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Nano materials in health Care

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Abstract:

"Nanomaterials have emerged as a transformative force in healthcare, showcasing immense potential in revolutionizing diagnostics, therapeutics, and medical device technology. Operating at the nanoscale, these materials exhibit unique physicochemical properties that enable precise interactions with biological systems, offering novel solutions to longstanding healthcare challenges. This abstract explores the multifaceted roles of nanomaterials in healthcare, encompassing targeted drug delivery systems, advanced diagnostic tools with heightened sensitivity, tissue engineering for regenerative medicine, and enhanced medical devices. While presenting promising opportunities for personalized and minimally invasive treatments, the abstract also addresses safety concerns, ethical considerations, and the imperative for comprehensive education and outreach to ensure responsible and effective integration of nanomaterials in healthcare."

Keywords: Nano medicine, Dendrimers, Liposome, Nanoparticle Albumin-bound (nab)

Nanomaterials have emerged as powerful tools in revolutionizing healthcare, offering unprecedented opportunities to address challenges in diagnosis, treatment, and disease management. At the nanoscale, these materials exhibit exceptional properties that enable precise interactions with biological systems, opening new frontiers in medicine. From targeted drug delivery systems to innovative diagnostic tools and advanced tissue engineering, the integration of nanomaterials in healthcare holds immense promise for

transforming the landscape of medical interventions, paving the way for more effective, personalized, and minimally invasive treatments.

Nanomedicine is a broad-spectrum field of science and technology that unites multiple streams of medical applications such as disease treatment and diagnosis, disease prevention, pain relieving technologies, human health improvement medicine, nanoscale technology against traumatic injury, and treatment options for diseases .Thus, an interdisciplinary approach is being adopted to apply the outcomes of biotechnology, nanomaterials, biomedical robotics, and genetic engineering combined under the broad category of nanomedicine

Nanotechnology in Diagnosis

Nanoparticle platforms have been developed and optimized for the detection of pathogens and cancer biomarkers such that diagnostic procedures now become less cumbersome but more sensitive because most of the complex procedures are now integrated onto a simple device having the capacity to be used for on-the-spot diagnosis.

Nanomedicine is an emerging approach for the implementation of nanotechnological systems in disease diagnosis and therapy. This branch of nanotechnology can be classified in two main categories: nanodevices and nanomaterials. Nanodevices are miniature devices at nanoscale including microarrays and some intelligent machines like reciprocates. Nanomaterials contain particles smaller than 100 nanometres (nm) in at least one dimension.

The application of conventional therapeutic agents has limitations such as non-selectivity, undesirable side effects, low efficiency, and poor biodistribution. Therefore, the focus of current research activities is to design well-controlled and multifunctional delivery systems.

As soon as nanoparticles enter to the bloodstream, they are prone to aggregation and protein opsonization (protein binding to nanoparticle surface as a tag for immune system recognition). The

opsonized nanoparticles could be cleared from the bloodstream by phagocytosis or filtration in the liver, spleen, and kidney. This rapid and non-specific clearance by the immune system results in decreased retention time and thus limits bioavailability. By decorating the nanoparticle surface with polyethylene glycol (PEG), carbohydrates, acetyl groups, or protein moieties (arginine-glycine-aspartate (RGD) peptide, albumin), retention time can be altered

Size is another important factor playing role in controlling circulation and biodistribution of therapeutic nanoparticles. Nanoparticles smaller than 10 nm, can be easily cleared by physiological systems (filtration through the kidney), while particles larger than 200 nm may be cleared by phagocytic cells in the reticuloendothelial system (RES). Accordingly, therapeutic nanoparticles with a size of <100 nm have longer circulation time in the bloodstream. Many studies reported that therapeutic nanoparticles in 20–200 nm size showed a higher accumulation rate in tumors because they cannot be recognized by the RES and filtrated by the kidney

Nanoparticle drug delivery:

Nanoparticle drug delivery systems are engineered technologies that use nanoparticles for the targeted delivery and controlled release of therapeutic agents. The modern form of a drug delivery system should minimize side-effects and reduce both dosage and dosage frequency. Recently, nanoparticles have aroused attention due to their potential application for effective drug delivery.

The National Institute of Biomedical Imaging and Bioengineering has issued the following prospects for future research in nanoparticle drug delivery systems:

1. crossing the blood-brain barrier (BBB) in brain diseases and disorders;
2. enhancing targeted intracellular delivery to ensure the treatments reach the correct structures inside cells;

3. combining diagnosis and treatment.

The development of new drug systems is time-consuming; it takes approximately seven years to complete fundamental research and development before advancing to preclinical animal studies.

Nanoparticle drug delivery focuses on maximizing drug efficacy and minimizing cytotoxicity. Fine-tuning nanoparticle properties for effective drug delivery involves addressing the following factors. The surface-area-to-volume ratio of nanoparticles can be altered to allow for more ligand binding to the surface. Increasing ligand binding efficiency can decrease dosage and minimize nanoparticle toxicity. Minimizing dosage or dosage frequency also lowers the mass of nanoparticle per mass of drug, thus achieving greater efficiency.

Current nanoparticle drug delivery systems can be cataloged based on their platform composition into several groups: polymeric nanoparticles, inorganic nanoparticles, viral nanoparticles, lipid-based nanoparticles, and nanoparticle albumin-bound (nab) technology. Each family has its unique characteristics.

Polymeric nanoparticles

Polymeric nanoparticles are synthetic polymers with a size ranging from 10 to 100 nm. Common synthetic polymeric nanoparticles include polyacrylamide, polyacrylate,—and chitosan.[1] Drug molecules can be incorporated either during or after polymerization.

Dendrimers

Dendrimers are unique hyper-branched synthetic polymers with monodispersed size, well-defined structure, and a highly functionalized terminal surface. They are typically composed of synthetic or natural amino acid, nucleic acids, and carbohydrates. Therapeutics can be loaded with relative ease onto the interior of the dendrimers or the terminal surface of the branches via electrostatic interaction, hydrophobic interactions, hydrogen bonds, chemical linkages, or covalent conjugation. Drug-dendrimer conjugation can elongate the half-life of drugs.

Inorganic Nanoparticles and Nanocrystals

Inorganic nanoparticles have emerged as highly valuable functional building blocks for drug delivery systems due to their well-defined and highly tunable properties such as size, shape, and surface functionalization. Inorganic nanoparticles have been largely adopted to biological and medical applications ranging from imaging and diagnoses to drug delivery.] Inorganic nanoparticles are usually composed of inert metals such as gold and titanium that form nanospheres, however, iron oxide nanoparticles have also become an option.

Toxicity

While application of inorganic nanoparticles in bionanotechnology shows encouraging advancements from a materials science perspective, the use of such materials in vivo is limited by issues related with toxicity, biodistribution and bioaccumulation. Because metal inorganic nanoparticle systems degrade into their constituent metal atoms, challenges may arise from the interactions of these materials with biosystems, and a considerable amount of the particles may remain in the body after treatment, leading to buildup of metal particles potentially resulting in toxicity.

Organic Nanocrystals

Organic nanocrystals consist of pure drugs and surface active agents required for stabilization. They are defined as carrier-free submicron colloidal drug delivery systems with a mean particle size in the nanometer range. The primary importance of the formulation of drugs into nanocrystals is the increase in particle surface area in contact with the dissolution medium, therefore increasing bioavailability. A number of drug products formulated in this way are on the market.

Liposome delivery

Liposomes are spherical vesicles composed of synthetic or natural phospholipids that self-assemble in aqueous solution in sizes ranging from tens of nanometers to micrometers. The resulting vesicle, which

has an aqueous core surrounded by a hydrophobic membrane, can be loaded with a wide variety of hydrophobic or hydrophilic molecules for therapeutic purposes.

Biological Nanocarriers

Viruses can be used to deliver genes for genetic engineering or gene therapy. Commonly used viruses include adenoviruses, retroviruses, and various bacteriophages. The surface of the viral particle can also be modified with ligands to increase targeting capabilities. While viral vectors can be used to great efficacy, one concern is that may cause off-target effects due to its natural tropism. This usually requires replacing the proteins causing virus-cell interactions with chimeric proteins.

Nanoparticle Albumin-bound (nab) Technology

Nanoparticle albumin-bound technology utilizes the protein albumin as a carrier for hydrophobic chemotherapy drugs through noncovalent binding. Because albumin is already a natural carrier of hydrophobic particles and is able to transcytose molecules bound to itself, albumin composed nanoparticles have become an effective strategy for the treatment of many diseases in clinical research.

Delivery and Release mechanism

An ideal drug delivery system should have effective targeting and controlled release. The two main targeting strategies are passive targeting and active targeting. Passive targeting depends on the fact that tumors have abnormally structured blood vessels that favor accumulation of relatively large macromolecules and nanoparticles. This so-called enhanced permeability and retention effect (EPR)allows the drug-carrier be transported specifically to the tumor cells. Active targeting is, as the name suggests, much more specific and is achieved by taking advantage of receptor-ligand interactions at the surface of the cell membrane.

Toxicity:

Some of the same properties that make nanoparticles efficient drug carriers also contribute to their toxicity. For example, gold nanoparticles are known to interact with proteins through surface adsorption, forming a protein corona, which can be utilized for cargo loading and immune shielding. However, this protein-adsorption property can also disrupt normal protein function that is essential for homeostasis, especially when the protein contains exposed sulfur groups.

Conclusion:

In conclusion, nanoparticle drug delivery systems represent a groundbreaking approach with the potential to revolutionize the field of medicine. Their ability to encapsulate, protect, and precisely deliver therapeutic agents to targeted sites offers numerous advantages, including enhanced drug efficacy, reduced side effects, and improved patient outcomes. However, challenges such as long-term safety, scalability, and regulatory considerations persist, warranting continued research and development. Despite these hurdles, the immense promise of nanoparticle drug delivery systems underscores their pivotal role in shaping the future of pharmaceuticals, paving the way for more precise, personalized, and effective therapies across a wide spectrum of diseases and medical conditions

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