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Applications of Nanotechnology in Medical Science

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ABSTRACT

When applied to materials and technologies, nanotechnology refers to the study and manipulation of these systems at the nanoscale scale (one billionth of a meter). Control over the fundamental molecular structure permits control over the macroscopic chemical and physical characteristics, therefore at these sizes, examination of individual molecules and interacting groups of molecules in connection to the bulk macroscopic qualities of the material or device is vital. Material and devices for use in medicine and physiology must be developed to interact with the body at subcellular (i.e. molecule) scales with a high degree of specificity. This has the potential to transfer into clinical applications that are cell- and tissue-specific, aiming for maximum therapeutic results with minimal adverse effects. This overview provides an introduction to the fundamental scientific and technological features of nanotechnology, as well as a discussion of its possible medicinal applications.

Key words: Medical, Nanotechnology, Molecules, Medicinal applications, Material

1. INTRODUCTION

Nanotechnology is the science and engineering that is involved in the synthesis, design, characterization, and application of materials and devices whose lowest functional organization is one billionth of a meter [1].

It is the study of extremely small structures. The size of these small structures ranges from 0.1 to 100 nm [5]. The word "nano," is derived from a Greek word "nannos" which means "dwarf," is a preface that precisely refers to 1 billionth of a physical size. Keeping in mind that the size of a practical nanostructure is 1 to 100 nm, it is seen that the range of nanotechnology works at the level of molecules and atoms [3]. As a result of the control over their molecular synthesis and assembly, nano-engineered substrates can be designed to exhibit extremely precise and controlled bulk chemical and physical properties [1] for example, improved catalysis [7], tunable wavelength sensing ability (Chan et al., 2002) and increased mechanical strength [2].

Nanotechnology is typically exemplified by two different approaches that are top-down and bottom-up. 'Top-down' indicates the manufacturing of nanoscale structures from smallest structures by templating, machining and lithographic techniques, such as photonics applications in nanoengineering and nanoelectronics. However bottom-up, or molecular nanotechnology, relates to constructing of inorganic and organic materials into definite structures, atom by atom or molecule by molecule by self-organization, that are applicable in numerous biological processes [4]. Biologists and chemists are keenly involved in the synthesis of organic, inorganic, hybrid and metal nanomaterials comprising various types of nanoparticles bearing infrequent properties like physical, optical, biological, etc. because of such properties, nanoparticles have many applications in various fields like medicine, electronics, pharmaceuticals, agriculture and engineering [5][6].

There is a very rapid growth of nanotechnology with a number of potential applications in the biomedical field comprising the infectious disease control, diagnosis and prevention of different diseases to modify the health care in a basic manner [14]. Nanoparticles are now being used in medicine for targeted drug delivery inside the body, to diagnose and treat various pathological conditions, to reduce the antibiotic resistance and for cross infection control etc.

Nanoparticles; As drug delivery carriers

To target drugs to site of action, the drug can be conjugated to a tissue or cell specific ligand or coupled to macromolecules that reach the target organs. To target an anticancer agent to the liver, polymeric conjugate nanoparticles which comprised biotin and poly ethylene glycol with a galactose moiety from lacto bionic acid are used [8]. Liposomes and dendrimers are

nanoparticles which are most widely used for drug delivery purposes.

1.1. Liposomes

Liposomes are small artificial vesicles (50 – 100nm) that developed from phospholipids such as Phosphatidylserine, Phosphatidylcholine, Phosphatidylethanolamine, Phosphatidylglycerol [9]. Due to their ability to prevent degradation of drugs, reduce side effects and target drugs to site of action, liposomes have been applied as drug carriers [11]. Liposomes have applications like to reduce toxicity possible drug delivery to the lungs, transdermal drug delivery to enhance skin permeation of drugs with high molecular weight and poor water solubility and as a carrier for delivery of drugs, such as gentamicin, in the treatment of parasitic infections and in ocular drug delivery [10].

1.2. Dendrimers

These are highly branched and have tree-like structures with improved biological, physical and chemical properties. Several unique properties are related to their globular shape and the presence of internal cavities offering the possibility as medical Nano-vehicles [14]. Dendrimers are nanostructures produced from macromolecules such as, Poly-aryl ether, Polyamidoamine and Polypropyleneimine. They are highly branched with an inner core. Particle sizerange is between 1 to 100nm (mostly less than 10nm) [12]. Dendrimers have been reported to provide controlled release from the inner core. Drugs are attached on the surface or they are incorporated in the interior [13]. Both hydrophobic and hydrophilic drugs can be incorporated into dendrimers due to their versatility. Drug delivery applications include therapeutic and diagnostic utilization for cancer treatment and intracellular enhancement of drug solubility and permeability [10].

2. IMMUNIZATIONBY NANOPARTICLES

Treatment with conventional medication is becoming challenging due to emergence of new and drug resistant strains. Therefore, prevention through immunization by vaccination is the best alternative to prevent and combat infectious diseases. Nanotechnology based Mucosal vaccines offer great potential as they improve overall patient compliance and acceptance [16].The application of nanotechnology in the development of particle mediated delivery systems for vaccines is an attractive option. Nanotechnology is a fast growing field that is of particular interest to biological sciences since physiological functions are based on nano-sized compounds e.g., genetic material, extracellular components and viruses [15].

Immunization via nanotechnology is being used for intravenous, oral or intranasal vaccine administration. By Intravenous administration nanoparticles will not block capillary passages and allow uptake via circulating macrophages or hepatic Kupffer cells. Oral administration of nanoparticles permits particle uptake in the gastrointestinal tract by intestinal epithelial cells in the mucosa, M-cells, and cells of the Peyer's patches [17]. Similarly, administration via inhalation is also possible, which is an attractive application in the combat of airborne pathogens, since particles can be produced in precise size ranges [18].

Nanoemulsions, which contain small droplets of oil suspended in water and they are stabilized by detergents, are the finding applications for both prevention and also for treatment of a wide variety of infections. Dropletsare surface active in nanoemulsions and specifically react with the outer membrane of infectious organisms. As colloidal vaccine carriers the potential of nanoemulsions are being explored in the field of immunization against Schistosomiasis, calcium nanoparticles have been examined as a vaccine adjuvant of anti-idiotypic antibody [16]. In addition to single emulsions systems, multiple emulsion formulations can also be used as vaccine carrier systems.Water-in-oil-in-water (W/O/W) multiple emulsions, have been evaluated as prolonged drug release systems for various drugs. They have been shown to remain stable for several months and to entrap protein antigens without damage during emulsification procedures [19]. Challenges in producing multiple emulsions smaller than 100 nm have been overcome by using synthetic amphiphilic diblock copolypeptide surfactants and ultrasonic homogenization followed by microfluidic homogenization. The W/O/W double emulsions were stabilized via hydrogen bond interactions in the oil phase by racemic, disordered hydrophobic polypeptide segments, thereby reducing coalescence of the internal droplets [20].

Another major type of nanoparticle delivery systems having properties of interest are metallic nanoparticles. These may have innate immunological activity or the ability to function as carrier systems. Silver has long been known to have bactericidal properties [22] but more recently have been shown to have protective activity against HIV-1. Silver nanoparticles with diameters ranging from 1 to 10 nm may block HIV-1 binding to T cell CD4 receptors by interacting with the glycoprotein 120 knobs on the viral surface [21], 2005).They may further impede the HIV-1 reverse transcriptase activity, while binding silver nanoparticles to human serum albumin has been demonstrated to act as a potential carrier for these cytoprotective particles in vivo [23].

3. CROSS INFECTION CONTROL VIA NANOPARTICLES

Taking advantage of the toxic properties of nano particle metal oxides and metals, particularly those that produce reactive oxygen species under UV light, are finding increasing use in antimicrobial formulations.Copper, silver and their compounds have been used widely. Nano silver particles (5-40 nm) have been reported to inactivate most microorganisms, such as HIV-1.

For their bactericidal purposes, high reactivity of silicon dioxide and titaniumdioxide also exploited extensively in filters and coatings on substrates like alumina [24].

4.NANOPARTICLES REDUCE ANTIBIOTIC RESISTANCE

By the use of nano particles, antibiotic resistance can be decreased in combination therapy. To decrease the antibiotic resistance, Zinc Oxide nano particles can be used thus enhance the antibacterial activity of Ciprofloxacin against microorganism, by interfering pharmacologic mechanisms of drugs that are interacting in the antibiotic resistance [25].

5.DETECTION OF DISEASES BY NANOPARTICLES

Improved diagnosis, proper treatment, early detection and prevention and follow-up of diseases is possible with the help of nano medicine. Several nano scale particles are used as tags and labels, biologically can be performed quickly, testing has become moreflexible and sensitive).In the rapid diagnosis of infectious diseases nanotechnology is finding uses. Biosensors are also being developed which are the devices in which a biological sensing element is either intimately connected to or integrated within a transducer. In biosensors Nano-fabricated structures that are coated with elements such as gold that have affinity for biomolecules are incorporated. For example, with the application of such a nanotechnology, for the detection of urinary tract infection that is caused by *Escherichia coli*,a rapid method has been developed [26].The detection system that is based upon enzyme-linked immunosorbent assay (ELISA) technology utilizes anti-*E.coli*antibody-bound Gold Nanowire Arrays (GNWA) on an anodized porous alumina template. It has also been shown possible to detect minute amounts of target DNA strands with complementary DNA linked to gold nanoparticles [27].

One of the most important aspects is detecting the molecules which are associated with diseases like diabetes mellitus, neurodegenerative diseases and cancer. They also used for detecting microorganisms and viruses that associated with infections, such asHIV viruses, pathogenic bacteria and fungi. Rarest bimolecular signals at a very early stage of the disease can be detected withmacro scale devices such as nanotubes and nanowires [14]

6.NANOTECHNOLOGY AND DISEASETREATMENT

At the Nanometer level important properties and bioactivity of drugs and some other materials can be changed.It should be possible to control the characteristics of drugs. These characteristics includecontrolled release, specific site-targeted delivery and solubility. Chitosan-coated Nano capsules as triclosan carriers have effective role for this capacity. This approach may be of use in the delivery of triclosanby inhibiting the growth of *Plasmodium falciparum* as an effective antimalarial drug [28].

Under clinical investigation increasing number of nanotechnology based products are currentlyavailable. Surgical blades, suture needles,wound dressings, contrast-enhancing agents for magnetic resonance imaging,anti-microbial textiles, bone replacement materials, chips for *in vitro* molecular diagnostics and micro needle products are already commercially available [14].

6.1 Nanotechnology and Cancer

In oncology, nano particles can be of great use due to their small size and particularly use in imaging. Nano particles, such as quantum dots which have quantum confinement properties, can be used with magnetic resonance imaging that are important to produce exceptional images of tumor sites. Nano particles are much brighter so they have need only one light source for excitations compared to organic dyes. Higher contrast image produced by the use of fluorescent quantum dots at a lower cost than organic dyes that are used as contrast media [29].

Kanzius RF therapy attaches microscopic nano particles to cancer cells and then "cooks" tumors inside the body with radio waves that heat only the nanoparticles and the adjacent (cancerous) cells.Other biomarkers left behind by cancer cells and proteinscan be detected by the use of nano wires are used to prepare sensor test chips. This make diagnosis of cancer possible from a single drops of a patient's blood in early stages [30].

In cancer photodynamic therapy nano particles are used. Photo light is illuminated from outside and the particle is inserted within the tumor in the body thus photo light illuminate particles.If particle is of metal, it willabsorb light and it will get heated because of energy from the light. Due to light high energy oxygen molecules are produced which chemically react withtumors cell and destroy them without reacting with other body cells. As a noninvasive technique, Photodynamic therapy has gained importance for dealing with tumors [32].

High surface area to volume ratio is the special property of Nano particles, which allows different functional groups to get attached to a Nano particle and thus they bind to certain tumor cells. For the detection of image multifunctional Nano particles can be manufactured and are used to treat a tumor in cancer treatment [29].

6.2Nanotechnology &Alzheimer's Disease

It is a neurodegenerative disorder manifested by progressive loss of memory followed by irreversible dementia. AD neurodegeneration is characterized by the cytoskeleton damage due to complex molecular pathways and loss of neurons .

Treatments of AD can only partially minimize symptoms, but there exists no cure to slow Neurodegeneration or stop this. Cholinesterase inhibitor was the first drug used to treat AD that breaks down acetylcholine. These maintain greater level of acetylcholine in the synaptic cleft. Thus promote improve neuronal function and signaling. Underlying neurodegeneration is not prevented by this. Major molecular pathways involved in AD can potentially be targeted through nanotechnology. The applications of nanotechnology in neurology consist of drug delivery beyond the blood brain barrier (BBB), neuroprotection and neuro-regeneration [31].

Engineeringand designing of nanoparticulate entities with high specificity for brain capillary endothelial cells are involved in early AD diagnosis and treatment is made possible by using these nanoparticles . In effective disease-modifying strategies for AD, nanotechnology based neuroprotective approaches can be of great implication. Especially, when the targeted molecular pathways are involved in more initial phases of AD pathogenesis. Nanotechnology is a major source of potent agents to modify the course of several pathological mechanisms that are involve in AD [33].

6.3 Nanotechnology & Diabetes

Diabetes the most common metabolic disorders worldwide. The disease is generally believed to be incurable and the few conventional drugs available to manage the disease are not readily affordable to all. Over the past 30 years, the status of diabetes has changed from being considered as a mild disorder of the elderly to one of the major causes of morbidity and mortality affecting the youth and middle aged people [34]. Nanotechnologyis a new method to rapidly measure small amounts of insulin and blood sugar level in diabetic patients.

7. NANOTECHNOLOGY IN MONITORING OF INSULIN LEVEL

Multi-walled carbon nanotubes are microphysiometer**,** which are like different flat sheets of carbon atoms stacked and they rolled into very small tubes to measures insulin production at intervals. When insulin molecules oxidize in the presence of glucose, sensor detects insulin levels continuously. The current in the sensor increases when the cells produce more insulin molecules, and vice versa, that allow monitoring insulin concentrations in real time . Long-term monitoring of tissue glucose concentrations by wireless telemetry has been developed for diabetes by **implantable sensor**. The implantable sensor is designed to deliver diabetes patients an alternative to short-term glucose sensors and finger-sticking or limit dangerous glucose level fluctuations. These fluctuations are known as glucose excursions [36].

Sensor microchips are also being developed to continuously monitor body parameters. These parameters include temperature, blood glucose and pulse. Under the skin a chip would be implanted and transmit a signal that could be monitored continuously [35]. Proper delivery of insulin in the blood stream is involved in treatment of diabetes which canbe achieved by using Nanopumps. It's a powerful device and has many possible applications in the medical field. The pump injects insulin to the patient's body in a constant rate, balancing the amount of sugars in his or her blood. The pump can also administer small drug doses over a long period of time [36].

8. NANOTECHNOLOGY IN DENTISTRY

By the use of nanomaterials and biotechnologies, the development of nano dentistryallowsa perfect oral health.

a. Nanocomposites

Increasing interest in appealing renovations in recent years led to development of materials that have the same color as that of teeth. The implementation of nanoparticle technology into healing materials is the latest advance in composite resins. Nano-dimensional filler particles are produced by the use of nanotechnology, which are added as nanoclusters into composite resins. They are different from traditional fillers [37]. The production of composites is made possible by the use of nanoparticles with a smooth surface after the polishing process which gives great esthetic features to the material. Composite resins containing such particles have a high degree of strength and resistance to abrasion and are easy to shape [39].

b. Dental Nano robots

Dental Nano robots are able to move through teeth and surrounding tissues by using specific movement mechanisms.Nano robots (dentifrobots) left by toothpaste or mouthwash on the occlusal surfaces of teeth can clean organic residues by moving throughout the supragingival and subgingival surfaces. Accumulation of calculus is also prevented by using those These Nanorobots are safely deactivated when they are swallowed and can move as fast as 1-10 microsecond [38].

9. NANOTECHNOLOGY FOR PREVENTING DENTAL CARIES

The use of a toothpaste containing man-sized calcium carbonate enabled remineralization of early enamel lesions [40]. The bacteriostatic effects ofgold nanoparticles, zinc oxide and silver on Streptococcus mutans that causes dental caries. Studies reported that silver nanoparticles had an antimicrobial effect with lower toxicity and in lower concentrations as compared to the other nanoparticles [41].

Limitations of Nanotechnology

There are some restrictions which are not allowing nanotechnology based systems to achieve their potential with reference to its goal. Some of the prominent constrains are [42]:

1.	There is very low investment for research and growth of nanotechnology based products.
2.	Because of organizational lack of knowledge and use of wrong strategies to commercialize, a number of nanotechnology products are designed but they still cannot reach the market.
3.	There is no proper information is given about the nanotechnology based products about their effects on human health and environment.
4.	There is very less awareness about what nanotechnology can do for the betterment of mankind in future.
5.	There are a few trained professionals available to do research and bring innovations in the field of nanotechnology.
6.	Nanotechnology can provide a lot of benefits to developing countries but their governments are paying very less attention towards this technology.
7.	Companies have no confidence to bring innovations in this field as governments are not encouraging them for developments of nanotechnology based products.

10. CONCLUSION

Nanotechnology could be the future of any nation as its excelling in almost every field of life. It has potential to improve quality of life as it has vast applications in medical science to help mankind. It's for sure that nanotechnology is helping us in various possible ways but we should be very careful about such a new technology as there are many unpredicted risks that may come through its productive potential. For a nation it is very important that it creates a fully trained workforce to do research and development. In this process, public awareness should be the first step to make people well aware about the possible benefits of nanotechnology. Once there is enough information to the public about this filed there will be more interest and finding of new applications in all domains.

The purpose of this article is to provide information about different applications of nanotechnology, knowledge of its benefits and disadvantages and what limitations is its facing currently around the world. Although it has many benefits but still the future of nanotechnology is uncertain because of adverse effects of nanoparticles on the environment that we live in. There is a lack of required skills and equipment in organizations to do research in this field. More ever regulatory authorities are also doubtful to deal with such new technologies. There is a need of reducing the limitations that are keeping the nanotechnology to give us a healthier and desirable future. This could be done if there is collaboration between international organization of developed and developing countries.

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