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RESEARCH ARTICLE

NANOMEDICINE- THE SOLUTION TO MODERN MEDICINE'S UNSOLVED PROBLEMS

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ABSTRACT

Developments in nanomedicine are expected to provide solutions to many of modern medicine's unsolved problems. The great appeal of nanomedicine lies in its promise of using the unique properties of nanoscale materials to address some of the most challenging problems of medical diagnosis and therapy. Applications of nanotechnology for treatment, diagnosis, monitoring, and control of biological systems has recently been referred to as "nanomedicine" by the National Institutes of Health. Research into the delivery and targeting of pharmaceutical, therapeutic, and diagnostic agents is at the forefront of projects in nanomedicine. These involve the identification of precise targets related to specific clinical conditions and choice of the appropriate nanocarriers to achieve the required responses while minimizing the side effects. Mononuclear phagocytes, dendritic cells, endothelial cells, and cancers are key targets. Today, nanotechnology approaches to particle design and formulation are beginning to expand the market for many drugs and are forming the basis for a highly profitable niche within the industry. This article presents an overview of some of the applications of nanotechnology in nanomedicine.

INTRODUCTION

One of the 21st century's most promising technologies is nanotechnology. Nanomedicine, an offshoot of nanotechnology, refers to highly specific medical intervention at the molecular scale for curing disease or repairing damaged tissues, such as bone, muscle, or nerve. Nanotechnology is a collective term referring to technological developments on the nanometer scale, usually 0.1-100 nm. A nanometer is one-billionth of a meter, too small to be seen with a conventional laboratory microscope. It is at this size scale - about 100 nanometers or less - that biological molecules and structures inside living cells operate. Therefore, nanotechnology is engineering and manufacturing at the molecular scale. Utilities of nanotechnology to biomedical sciences imply creation of materials and devices designed to interact with the body at sub-cellular scales with a high degree of specificity. This could be potentially translated into targeted cellular and tissue-specific clinical applications aimed at maximal therapeutic effects with very limited adverse-effects. (Nanomedicine, 1999)

Nanotechnology

Nanotechnology is the manipulation of matter on an atomic, molecular, and supramolecular scale. Matter is manipulated with at least one dimension sized from 1 to 100 nanometers. This definition reflects the fact that quantum mechanicaleffects are important at this quantum-realm scale, and so the definition shifted from a particular technological goal to a research category inclusive of all types of research and technologies that deal with the special properties of matter that occur below the given size threshold. Nanotechnology as defined by size is naturally very broad, including fields of science as diverse as surface science, organic chemistry, molecular biology, semiconductor physics, microfabrication, etc. Scientists currently debate the future implications of nanotechnology. Nanotechnology may be able to create many new materials and devices with a vast range of applications, such as in medicine, electronics, biomaterialsand energy production. Nanomedicine, which is the application of nanoparticles in medicine, is a hope for a very bright future in curing many diseases. (Wagner *et al*., 2006)

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Nanomedicine

Nanomedicine is the medical application of nanotechnology. Nanomedicine ranges from the medical applications of nanomaterials, to nanoelectronic biosensors, and even possible future applications of molecular nanotechnology. Current problems for nanomedicine involve understanding the issues related to toxicity and environmental impact of nanoscale materials. Functionalities can be added to nanomaterials by interfacing them with biological molecules or structures. The size of nanomaterials is similar to that of most biological molecules and structures; therefore, nanomaterials can be useful for both in vivo and in vitro biomedical research and applications. Thus far, the integration of nanomaterials with biology has led to the development of diagnostic devices, contrast agents, analytical tools, physical therapy applications, and drug delivery vehicles. Nanomedicine seeks to deliver a valuable set of research tools and clinically useful 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. As the nanomedicine industry continues to grow, it is expected to have a significant impact on the economy. (Freitas, 2005; Nanotechnology in Medicine and the Biosciences, 1996)

Nanorobots

A nanorobot is a tiny machine designed to perform a specific task or tasks repeatedly and with precision at nanoscale dimensions, that is, dimensions of a few nanometers (nm) or less. Nanorobots have potential applications in the assembly and maintenance of sophisticated systems. Nanorobots might function at the atomic or molecular level to build devices, machines, or circuits, a process known as molecular manufacturing. Nanorobots might also produce copies of themselves to replace worn-out units, a process called self-replication. (Ratner and Ratner, 2002) Nanorobots are of special interest to researchers in the medical industry. This has given rise to the field of nanomedicine. It has been suggested that a fleet of nanorobots might serve as antibodies or antiviral agents in patients with compromised immune systems, or in diseases that do not respond to more conventional measures. There are numerous other potential medical applications, including repair of damaged tissue, unblocking of arteries affected by plaques, and perhaps the construction of complete replacement body organs. A major advantage of nanorobots is thought to be their durability. In theory, they can remain operational for years, decades, or centuries. Nanoscale systems can also operate much faster than their larger counterparts because displacements are smaller; this allows mechanical and electrical events to occur in less time at a given speed. (Cavalcanti *et al*., 2008)

Diagnostic applications of nanomedicine imaging

Using nanoparticle contrast agents, images such as ultrasound and MRI have a favorable distribution and improved contrast. This might be accomplished by self assembled biocompatible nanodevices that will detect, evaluate, treat and report to the clinical doctor automatically. The small size of nanoparticles endows them with properties that can be very useful in oncology, particularly in imaging. Quantum dots which are nanoparticles with quantum confinement properties, such as size-tunable light emission, when used in conjunction with MRI, can produce exceptional images of tumor sites. (Boisseau and Loubaton, 2011) Nanoparticles of cadmium selenide (quantum dots) glow when exposed to ultraviolet light and seep into cancer tumors when injected. The surgeon can see the glowing tumor, and can be used as a guide for more accurate tumor removal. (University of Waterloo, 2010) These nanoparticles are much brighter than organic dyes and only need one light source for excitation. This means that the use of fluorescent quantum dots could produce a higher contrast image and at a much lower cost. Tracking movement can help determine how well drugs are being distributed or how substances are metabolized. It is difficult to track a small group of cells throughout the body, so scientists used to dye the cells. These dyes needed to be excited by light of a certain wavelength in order for them to light up. While different color dyes absorb different frequencies of light, there was a need for as many light sources as cells. A way around this problem is with luminescent tags. These tags are quantum dots attached to proteins that penetrate cell membranes. The dots can be random in size, can be made of bio-inert material. They demonstrate the nanoscale property that color is size-dependent. Another way has been discovered to insert nanoparticles into the affected parts of the body so that those parts of the body will glow showing the tumor growth or shrinkage or also organ trouble. (Allen and Cullis, 2004; Walsh *et al*., 2012)

Sensing

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. (Boisseau and Loubaton, 2011; University of Waterloo, 2010) Nanopore technology for analysis of nucleic acids converts strings of nucleotides directly into electronic signatures.Sensor test chips containing thousands of nanowires, able to detect proteins and other biomarkers left behind by cancer cells, could enable the detection and diagnosis of cancer in the early stages from a few drops of a patient's blood.Nanotechnology is helping to advance the use of arthroscopes, which are pencil-sized devices that are used in surgeries with lights and cameras so surgeons can do the surgeries with smaller incisions. The smaller the incisions the faster the healing time which is better for the patients. It is also helping to find a way to make an arthroscope smaller than a strand of hair. (Allen and Cullis, 2004; Chu *et al*., 2013)

Therapeutic applications of nanomedicine drug delivary

Nanomedical approaches to drug delivery center on developing nanoscale particles or molecules to improve drug bioavailability and targeting. The future of nanomedicine will likely include self assembling biocompatible nanodevices that will detect, evaluate, treat and automatically report to the clinical doctor. Nanoparticles, as drug delivery systems, can be designed to improve the pharmacological and therapeutic properties of drugs. The strength of nanoparticulate drug delivery systems is their ability to alter the pharmacokinetics and biodistribution of drugs. (Caron *et al*., 2012) The overall drug consumption and side-effects may be lowered significantly by depositing the active agent in the morbid region only and in no higher dose than needed. Targeted drug delivery is intended to reduce the side effects of drugs with concomitant decreases in consumption and treatment expenses. Drug delivery focuses on maximizing bioavailability both at specific places in the body and over a period of time. This can potentially be achieved by molecular targeting by nanoengineered devices. (Bertrand and Leroux,

2011) A benefit of using nanoscale for medical technologies is that smaller devices are less invasive and can possibly be implanted inside the body, plus biochemical reaction times are much shorter. These devices are faster and more sensitive than typical drug delivery. The basic point to use drug delivery is based upon three facts: a) efficient encapsulation of the drugs, b) successful delivery of said drugs to the targeted region of the body, and c) successful release of that drug there. When designed to avoid the body's defence mechanisms, nanoparticles have beneficial properties that can be used to improve drug delivery. Nanoparticles can be used in combination therapy for decreasing antibiotic resistance or for their antimicrobial properties. Some nanotechnology-based drugs that are commercially available or in human clinical trials include abraxane, doxil, c-dots, etc. (Nagy *et al*., 2011)

Cancer

A nanoproperty, high surface area to volume ratio, allows many functional groups to be attached to a nanoparticle, which can seek out and bind to certain tumor cells. Additionally, the small size of nanoparticles allows them to preferentially accumulate at tumor sites. This is because tumors lack an effective lymphatic drainage system. Limitations to conventional cancer chemotherapy include drug resistance, lack of selectivity, and lack of solubility. Nanoparticles have the potential to overcome these problems. In photodynamic therapy, a particle is placed within the body and is illuminated with light from the outside. The light gets absorbed by the particle and if the particle is metal, energy from the light will heat the particle and surrounding tissue. Light may also be used to produce high energy oxygen molecules which will chemically react with and destroy most organic molecules that are next to them (like tumors). This therapy is appealing for many reasons. It does not leave a "toxic trail" of reactive molecules throughout the body (chemotherapy) because it is directed where only the light is shined and the particles exist. Photodynamic therapy has potential for a noninvasive procedure for dealing with diseases, growth and tumors. Kanzius RF therapy is one example of such therapy. Gold nanoparticles have the potential to join numerous therapeutic functions into a single platform, by targeting specific tumor cells, tissues and organs. (Bertrand and Leroux, 2011; Nagy *et al*., 2011; Minchin, Rod 2008)

Skin diseases

Nanomedicine applied to dermatology, represents one of the most advanced field for which an increasing interest, both economic and scientific, is rising. The skin is the first point of contact for a whole host of nanomaterials, ranging from topical preparations, articles of clothing and household products, to sporting goods and industrial manufactured goods. Applications of nanomedicine in dermatology include new direction in medical diagnosis, monitoring and treatment. Gold nanoparticle, quantum dots and magnetic nanoparticles are used in non-invasive nanoimaging of high-resolution dermoscopy, microscopy, nanopunch, and spectroscopy, offering advanced diagnostic and therapeutic modalities. Nanotherapeutics has been considered in immunotherapy, genetherapy, and drug therapy. In drug therapy, because of size reduction or encapsulation of drug particles, the therapeutic potential of water insoluble and unstable drugs improve, and also facilitate the delivery of small molecules across blood, skin, nails, and pilosebaceous unit. (Banoee *et al*., 2010)

Cleaning of mouth

The nanorobots ingest and destroy the harmful bacteria they encounter using mechanical and chemical phagocytosis. The patient feels nothing: nanorobots are the size of bacteria, which constantly crawl on and inside the body without ever being noticed. After several minutes, the physician activates an acoustic homing beacon to guide the nanorobots back into the patient's mouth, where he retrieves them through a collection port on the tip of the homing device. A further survey with the original diagnostic probe reveals no evidence of the pathogen. (Seil and Webster, 2012)

Advantages of nanomedicine

In the medical world, nanotechnology is also seen as a boon since these can help with creating what is called smart drugs. These help cure people faster and without the side effects that other traditional drugs have. You will also find that the research of nanotechnology in medicine is now focusing on areas like tissue regeneration, bone repair, immunity and even cures for such ailments like cancer, diabetes, and other life threatening diseases. Nanomedicine is one of the biggest projects in the world right now and once perfrected it will be the biggest medical breakthrough in history. Nanomedicine will have many more advantages than the medical practices that we use today. Some of the benefits of nanomedicine are faster cures, no side effects, reduced level of drug consumption and target diseased cells. (Borzabadi-Farahani *et al*., 2013; Nanomedicine, 2003)

Disadvantages of nanomedicine

Some of the disadvantages of nanomedicine are: nanorobots could cause clot in bloodstream and engineered diseases. It is not fully practical yet and has high cost and difficulties in implementation. The ways in which these particles are capable of interfering with the human body and its biochemical pathways are troublesome and worrying. The medical issues are still unknown to a great level, but possibilities and theories are being formed by scientists. (20)

Conclusion

Nanomedicine can offer impressive resolutions for various life threatening diseases. Disease areas which can be expected to benefit most from nanotechnology within the next few years are cancer, diseases of the cardiovascular system, the lungs, blood, neurological (especially neurodegenerative) diseases, diabetes, inflammatory/infectious diseases, Parkinson's or Alzheimer's disease and orthopaedic problems. In the first half of the 21st century, nanomedicine should eliminate virtually all common diseases of the 20th century, and virtually all medical pain.

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