticle, is employed in a range of shapes, including

nanospheres, nanorods, nanostars, nanoshells, and nanocages. Free electrons in AuNPs, for example, fluctuate at a frequency that varies with their size. In addition to their photothermal properties, AuNPs can be easily functionalized to acquire other characteristics and transport capacities (Mitchell et al., 2021). Inorganic nanoparticles have drawn the attention of researchers in preclinical phase as potential diagnostic and therapeutic systems in cancer for a range of applications including cancer diagnostics, tumor drug administration, and radiation enhancement. Inorganic NPs are substantially more stable, water-loving, and biocompatible than organic compounds (Paul & Sharma, 2019).

1.6 Significance of Nanoparticle Drug Delivery

Nanoparticles aim to give a more efficient drug delivery system than traditional anti-cancer drugs by lowering the toxicity level and offering more excellent antineoplastic effects such as ease of manufacture and active tumor targeting activity (Liu et al., 2021). Nanoparticles' main aim is to target tumors and regulate drug release to specific areas, promoting therapeutic drug efficacy while lowering toxicity to normal tissues or organs. Furthermore, nanoparticles can stimulate immune cells against malignancies. As a result, nanoparticles possess significant promise for the study and treatment of cancer in the future (Tran et al., 2020). The development of nanoparticles is still centered on enhancing delivery platforms in a one-size-fits-all manner. Liposomes, Polymer and inorganic nanoparticles become more precisely engineered, they can be customized for more personalized drug delivery, bringing in the era of targeted medicine (Mitchell et al., 2021). The main intention of this article is to discuss nanoparticle-based drug delivery systems in cancer therapy, including, Liposome, Polymer NPs drug delivery, nanocage, theranostic drug delivery, and gold nanoparticle delivery systems. This study will also cover the most recent advances, existing constraints, and future prospects for these nanoparticles in cancer treatment.

1.7 Aims And Objectives

The main goal of this project work is to review a novel drug delivery system, nanoparticles, as well as recent breakthroughs in nanoparticles and future elements of nanoparticle DDS for cancer treatment.

Objectives

- To identify several types of recent nanoparticle drug delivery systems
- To understand how these nanoparticles' drug delivery assist in cancer treatment
- To evaluate these nanoparticles drug delivery system whether it shows any toxicity or not and also evaluate the effectiveness level of cancer treatment over other conventional drug delivery.
- Recent progress in nanoparticle drug delivery systems in cancer treatment.

Chapter 2

Methodology

For this review, relevant literature which is related to Nanoparticle drug delivery system in cancer treatment was chosen, analyzed, and summarized. This review's information and data were gathered from relevant articles. According to this work, it was important to explore the several types of nanoparticles and their delivery system as well as the need to know about the recent advancements and future aspects of nanoparticle drug delivery systems to treat cancer.

To gather sufficient information as possible regarding nanoparticle drug delivery to treat cancer disease, a thorough search of several journals, review articles, and research papers from official websites and research databases was carried out. Utilizing well-known and reliable sources including PubMed, Springer, Google Scholar, Science Direct, and Scopus, the articles for this review study were collected. Relevant articles are gathered using appropriate keywords such as recent developments in nanoparticle drug Delivery System, Theranostic, Polymer nanoparticles, Inorganic Nanoparticles, Liposome Nanoparticles, and Nanocage. Articles were chosen carefully individually for different types of nanoparticle drug delivery systems. Recent articles are collected for writing this review paper. All the figures in this review were relevant to the topic and citations are done properly. All the published articles between 2016 to 2023 are collected. As a result, recent and new information is included in this review. Many relevant papers were collected and half were reduced by reading their abstracts. Mendeley software played an important role in writing this review. In-text citations and bibliography were added by using Mendeley software. All the citations and bibliography were included by using APA 6^{th} edition format.

Chapter 3

Result

According to Gu et al. the unique capabilities of nanotechnology in DDS, diagnostics, and imaging are driving tremendous expansion in its implementation in cancer therapy. These properties make nanoparticles highly promising for clinical uses. Liposome NPs, Polymer NPs, inorganic NPs, and virus types NPs are examples of nanoparticles that have been utilized to improve the DDS of chemotherapeutics, radiation treatment, therapy of gene and immunotherapy (Gu et al., 2020). Additionally, Sahu et al. explained Polyvalent targeting ligands can be linked to nanoparticles which have higher affinity level and specification for target cells. Nanoparticles can be tailored to take multiple therapeutic substances, allowing for simultaneous cancer treatment (Sahu et al., 2021).

According to Almeida et al., Liposomes have grown in popularity as drug delivery carriers and delivering molecules, and they are now the most common nanoparticle drug delivery technology that is FDA authorized for clinical usage. Clinical research of lipid nanoparticles products are currently focused on enhancing already-approved pharmaceutical formulations using liposomal encapsulation. This study of chemotherapeutic liposomal formulations is well-known because liposome NPs can protect the cells from the anticancer activity of the encapsulation of drug. Nevertheless, there are several documented advantages of using liposomal encapsulation over traditional methods, including improved tumor site delivery, efficiency, and lower toxicities, and all of these are main purpose for most new medications entering clinical trials (Almeida et al., 2020). Moreover, according to Olusanya et al., Because surgical removal, radiation treatment, and chemotherapeutic serve as initial treatments for cancer, this feature is very beneficial in cancer treatment. The natural tissue uptake of chemotherapeutic medications is limited by encapsulating them in liposomal structures, improving their therapeutic index. Liposomes can preferentially cluster in the tumor throughout 24-48 hours because of the vasculature's improved permeability and retention effect, in which leaky tumor veins combine with absent lymph outflow. Liposomes may target tumor tissues in an active way via an antibody technique. This can be performed by attaching particular antibodies, known as immunoliposomes (ILP), to the liposomal surface which are particular to the tumors or endothelial in the tumor vasculature (Olusanya et al., 2018).

Table 1: Comparison between Conventional Drug delivery and Nanoparticle Drug Delivery

Conventional DDS	**Nanoparticle DDS**
Targeting specificity cannot be accomplished here. (Sur et al., 2019)	Nanoparticles are target specific. (Dang & Guan, 2020)
Conventional drug delivery systems can not produce a better significant therapeutic effect than nanoparticle drug delivery systems. (Shivakalyani & Seeram, 2021)	Nanoparticle drug delivery system can give better therapeutic effect (Shivakalyani & Seeram, 2021).
Conventional drug delivery systems show higher renal toxicity than nanoparticle drug delivery systems. (Shivakalyani & Seeram, 2021)	Nanoparticle DDS can reduce the renal toxic effects. (Shivakalyani & Seeram, 2021)
Conventional drug delivery has a lower half-life and lower solubility than nanoparticle drug delivery. (Sur et al., 2019)	Nanoparticles can increase both the solubility level as well as drug's half-life (Carrese et al., 2022)
It shows inadequate drug biodistribution than nanoparticle drug delivery. (Dang & Guan, 2020)	Nanoparticle DDS are capable of controlling drug biodistribution. (Dang & Guan, 2020)

According to Sur et al., the growing use of polymeric NPs was attributed to their smart polymer application, target selectivity, and reduced adverse effects. Until recently, it was difficult to cure diseases that required target-specific intervention, such as cancer. Yet, cancer treatment is no longer a disaster thanks to the invention of polymeric nanoparticles. Polymeric nanoparticles transport drugs not only to a particular site but also at a specified rate, which is important for treating several illnesses (Sur et al., 2019). Gagliardi et al., explained, to enhance anticancer effectiveness, inhibit metastasis, and reduce effective dose and adverse effects, many chemotherapeutics are encased in Polymeric DDS. Furthermore, polymers which are non-degradable typically needed longer degradation duration than their effective application duration, in contrary, the degradation rate of biodegradable nanomaterials might be affected due to a wide range of variables, such as their physicochemical characteristics and outcasts events and that are pH and temperature (Gagliardi et al., 2021).

In another review paper, according to Anani et al., Theranostic nanoparticles showed both therapeutic and diagnostic purposes. The four major parameters that must be improved to achieve theranostic efficiency, are all-in-one imaging, therapeutic potential, reduced toxicity, and tumor target specificity. MRI-guided nano theranostics and techniques used to improve chemotherapeutic efficacy, such as overcoming tumor barriers, improving active target system via dual receptor targeting process, or employing numerous cancer targeted methods. Increasing anticancer efficacy with dual-drug administration, and overcoming MRI limitations with multimodal imaging (Anani et al., 2020).

Table 2: Summary of recent nanotechnologies used in cancer Treatment

Name	**Descriptions**	**Reference**
Liposome Nanoparticle	Liposomes can be prepared easily and shows high biocompatibility. Recently, there are an increasing	(Filipczak et al., 2020)

	number of FDA approval liposomal-based therapies on the market, and more and more in clinical phases, covering a wide range of anticancer treatments.	
Polymer Nanoparticle	Polymer NPs have been improved and studied for their effective cancer treatment. Numerous different forms of pH-sensitive nano vehicles have been created for drug delivery into tumor tissue efficiently. Currently, a lot of interest is seen in polyamidoamine dendrimer as a novel nanotechnology synthetic polymer, especially in DDS. It is highly invasive and has a positively charged surface.	(Cheng & Ji, 2019).
Inorganic Nanoparticle	Currently, inorganic NPs such as gold nanoparticles and iron-oxide NPs in cancer treatment, and numerous treatments are already in clinical studies. Gold nanoparticles have gained	(Paris et al., 2019)

	greater prominence in the therapeutic field over the past few years than other inorganic nanoparticles because of their unique optical properties, as well as their high biocompatibility and less adverse effects.	
Theranostic Nanoparticle	Despite the fact that theranostic approaches to cancer diagnosis and treatment have enormous promise to improve human health, clinical application is still a long way off. Furthermore, this strategy provides the solution to common challenges associated with traditional diagnostic and treatment procedures when utilized independently, as well as saving time and money.	(Carrese et al., 2022)

Chapter 4

Discussion

Polymer NPs, Liposomes NPs, and Inorganic NPs were used to modulate the release of therapeutic drugs inside tumor tissue, lowering dosage frequency and enhancing patient compliance. Polymeric nanoparticles have emerged as an exciting cancer therapy strategy in the arena of nanotechnology since their composition and form may be customized according to the requirements of the patient. Because these polymers are biocompatible as well as biodegradable, they have lower toxicity and higher bioavailability. Polymeric nanoparticles found recently shown increased activity and monitoring capacities during therapeutic drug administration. In recent years, hyaluronan/polyethyleneimine-coated Polymer NPs for the targeted administration named Docetaxel to lung carcinoma cells with CD4 receptors were developed (Sharma et al., 2019). They have significant benefits over some other nanoparticles such as liposomes, micelles, and inorganic nanoparticles, including scale-up and Good Manufacturing Practices compliance (Gagliardi et al., 2021). The production of NPs enabled for the specific location of action to be identified, avoided high systemic concentrations and limited adverse reactions. This trait has proven particularly beneficial for detecting cancer by combining selectively target with the administration as well as contrast agent release. Polymers are not just a distinct sort of material that can have all of the features such as biodegradability and biocompatibility, but their high synthetic adaptability allows researchers to modify them to specific needs or goals Thus polymers can easily be modified according to the needs than other nanoparticles. Because of their surface modified characteristics and ability for controlling the solubility of the embedding agents due to maximize tumor tissue imaging, they have also been noticed (Begines et al., 2020). Polymeric NPs can protect pharmaceuticals and other biologically active compounds from the environment while also increasing bioavailability and therapeutic index. Polymers act as inert carriers for pharmaceuticals, permitting the polymers to act as a transporter to convey the drug molecule to the desired region. As a result, it is unable to influence other normal tissue (Zielinska et al., 2020). Several chemotherapeutics have been found to be combined into polymeric delivery techniques in order to boost antitumor efficacy, limit metastasis, and reduce efficacious dosage and harmful impacts. Within their structure, polymers can encapsulate or adsorb an active ingredient. Polymers which are non-degradable are needed longer degradation times for their effective application, whereas

biodegradable polymeric nanoparticles degradation rate might be effected by different variables, including their physicochemical characteristics such as size, framework, or molecular weight and external events such as temperature and pH. Both FDA and the European Medicines Agency have approved biodegradable polymer materials for pharmaceutical application. Generally, biodegradable Polymeric NPs have lower toxicity level, are even more biocompatible, and allow for drug release kinetics management. (Gagliardi et al., 2021).

Nanotheranostics is a fast-evolving pharmaceutical technology that monitors medication release and distribution while also assessing real-time treatment effectiveness on nanometer for the treatment and diagnosis of serious diseases like cancer. Biodegradable polymers and biomolecules like as nucleic acid, peptide, and protein have been discovered to be vital and powerful Polymer therapies in past years. The development of Polymeric DDS techniques was motivated by nonspecific distribution, half-life, and toxic effects of therapies or therapeutic chemicals. Using polymer nano-particles for theranostic applications has several advantages, including adjustable physicochemical properties, regulation of surfaces charges, shape of particles, and degradation rate. It may easily move many imaging probes or medicinal compounds, and its surface observed to be manipulated with many different targeting molecules. It may also spontaneously degrade into innocuous and nontoxic components inside the body (Indoria et al., 2020). Furthermore, multifunction vectors with cancer imaging, medication loading, and targeting properties were produced using pH-sensitive polymeric nanoparticles to build MRI-based theranostics (Li et al., 2018). MRI-guided nanotheranostics can easily overcome chemotherapy effects. Although huge improvements in the development of MRI-targeted nanotheranostic systems and their tremendous promise for predictive, preventative, and personalized treatment, information gaps continue, and hardly any nanotheranostic systems have been clinically tested. It might be happened for a variety of factors, including complex hybrid nanosystems, observed difficulty in understanding this nanoparticle, immune response interacted by biologicals and toxic effects species-dependent profiles, difficulty managing the pharmacokinetic and biodistribution characteristics, tentative release of the therapeutic cargo in blood capillaries and normal tissues, and significant change in toxicity concerns between animal models (Anani et al., 2021).

Polymers and Liposomes both are organic nanoparticles that are observed more effective in nanoparticle drug delivery in cancer treatment. Both nanoparticles showed amphiphilic in nature

and were also convenient to modify their surfaces. These particles are observed release at a distinct time and deliver drug to a specified site which reduces the toxicity and gives more effective treatment. There is a significant use of polymer NPs are biodegradable. Vesicular nano-capsules and matrix systems are seen in polymer NPs which is known to be nano-spheres (Aghebati-Maleki et al., 2020). However, Liposomes NPs are spherical shaped vesicles and comprised of lipid bilayers separated by distinct aquatic gaps. In addition to delivering chemotherapeutic drugs to the desired site of action, these nanocarriers minimize elimination and toxicity and shield them from the surrounding environment. Liposomes can be surface-functionalized with a variety of biomolecules to achieve receptor-specific targeting (Olusanya et al., 2018). Liposomal Doxorubicin which is a liposomal nanotechnology and approved by FDA used to treat metastatic Breast Cancer. Another drug is Paclitaxel which is a Polymer nanotechnology approved in Korea to treat Breast Cancer (Raj et al., 2021).

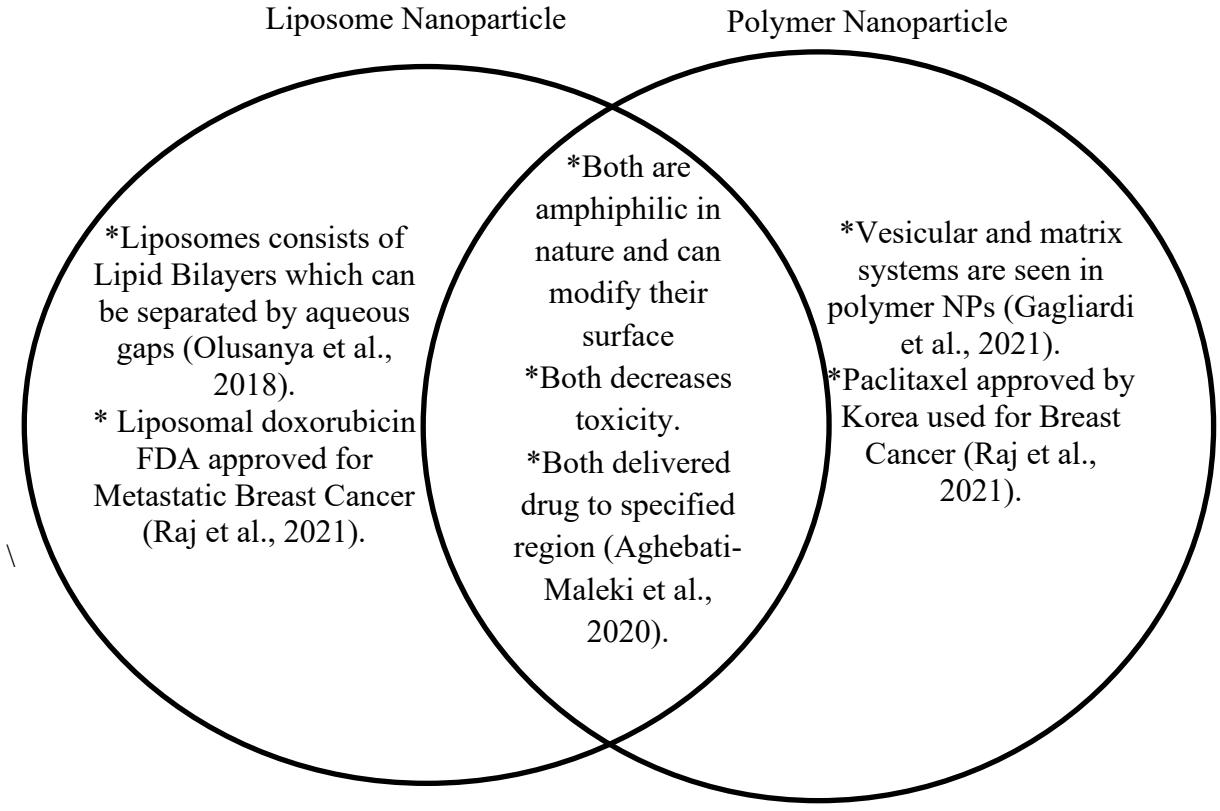

Figure 5: Compare and Contrast between Liposome Nanoparticle and Polymer Nanoparticle

Chapter 5

Conclusion

Researchers all across the nation are investigating nanoparticles as a viable technique for DDS and successful therapies. Nanoparticles has enormous potential for cancer therapy throughout cancer research. Nanoparticle surfaces, as well as their small dimensions and shape, have been used as distinguishing qualities of NPs to contribute significantly in efficient therapy and targeting. Nanotechnology depended diagnostics and treatments are extremely promising solutions for simple and low-cost cancer detection (Raj et al., 2021). DDS's most effective purpose is represented by NPs. Polymeric NPs, liposomes, metals, and other carriers are used in medication delivery for a range of illnesses, including cancer. NPs can be used to identify and treat diseases, administer medications, and do biomedical imaging. Nanotechnology advancements will increase the ability to target several chemicals in tumor samples at the same time and use appropriate therapy tactics. NPs use in the treatment of cancers is increasing day by day. These breakthroughs could pave the path for tumor antigen targeting. In the coming years, nanoparticle technology will trigger a tremendous change not just in oncology but also in all medical sectors. (Aghebati-Maleki et al., 2020). Nanoparticles possesses a wide range of opportunities, particularly in the treatment of diseases such as cancer. Scientists anticipate that nanomedicine will increase the therapeutic index by improving the efficacy of delivery of drug in target organs and controlling release of drug at a particular location. As a result, in order to gain community support, the ethical, social, as well as economic aspects of nanoparticles must be appropriately addressed. Despite efforts to raise knowledge regarding the application of nanoparticles in humans, there is confusion more about adverse outcomes to which individuals could be exposed while using nanoparticle. Further medical trials utilizing nanoparticle which are required for clear confirmation. In clinical research, major ethical considerations include risk assessment, management, and communication (Sahu et al., 2021).

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