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Applications of nanomedicine- Overview

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ABSTRACT

Nanotechnology is the study of extremely small structures, having a size of 0.1 to 100 nm. The ideas and concepts behind nano science and nanotechnology were started by Physicist Richard Feynman. He described a process in which scientists would be able to manipulate and control individual atoms and molecules. Particles are engineered so that they are attracted to diseased cells, which allow direct treatment of those cells. This technique reduces damage to healthy cells in the body and allows for earlier detection of disease. An important application of nanotechnology in biomedical science deals with novel drug synthesis, drug delivery, imaging, gene therapy etc. Lipid and polymer-based nanoparticles are the most commonly used drug delivery systems. They offer several advantages such as improved drug solubility, preferential drug accumulation in tumor site, sustained drug release, improved bioavailability and biocompatibility over the conventional treatment methods. Nanoparticles also carry the potential for targeted and time-release drugs. Currently many substances are under investigation for drug delivery and more specifically for cancer therapy. An ideal drug-delivery system possesses two elements: the ability to target and to control the drug release. Targeting will ensure high efficiency of the drug and reduce the side effects, especially when dealing with drugs that are presumed to kill cancer cells but can also kill healthy cells when delivered to them. The reduction or prevention of side effects can also be achieved by controlled release. So Controlled drug delivery systems (DDS) have several advantages compared to the traditional forms of drugs. A drug is transported to the place of action, hence, its influence on vital tissues and undesirable side effects can be minimized.

Keywords— *Nanomedicine, Nanoparticles, Drug delivery, Minimized side effects*

1. INTRODUCTION

Nanotechnology is the study of extremely small structures, having a size of 0.1 to 100 nm. The prefix “nano” is a Greek word which means “dwarf”. The word “nano” means very small or miniature size. The ideas and concepts behind nano science and nanotechnology started by Physicist Richard Feynman. He described a process in which scientists would be able to manipulate and control individual atoms and molecules. The major application of nanotechnology in biomedical science involves novel drug synthesis, drug delivery, imaging, gene therapy etc. Imaging is an important area of application where nanoparticles can be employed to detect tumor cells. When injected into the body these nanoparticles or nano devices specially detect and bind to the cancer cells and behaves as contrast agents thus producing images of ultrasound and MRI with improved contrast.

Nano medicines used for drug delivery, are made up of nano scale particles or molecules which can improve drug bioavailability. For maximizing bioavailability both at specific places in the body and over a period of time, molecular targeting is done by nano engineered devices such as nano robots [1]

The pharmacological and therapeutic properties of drugs can be improved by proper designing of drug delivery systems, by use of lipid and polymer-based nano particles [2].

The strength of drug delivery systems is their ability to alter the pharmacokinetics and bio-distribution of the drug. Nano particles are designed to avoid the body's defense mechanisms [3] can be used to improve drug delivery. New, complex drug delivery mechanisms are being developed, which can get drugs through cell membranes and into cell cytoplasm, thereby increasing efficiency. The triggered response is one way for drug molecules to be used more efficiently. Drugs that are placed in the body can activate only on receiving a particular signal. A drug with poor solubility will be replaced by a drug delivery system, having improved solubility due to the presence of both hydrophilic and hydrophobic environments [4].

Abraxane, is albumin bound paclitaxel, a nano particle used for the treatment of breast cancer and non-small- cell lung cancer (NSCLC). Nano particles are used to deliver the drug with enhanced effectiveness for treatment for head and neck cancer**,** in mice model study, which was carried out at from Rice University and University of Texas MD Anderson Cancer Center. The reported treatment uses Cremophor EL which allows the hydrophobic paclitaxel to be delivered intravenously. When the toxic Cremophor is replaced with carbon nano particles its side effects diminished and drug targeting was much improved and needs a lower dose of the toxic paclitaxel [5].

Nano particle chain was used to deliver the drug doxorubicin to breast cancer cells in a mice study at Case Western Reserve University. The scientists prepared a 100 nm long nano particle chain by chemically linking three magnetic, iron-oxide nano spheres, to one doxorubicinloaded liposome. After penetration of the nano chains inside the tumor magnetic nanoparticles were made to vibrate by generating, a radiofrequency field which resulted in the rupture of the liposome**,** thereby dispersing the drug in its free from throughout the tumor. Tumor growth was halted more effectively by nanotechnology than the standard treatment with doxorubicin and is less harmful to healthy cells as very fewer doses of doxorubicin were used [6,7].

Polyethylene glycol (PEG) nano particles carrying a payload of antibiotics at its core were used to target bacterial infection more precisely inside the body, as reported by scientists of MIT. The nano delivery of particles, containing a sub-layer of pH sensitive chains of the amino acid histidine, is used to destroy bacteria that have developed resistance to antibiotics because of the targeted high dose and prolonged release of the drug. Nanotechnology can be efficiently used to treat various infectious diseases [8,9]. Nano shells of 120 nm diameter, coated with gold were used to kill cancer tumors in mice by Prof. Jennifer at Rice University. These nano shells are targeted to bond to cancerous cells by conjugating antibodies or peptides to the nano shell surface. Area of the tumor is irradiated with an infrared laser, which heats the gold sufficiently and kills the cancer cells [10].

The applications of various nano systems in cancer therapy [11] are summarized as:
- **Carbon nano tubes,** 0.5–3 nm in diameter and 20–1000 nm length, are used for detection of DNA mutation and for detection of disease protein biomarker.
- **Dendrimers,** less than 10 nm in size are useful for controlled release drug delivery, and as image contrast agents.
- **Nano crystals,** of 2-9.5 nm size cause improved formulation for poorly-soluble drugs, labelling of breast cancer marker HeR2 surface of cancer cells.
- **Nano particles** are of 10-1000 nm size and are used in MRI and ultrasound image contrast agents and for targeted drug delivery, as permeation enhancers and as reporters of apoptosis, angiogenesis.
- Nano shells find application in tumour-specific imaging, deep tissue thermal ablation.
- **Nano wires** are useful for disease protein biomarker detection, DNA mutation detection and for gene expression detection.
- Quantum dots, 2-9.5 nm in size, can help in optical detection of genes and proteins in animal models and cell assays, tumor and lymph node visualization.

2. ALZHEIMER'S DISEASE

Worldwide, more than 35 million people are affected by Alzheimer's disease (AD), which is the most common form of dementia. Nano technology finds significant applications in neurology. These approaches are based on the early AD diagnosis and treatment is made possible by designing and engineering of a plethora of nano-particulate entities with high specificity for brain capillary endothelial cells. Nano particles (NPs) have a high affinity for the circulating amyloid-β (Aβ) forms and therefore may induce "sink effect" and improve the AD condition. In vitro diagnostics for AD has advanced due to ultrasensitive NP-based bio-barcodes and immune sensors, as well as scanning tunneling microscopy procedures capable of detecting Aβ1−40 and Aβ1−42. The recent research on the use of nano particles in the treatment of Alzheimer's disease is as shown in [12].

The nano device bucky balls have been used to alter the allergy/ immune response. They prevent mast cells from releasing histamine into the blood and tissues, as these bind to free radicals better than any anti-oxidant available, such as vitamin E [13].

3. DRUG DELIVERY

It is an interesting focus in this field is drug delivery. This interdisciplinary area involves design, synthesis, purification and characterization of nanosystems that can specifically deliver chemotherapeutic drugs to the target tissue or organ for a definite period of time. These nanosystems can also be designed in such a way that they deliver the drug in an active manner with the help of a targeting ligand or in a passive manner by exploiting the leaky tumor vasculature. Lipid and polymer-based nanoparticles are the most commonly used drug delivery systems. They offer several advantages such as improved drug solubility, preferential drug accumulation in tumor site, sustained drug release, improved bioavailability and biocompatibility over the conventional treatment methods. If scientists can load their cancer-detecting gold nanoparticles with anticancer drugs, they could attack cancer exactly where it lives. Such a treatment means fewer side effects and less medication used. Nanoparticles also carry the potential for targeted and time-release drugs. Currently many substances are under investigation for drug delivery and more specifically for cancer therapy.

A Targeted Drug Delivery System (TDDS) is a system, which releases the drug at a preselected bio site in a controlled manner. Nanotechnology-based delivery systems are making a significant impact on cancer treatment and the polymers play a key role in the development of nanoparticulate carriers for cancer therapy.

Nanoparticles used as drug delivery vehicles are generally <100 nm in at least one dimension and consist of different biodegradable materials such as natural or synthetic polymers, lipids, or metals. Nanoparticles are taken up by cells more efficiently than larger micromolecules and therefore, could be used as effective transport and delivery systems. For therapeutic applications, drugs can either be integrated into the matrix of the particle or attached to the particle surface. A drug targeting system should be able to control the fate of a drug entering the biological environment. Nanosystems with different compositions and biological properties have been extensively investigated for drug and gene delivery applications.

4. IMAGING

In vivo imaging is another area where tools and devices are being developed.[14] Using nanoparticle contrast agents, images such as ultrasound and MRI have a favourable distribution and improved contrast. In cardiovascular imaging, nanoparticles have the potential to aid visualization of blood pooling, ischemia, angiogenesis, atherosclerosis, and focal areas where inflammation is present [14]

5. GENE THERAPY

Gene therapy is emerging as a new class of therapeutics for the treatment of inherited and acquired diseases. However, poor cellular uptake and instability of DNA in the physiological milieu limits its therapeutic potential, hence a vector which can protect and efficiently transport DNA to the target cells must be developed. Gene therapy gives a systematic account of the many aspects of nanotechnology mediated gene therapy, from the preparation of nanoparticles to physicochemical characterization, and follows with applications in vitro and in vivo models. This book emphasizes the various aspects of nanotechnology-based gene therapy, with initial chapters detailing the tools and techniques available for preparation and in vitro and in vivo characterization of nanoparticles [15].

The reduction or prevention of side effects can also be achieved by controlled release. So Controlled drug delivery systems (DDS) have several advantages compared to the traditional forms of drugs. A drug is transported to the place of action, hence, its influence on vital tissues and undesirable side effects can be minimized. Nanotechnology can increase the chances of dyes and gold particles reaching the cancer cell. This means greater detection rates, which makes it easy to catch the problem and treat it faster. This could help to reduce prostate and colon cancer mortality rates.

6. CONCLUSION

Nanomaterials have increased surface area and nano scale effects, hence used as a promising tool for the advancement of drug and gene delivery, biomedical imaging and diagnostic biosensors. The properties of nano materials can greatly influence their interactions with bio molecules and cells, due to their peculiar size, shape, chemical composition, surface structure, charge, solubility and agglomeration. For example, nano particles can be used to produce exceptional images of tumor sites; single-walled carbon nanotubes, have been used as high-efficiency delivery transporters for bio molecules into cells. By further research in nanotechnology, it can be useful for every aspect of human life. Medicine, regenerative medicine, stem cell research and nutraceuticals are among the leading sectors that will be modified by nanotechnology innovations. For many, nanotechnology is a wonderful window into the future of biomechanics and medicine. The nature of the science and the minute details mean that this seems like a technology that should be out of reach. Biologists are using this innovative technology to overcome boundaries common to cell biology and clinical medicine. As more biologists learn about the capability of nanotechnology and develop cross-disciplinary collaborations with physicists, engineers, and material scientists, these breakthroughs will undoubtedly increase in magnitude and quantity.

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