ISSN:2230-7346

Review Article *Available online http://WWW.JGTPS.COM*

Journal of Global Trends in Pharmaceutical Sciences

VOL.2, ISSUE 1, PP- 21-30, JANUARY–MARCH 2011

NANOMEDICINE AND DRUG DELIVERY - REVOLUTION IN HEALTH SYSTEM

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ABSTRACT

Nanomedicine seeks to deliver a valuable set of research tools and clinically helpful devices in the near future. The National Nanotechnology Initiative expects new commercial applications in the pharmaceutical industry that may include advanced drug delivery systems, new therapies, and in vivo imaging. Neuro electronic interfaces and other nano electronics based sensors are another active goal of research. Nanomedicine is the medical application of nanotechnology. The approaches to Nanomedicine range from the medical use of nanomaterials, to nanoelectronic biosensors, and even possible future applications of molecular nanotechnology. The speculative field of molecular nanotechnology believes that cell repair machines could revolutionize medicine and the medical field. Nanotechnology's health implications can be split into two aspects: The potential for nanotechnological innovations to have medical applications to cure disease, and the potential health hazards posed by exposure to nanomaterials. Current problems for Nanomedicine involve understanding the issues related to toxicity and environmental impact of nanoscale materials.

Keywords: Drug delivery systems, Nanomedicine, Nanotechnology, Nanoscale

INTRODUCTION:

Nanomedical approaches to drug delivery center on developing Nanoscale particles or molecules to improve the bioavailability of a drug. Bioavailability refers to the presence of drug molecules where they are needed in the body and where they will do the most good. Drug delivery focuses on maximizing bioavailability both at specific places in the body and over a period of time. This will be achieved by molecular targeting by Nanoengineered devices. It is all about targeting the molecules and delivering drugs with cell precision. More than $65 billion are wasted each year due to poor bioavailability. *In vivo* imaging is another area where tools and devices are being developed. Using Nanoparticle contrast agents, images such as ultrasound and MRI have a favorable distribution and improved contrast. The new methods of Nanoengineered materials that are being developed might be effective in treating illnesses and diseases such as cancer. What Nano scientists will be able to achieve in the future is beyond current imagination. This will be accomplished by self assembled biocompatible Nanodevices that will detect, evaluate, treat and report to the clinical doctor automatically.[1,2,3] The study, manipulation and engineering of devices and structures less than 100 nanometers have become known as nanotechnology. As particles become nano sized, they exhibit unique chemical, biological, electrical and mechanical properties unlike their normal macroscopic state. Nanotechnology is beginning to change the scale and methods of drug delivery. Therapeutic and diagnostic agents can be encapsulated, covalently attached, or adsorbed onto nanoparticles. These approaches can easily overcome drug solubility issues, which has significant implications because more than 40% of the active substances being identified through combinatorial screening programs are poorly soluble in water.[4]

Recently, much attention has been devoted toward using nanotechnology to improve health care, and the medical application of nanotechnology has become known as Nanomedicine. In the near future, nanotechnology will revolutionize health care, as nanomedicine has the potential to cure diseases and repair tissues by manipulating individual cells at the molecular level.The limitations of current (conventional) drug-delivering systems include suboptimal bioavailability, limited effective targeting, potential cytotoxicity, and long, frequent treatments are often required. Nano-scale drug-delivery devices called nanocarriers overcome these limitations. Nanocarriers are also able to maximize therapeutic activity while minimizing toxic side effects and target specific cells rather than tissues because their unique properties allow for easy surface functionalization.

APPLICATIONS OF NANOMEDICINE:

DRUG DELIVERY:

Nanotechnology has been a boom in medical field by delivering drugs to specific cells using nanoparticles. The overall drug consumption and side effects can be lowered significantly by depositing the active agent in the morbid region only and in no higher dose than needed. This highly selective approach reduces costs and human suffering. An example can be found in dendrimers and nanoporous materials. Another example is to use block co-polymers, which form micelles for drug encapsulation. They could hold small drug molecules transporting them to the desired location. For example, Nanoparticles that deliver chemotherapy drugs directly to cancer cells are under development. Tests are in progress for targeted delivery of chemotherapy drugs and their final approval for their use with cancer patients is pending.

Another vision is based on small electromechanical systems; these are being investigated for the active release of drugs. Some potentially important applications include cancer treatment with iron nanoparticles or gold shells. A targeted or personalized medicine reduces the drug consumption and treatment expenses resulting in an overall societal benefit by reducing the costs to the public health system. Nanotechnology is also opening up new opportunities in implantable delivery systems, which are often preferable to the use of injectable drugs, because the latter frequently display first-order kinetics (the blood concentration goes up rapidly, but drops exponentially over time). This rapid rise may cause difficulties with toxicity, and drug efficacy can diminish as the drug concentration falls below the targeted range. [5]

TISSUE ENGINEERING:

Nanotechnology can help to reproduce or to repair damaged tissue. "Tissue engineering" makes use of artificially stimulated cell proliferation by using suitable nanomaterial-based scaffolds and growth factors. Tissue engineering might replace today's conventional treatments like organ transplants or artificial implants. Advanced forms of tissue engineering may lead to life extension.For patients with end-state organ failure, there may not be enough healthy cells for expansion and transplantation into the ECM (extracellular matrix). In this case, pluripotent stem cells are needed. One potential source for these cells is iPS (induced Pluripontent Stem cells), these are ordinary cells from the patient's own body that are reprogrammed into a pluripotent state, and has the advantage of avoiding rejection (and the potentially life-threatening complications associated with immunosuppressive treatments). Another potential source of pluripotent cells is from embryos.

DIAGNOSTICS:

Nanotechnology-on-a-chip is one more dimension of lab-on-a-chip technology. Magnetic nanoparticles, bound to a suitable antibody, are used to label specific molecules, structures or microorganisms. Gold nanoparticles tagged with short segments of DNA can be used for detection of genetic sequence in a sample. Multicolor optical coding for biological assays has been achieved by embedding different-sized quantum dots into polymeric microbeads. Nanopore technology for analysis of nucleic acids converts strings of nucleotides directly into electronic signatures. [6]

Iron oxide nanoparticles can used to improve MRI images of cancer tumors. The nanoparticle is coated with a peptide that binds to a cancer tumor; once the nanoparticles are attached to the tumor the magnetic property of the iron oxide enhances the images from the Magnetic Resonance Imagining scan.

EARLY CANCER DETECTION:

Biconjugated particles and devices are also under development for early cancer detection in body fluids such as blood and serum. These nanoscale devices operate on the principles of selectively capturing cancer cells or target protiens. The sensors are often coated with a cancer-specific antibody or other biorecognition ligands. So that the capture of a cancer cell or target protien yields an electrical mechanical or optical signal for detection and analysis of circulating tumor cells and biomarkers in blood/serum samples. The ability to enrich for circulating cancer cells from both bone marrow aspirates and peripheral blood samples. Through the combinatorial use of magnetic nanoparticles and semiconductor quantum dots (QDs), it is possible to increase the ability to capture and evaluate these rare circulating cancer cells. [7,8]

CANCER THERAPY:

Cancer nanotechnology is the latest trend in cancer therapy. It helps the pharmacist to formulate the product with maximum therapeutic value and minimum or neglible range side effects. Cancer is the disease in which the abnormal cells are quite similar to the normal cells with just minute functional or genetic change. Thus, it is very hard to target the abnormal cells by the conventional method of the drug delivery system. Nanotechnology is probably the only method that can be used for site-specific action without causing the side effects by killing the normal cells. [9]

NANO NEPHROLOGY:

Nano nephrology is a branch of Nanomedicine and Nanotechnology that deals with 1) the study of kidney protein structures at the atomic level; 2) Nano imaging approaches to study cellular processes in kidney cells; and 3) Nano medical treatments that utilize Nanoparticles and to treat various kidney diseases. The creation and use of materials and devices at the molecular and atomic levels that can be used for the diagnosis and therapy of renal diseases is also a part of Nano nephrology that will play a role in the management of patients with kidney disease in the future. Advances in Nano nephrology will be based on discoveries in the above areas that can provide Nano scale information on the cellular molecular machinery involved in normal kidney processes and in pathological states. By understanding the physical and chemical properties of proteins and other macromolecules at the atomic level in various cells in the kidney, novel therapeutic approaches can be designed to combat major renal diseases. The Nano-scale artificial kidney is a goal that many physicians dream of. Nano-scale engineering advances will permit programmable and controllable Nano-scale robots to execute curative and reconstructive procedures in the human kidney at the cellular and molecular levels. [10]

NANOSURGERY:

Over the past couple decades, surgery has evolved from a macro-scale procedure to a micro-scale level. Surgeons are emphasizing minimally invasive procedures to reduce scar formation and excessive harm to other body parts. Nanosurgery provides the tools to advance surgery even further into the nano-scale level where individual organelles can be manipulated within living cells. Novel tools and techniques are being developed to perform Nanosurgery. Three such tools are using for this which are nanoneedle, nanotweezers, and femtosecond lasers. Using atomic force microscopy and attaching a carbon nanotube to the tip allows nanosurgeons to perform surgical operations on individual cells. The Nanoneedle can accurately penetrate a cell of nuclear envelope, deposit material, and leave without harming the cell. [11]

An application of Nanotweezers involves moving and manipulating objects on the Nano-scale level. After attaching two nanotubes on a glass electrode, a voltage can be applied to induce tweezer-like motion of the nanotubes. Some applications involve manipulate and modify biological structures inside a living cell.

ANTI MICROBIAL TECHNIQUES:

A welcome idea in the early study stages is the elimination of bacterial infections in a patient within minutes, instead of delivering treatment with antibiotics over a period of weeks. A Nanoparticle cream has been shown to fight staph infections. The Nanoparticles contain nitric oxide gas, which is known to kill bacteria.

Studies on mice have shown that using the Nanoparticle cream to release nitric oxide gas at the site of staph abscesses significantly reduced the infection.

CURRENT PROBLEMS FOR NANOMEDICINE:

NANOTOXICOLOGY:

Nanotoxicology is the study of the toxicity of nanomaterials. Because of quantum size effects and large surface area, nanomaterials have unique properties compared with their larger counterparts. Nanotoxicology is a branch of bionanoscience which deals with the study and application of toxicity of Nanomaterials [12]. Nanomaterials, even when made of inert elements like gold, become highly active at nanometer dimensions. Nanotoxicological studies are intended to determine whether and to what extent these properties may pose a threat to the environment and to human beings. For instance, Diesel nanoparticles have been found to damage the cardiovascular system in a mouse model.

ENVIRONMENTAL ISSUES:

Nanopollution is a generic name for all waste generated by Nanodevices or during the nanomaterials manufacturing process. This kind of waste may be very dangerous because of its size. It can float in the air and might easily penetrate animal and plant cells causing unknown effects. Most human made Nanoparticles do not appear in nature, so living organisms may not have appropriate means to deal with nanowaste. It is probably one great challenge to nanotechnology.

TABLES AND FIGURES

Table 1: Research reports of nanotechnology in cancer diagnostics and therapeutics

Nanomaterial	Example	Function	Application
Mettalic and metal nanoparticles(Radioactive and nonradioactive)	Silica nanoparticles,Gold coated nanoshells and gold nanoparticles	Therapeutic and diagnostics	Dye doped silica Nanoparticles Hep G liver cancer cell recognition.Gold nanoparticles photodynamic therapy,selective absorption/imaging of malignant tissues,

			Infrared hyperthermia and molecular markers.
Drug encapsulated nanoparticles	Cisplatin nanoparticles. Combination of drugs in nanoscale delivery systems	Therapeutic	Delivering a single or combination of chemotherapeutic agents
Engineered biomolecules	Hair pin shaped oligonucleotides	Diagnostics	Study of alterations in genes and protein structures
Engineered biomolecules encapsulated in nanoparticles.Functional nanomaterials(with/without encapsulation)	Nucleotides in polymeric nanovectors. Quantum dots,Ferrofluids,Iron based nanoparticles,carbon nanotubes and paramagnetic materials.	Therapeutics and diagnostics. Therapeutics and Diagnostics	Gene therapy diagnostics. Gadolinium containing nanoparticles lymphatic drainage imaging of breast cancer and neutron capture therapy of cancer. Magnetic nanoparticles hyperthermia and malignant tissue imaging
Nano and micro sized systems for diagnosis, treatment and invasive procedures.	MEMS/NEMS based devices containing biomarker molecules for diagnostics. Micro-antennas for hyperthermia. Smart pill for endoscopy applications. MEMS/NEMS devices for pain management. Nanorobots for detection and studying of cancer cells/tissues at practically anaccessible locations	MEMS/NEMS and "smart pill" devices for minimal invasive procedures.	---

TABLE 2: NANOTECHNOLOGY IN MEDICINE: COMPANY DIRECTORY

Company	Product
BioDelivery Sciences	Oral drug delivery of drugs encapuslated in a nanocrystalline structure called a cochleate
CytImmune	Gold nanoparticles for targeted delivery of drugs to tumors
Invitrogen	Qdots for medical imaging

Nucryst	Antimicrobial wound dressings using silver nanocrystals
Luna Inovations	Bucky balls to block inflammation by trapping free radicals
NanoBio	Nanoemulsions for nasal delivery to fight viruses (such as the flu and colds) or through the skin to fight bacteria
NanoBioMagnetics	Magnetically responsive nanoparticles for targeted drug delivery and other applications
Nanobiotix	Nanoparticles that target tumor cells, when irradiated by xrays the nanoparticles generate electrons which cause localized destruction of the tumor cells.
Nanospectra	AuroShell particles (nanoshells) for thermal destruction of cancer tissue
Nanosphere	Diagnostic testing using gold nanoparticles to detect low levels of proteins indicating particular diseases
Nanotherapeutics	Nanoparticles for improving the performance of drug delivery by oral or nasal methods
Oxonica	Diagnostic testing using gold nanoparticles (biomarkers)
T2 Biosystems	Diagnostic testing using magnetic nanoparticles
Z-Medica	Medical gauze containing aluminosilicate nanoparticles which help blood clot faster in open wounds.
Sirnaomics	Nanoparticle enhanced techniques for delivery of siRNA
Makefield Therapeutics	Nanoparticle cream for delivery of nitric oxide gas to treat infection
DNA Medicine Institute	Diagnostic testing system

CONCLUSION:

Nanotechnology has already significantly improved healthcare, and revolutionary changes will take place as Nanomedicine techniques are further incorporated into everyday medicine. Nanomedicine is showing promising results toward some of the most incurable diseases such as HIV and cancer. Perhaps the most intriguing aspect of Nanomedicine is that in the near future, doctors will not be treating symptoms; nanosurgery devices will provide the tools to treat individual cells. The versatility and numerous forms of nanocarriers will provide the means of transporting any needed agent to any specific location of the body

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