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How Nanotechnology is used for Targeted Drug Delivery

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A B S T R A C T

Nanotechnology has revolutionized the field of targeted drug delivery by offering precise control over drug release, biodistribution, and pharmacokinetics. This paper explores the key mechanisms and statergies employed in nano-based targeted drug delivery systems. Nano-sized drug carriers, such as liposomes, polymeric nanoparticles, and dendrimers, enable the encapsulation of therapeutic agents, protecting them from degradation and facilitating their delivery to specific sites within the body. Surface modifications and functionalization techniques further enhance targeting efficiency by promoting specific interactions with target cells pr tissues. Additionally, stimuli-responsive nano carriers respond to external cues, such as pH, temparature , or enzymatic activity, triggering drug release only at the desired location. The ability of nanotecnology to overcome biological barriers and delivery drugs selectively to diseased tissues holds great promise for improving therapeutic outcomes while minimizing systemic side effects.

Keywords: Nanotechnology, Liposomes, Polymeric nanoparticles, Dendrimers.

1. Introduction

The emergence of nanotechnology has revolutionized the field of drug delivery, offering unprecedented opportunities for precise targeting of therapeutic agents to specific sites within the body. Conventional drug delivery systems often suffer from limitations such as poor bioavailability, non-specific distribution, and systemic toxicity, hindering their therapeutic efficacy. Targeted drug delivery, enabled by nanotecnology, addresses these challenges by delivering drugs selectively to diseased tissues while minimizing exposure to healthy tissues, thus maximizing therapeutic efficacy and minimizing adverse effects. Nanotechnolog-based drug delivery systems utilize nanoscale materials as carriers for therapeutic agents, allowing for precise control over drug release kinetics, biodistribution,and cellular uptake. These nanocarriers can be engineered with a high degree of precision, enabling them to traverse biological barriers and target specific cells or tissues through active or passive mechanisms. Moreover, the small size of nanoparticles facilitates their accumulation in tumor tissues via the enhanced permeability and retention (EPR) effect, making them them particulary well-suited for cancer therapy. Various types of nanocarriers, including nanoparticles, liposomes, dendrimers, and micelles, have been developed for targeted drug delivery applications. These nanostructures can encapsulate a wide range of therapeutic agents, including small molecules, proteins, peptides, and nucleic acids, offering veratility in drug delivery. Furthermore, the surface of nanocarriers can be functionalized with targeting ligands such as antibodies, peptides, enabling specific recognition and binding to target cells or tissues.

2. Literature survey

Paper 1

Title : "nanotechnology-based drug delivery systems: an overview".

Authors : Pankaj Kumar Sing and Parul Dubey.

Published on : 2 may 2023.

Description : This paper provides an overview of various nanotechnology-based drug delivery systems and their applications in targeted drug delivery.

Paper 2

Title : "Targeted drug delivery systems: Promises and challenges".

Author : Ravi Kant Upadhyay.

Published on : Dec 2021.

Description : This paper discusses the promises and challenges associated with targeted drug delivery systems, including those based on nanotechnology.

Paper 3

Title : “Nanotechnology-based approaches for targeting and delivery of drugs and genes”.

Author : Sangiliyandi Gurunathan.

Published on : 23 Jan 2019.

Description : This review article discusses various nanotechnology-based approaches for targeting and delivering drugs and genes, including nanoparticles, liposomes, and polymeric nanoparticles.

3. Action mechanism of nano drug delivery systems

When designed to avoid the body’s defense mechanisms nanoparticles have beneficial properties that can be used to improve drug delivery. Various nanoparticle formations have been disseminated in drug development in an attempt to increase efficasy, safety and tolerability of incorpted drugs. Nanoparticle based formulation have shown high solubility, control release, improved pharmacokinetic and pharmacodynamic properties. Particle size, surface charge and shape play important roles in creating effective nanoparticle delivery systems that function through a variety of mechanisms.

1. **Particle size:** Particle size and size distribution are the most important characteristics because these determine the chemical and physical properties of nanomaterials. The hydrodynamic size and size distribution determine the in vivo distribution, biological fate, toxicity, and targeting ability of these nanpmaterials for drug delivery system. They can manipulate drug loading, its release and stability. It has been reported that nanomaterials are advantageous over micro scale particles and due to small size and high mobility that make them capable of higher cellular uptake suitable for wider range of cellular and intracellular targets.
2. **Surface charge:** Surface charge is usually expressed and measured in terms of the nanomaterials zeta potential which reflects the electrical potential that is influenced by its composition and the the medium in which it is dispersed. Zeta potential having a value of ±30 mv have been reported to be stable in suspension leads to preventing aggregation of particles. Surface charge of nanomaterials is crucial to drug loading. Drugs can be loaded via a number of processes such as covalent conjugation, hydrophobic interaction, charge-charge interaction or encapsulation. Loading of molecules depends upon nature of drugs as well as nature of targeti molecule, also alters the determined on the surface of nanopaticle.
3. **Drug loading:** Incorporation of a drug on or in nanomaterials is reffered to as drug loading. An ideal nanoparticles drug delivery system should have a high drug-loading capacity without aggregation. High drug loading capacity can minimize administration or the number of doses. Dispersibility is needed for smooth and efficient delivery of the drugs. Drug loading can be accomplished in several ways; however, drug loading and entrapment efficiency depend on drug solubility in the nanoparticles, dispersion medium, nanomaterials size and composition, drug molecular weight (MW) and solubility, drug-nanomaterials interaction, and/or the presence of surface functional groups (i.e carboxyl, amine, ester, etc.) on either the drugs or on the nanomaterials.
4. **Drug targeting:** Targeting of tumar leads to improving chemotherapy by nanomaterials provide a highly specific and versatile platform for cancer treatment. Enhancement permeability and retention enables selective localization in tumar spontaneously due to fenestrated blood vessels as in case of drug loaded liposome (doxorubicin-liposome complex). It has been shown to effectively improve selective localization in human tumors in vivo of small-molecule drugs such as doxorubicin as demonstrated by nanosize liposomes target tumors spontaneously because of the fenestrated blood vessels.
5. **Binding to the receptor sites:** conventional drug carriers lead to modification of the drug distribution profile as it is delivered to the MPS (mono phagocytic system) such as liver, spleen, lungs, and bone marrow. However, nanoparticles as drug carriers can be recognized by the host immune system when intravenous administered causing them to be cleared by phagocytes from the circulation. The size of the nanoparticles, surface hydrophobicity, and surface coating functionalities determine the level of blood components (e.g opsonins) that bind to its surface influencing the in vivo fate of nanoparticles.
6. **Release of drug:** the process of diffusing or dissolution drug in the body, which is loaded into nanoparticle, is known as drug release whiloe biodegradation refers to collapsing the drug delivery system inside the baby. Both drug release and biodegradation are important to consider when developing a nanoparticle drug delivery system. Besides active components, solubility, diffusion and particle size also determines the effectiveness of the drug.

4. Advantages and Applications

4.1 Advantages

1. Reduced toxicity.

2. Improved permeability to target sites.

3. Reduced side effects.

4. Enhanced bioavailability.

5. Increased efficiancy.

4.2 Applications

1. Cancer therapy.

2. Brain drug deivery.

3. Treatment of infectious diseases.

4. Cardiovascular therapy

5. Skin disorders.

5. Conclusion

Last few years several new technologies have been developed for the treatment of various diseases. 6the use of nanotechnology in developing nanocarriers for drug delivery is bring lots of hope and enthusiasm in the field of drug delivery research. Nanoscale drug delivery devices present some advantages which show higher intracellular uptake than the other conventional form of drug delivery systems. Nanocarriers can be conjugated with a ligand such as antibody to favor a targeted therapeutic approach. The empty virus capsids arecalso being tried to use for delivering drugs as a new therapeutic strategy. Thus, nanoscale size drug delivery systems may revolutionize the entire drug therapy strategy and bring it to a new height in near future. Hpwever, toxicity concerns of the nanosize formulations should not be ignored. Full proof methods should be established to evaluate both the short-term and long-term toxicity ananlysis of the nanosize drug delivery systems.

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