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A BRIEF REVIEW ON APPLICATIONS OF NANOMATERIALS IN MEDICINE

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ABSTRACT

Materials whose dimensions are in the nanoscale range that is 100nm or less are called nanomaterials. Their unique size-dependent properties viz. mechanical, electrical and optical properties make these materials superior and indispensable in many areas of human activity including medicine. The use of nanotechnology in the field of medicine could revolutionize the way we detect and treat damages, diseases in the human body in the future and many techniques only imagined a few years ago are making remarkable progress towards becoming realities. Applications of nanotechnology in medicine currently being developed involves employing nanoparticles for drug delivery, for the detection of biological molecules, imaging of diseased tissues and innovative therapeutics. This brief review summarises the most recent developments in the field of applied nanomaterials with respect to the applications in medicine.

KEYWORDS

Nanoscale, Nanotechnology, Size- dependent and Drug delivery.

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INTRODUCTON

Nanoparticles are tiny materials having size ranges from 1 to 100nm at least in one dimension. Materials made up of nanoparticles have a relatively larger surface area when compared to the same volume of material made up of bigger particles. This higher surface area to volume ratio of nanomaterials is responsible for the unique physical and chemical properties. For example, the mechanical, electronic, optical and chemical properties of nanoparticles may be very different from those of each component in the bulk. These unique properties bring innumerable applications in various fields to nanomaterials including medical field. Nanomedicine is the medical application of nanotechnology[1]. Nanomedicine ranges from the medical applications of nanomaterials and biological devices, to nanoelectronic biosensors, and even possible future applications of molecular nanotechnology such asbiological machines. Applications of nanomaterials are shown in the Figure No.1.

Nanomaterials can be categorized into four types- inorganic-based nanomaterials, carbon-based nanomaterials, organic-based nanomaterials and composite-based nanomaterials. Generally, inorganic-based nanomaterials include different metal and metal oxide nanomaterials. Each of the has a variety of applications in medicine.

Inorganic nanoparticles have gained significant attention in preclinical development as potential diagnostic and therapeutic systems in oncology for a variety of applications, including tumor imaging, tumor drug delivery or enhancement of radiotherapy. Carbon based nanoparticles have been successfully applied in pharmacy and medicine due to their high surface area that is capable of adsorbing or conjugating with a wide variety of therapeutic and diagnostic agents (drugs, genes, vaccines, antibodies, biosensors, etc.). There is a growing interest in the development of organic nanomaterials for biomedical applications. An increasing number of studies focus on the uses of nanomaterials with organic structure for regeneration of bone, cartilage, skin or dental tissues. Solid evidence has been found for several advantages of using natural or synthetic organic nanostructures in a wide variety of dental fields, from implantology, endodontics and periodontics, to regenerative dentistry and wound healing. Composite nanomaterials are being used in the development of biosensors for the diagnosis of diseases, drug targeting, controlled release applications, medical implants, speeding up the healing process for broken bones and imaging techniques. Nanoparticles for use in any biological or medical application must be non-toxic and show minimal bioaccumulation within the body. These properties can be improved by coating these particles with a nanoshell made from materials with low toxicity. These are nothing but nanocomposites. Silica is popularly employed for this purpose, coating nanoparticles for safe use in a clinical setting. In this review, concentration is focused exclusively on medical applications of exclusively nanomaterials.

APPLICATIONS OF NANOMATERIALS IN MEDICINE

Functionalities can be added to nanomaterials by interfacing them with biological molecules or structures. These functionalised nanomaterials find vast applications in medicine. 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.

Drug delivery

Nanotechnology has provided the possibility of delivering drugs to specific cells using nanoparticles[2]. The overall drug consumption and side-effects may be lowered significantly by depositing the active pharmaceutical 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. Additionally, targeted drug delivery reduces the side effect possessed by crude drug via minimizing undesired exposure to the healthy cells. 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 nano engineered devices[3]. 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[4]. The efficacy of drug delivery through nanomedicine is largely based upon: a) efficient encapsulation of the drugs, b) successful delivery of drug to the targeted region of the body and c) successful release of the drug[5]. Several nano-delivery drugs are in the market now. Chitosan, Alginate, cellulose, liposomes, dendrimers etc. are being used as nanodrug delivery systems nowadays. While advancement of research proves that targeting and distribution can be augmented by nanoparticles, the dangers of nanotoxicity become an important next step in further understanding of their medical uses[6]. The toxicity of nanoparticles varies, depending on size, shape, and material. These factors also affect the build-up and organ damage that may occur. Nanoparticles are made to be long-lasting, but this causes them to be trapped within organs, specifically in the liver and spleen, as they cannot be broken down or excreted. This build-up of non-biodegradable material has been observed to cause organ damage and inflammation in mice[7]. Magnetic targeted delivery of magnetic nanoparticles to the tumor site under the influence of inhomogeneous stationary magnetic fields may lead to enhanced tumor growth. In order to circumvent the pro-tumorigenic effects, alternating electromagnetic fields should be used[8].

Imaging

Nanotools and devices are being developed for *In vivo* imaging. Ultrasound and MRI images exhibit a favorable distribution and improved contrast when nanoparticle contrasting agents are used. In cardiovascular imaging, nanoparticles have potential to aid visualization of blood pooling, ischemia and focal areas where inflammation is present[9]. Nanoparticles play a vital role in oncology especially in imaging[2]. The use of fluorescent quantum dots could produce a higher contrast image and at a lower cost than today's organic dyes used as contrasting agents. Quantum dots are being used nowadays in conjugation with MRI for better images. For instance, Cadmium selenide quantum dots glow when exposed to UV light. When injected, they seep into cancer tumor and glow it. Hence, the surgeon can see the tumor well and use it as a guide for more accurate tumor removal. However, the toxicity of quantum dots needs to be addressed. Luminescent tags made with quantum dots attached to proteins, can penetrate through the cell membranes[10]. They fluoresce when exposed to light. When these luminescent quantum dots are attached to a small group of cells, can track their path in the body far better than traditional luminescent tags made up of dyes. Colour of quantum dots is size dependent. As a result, sizes are selected so that the frequency of light used to make a group of quantum dots fluoresce is an even multiple of the frequency required to make another group incandesce. Then both groups can be lit with a single light source. So, a single light source is enough to lit all the quantum dots attached to various cells. While different color dyes absorb different frequencies of light. So, when the cells are tagged with these different dyes, there is a need for as many light sources as dyes and hence cells.

Dialysis

Dialysis is a purification process, works on the principle of the size related diffusion of solutes across a semi permeable membrane. Dialysis done with nanoparticles allows specific targeting of substances[11]. Additionally larger compounds which are commonly not dialyzable can be removed[12]. Hence, dialysis with nanoparticles is advantageous. For instance, dialysis can be done with functionalized iron oxide or carbon coated metal nano particles with ferromagnetic orsuper paramagnetic properties. Binding agents such asproteins, antibiotics, or synthetic ligands are covalently linked to the particle surface. These binding agents are able to interact with target species forming an agglomerate. Applying an external magnetic field gradient allows exerting a force on the nanoparticles. Hence the particles can be separated from the bulk fluid, thereby cleaning it from the contaminants[13].

Pancreatic cancer therapy

It is one of the most life-threatening diseases due to lack of proper diagnosis methods and some disadvantages in pharmaceutical treatment. Targeted tumor cells develop resistance to anticancer drugs and leads to critical condition. Some of nanotechnology-based carriers have been used for both diagnosis and treatment and they proved to be more fruitful. For instance, curcumin filled polymeric nanoparticles have reduced the growth of primary tumor[14].

Diabetes

Spreading of diabetes has been increasing day by day in all age groups. The oral administration of insulin has been destroyed by the acid present in the stomach and it makes the objective of treatment useless. Inorder to deliver the insulin directly in to blood stream nanotechnology approach is more useful. In this, the insulin nanoparticles are bound to colloidal nanoparticles which protect the insulin from gastrointestinal tract and transports in to blood stream without any interruption. Hydrogels, antiproteases, cyclodextrins are used to encapsulate insulin molecules and it will be successfully absorbed in to blood. N, N- Dimethyl aminoethyl methacrylate, polyanhydrides, polyurethanes have been reported to be effective insulin carries. These carriers are pH sensitive and they release the loaded insulin when a desirable pH is achived[15].

Cardiovascular diseases

Hypertension and hypercholesterolemia are two main risk factors leading to cardiovascular diseases like thrombosis, infarction and stroke. The traditional drug therapy given to these diseases has some adverse effects. Application of nanotechnology proved to be more useful. Blood clots formed at the blood vessels are called thrombosis, due to this blood circulation is obstructed which ultimately leads to heart attack. Nanoparticle loaded with tissue plasminogen activator (tPA) is used to treat this. This loaded nanoparticle is directed to the thrombus site and it removes the blood clot leading to free blood circulation and thus reducing the possibility of heart attack[16].

Antimicrobial activities of nanomaterials

Resistance to antibiotic drugs has become a serious concern nowadays. The poor solubility, chemical stability and enhanced side effects are decreasing the utility of currently used antibacterial drugs. To overcome this, researchers are turning towards nanomaterials. Silver nanoparticles come for rescue in such cases. Silver nanoparticles incorporated natural or synthetic polymers composites have been used as antimicrobial agents for a long time. Silver nanoparticles incorporated in silver sulfadiazine is more active as antibacterial agent compared to just silver sulphadiazine. Recently, carbon nanotubes have been proved to be more active when compared to silver nanoparticles[17] as antibacterial agents.

Skin diseases therapy

Skin inflammation is the commonly seen problem in the people. Exposure of skin to UV light leads to inflammation. Nowadays nanomaterials are used to treat commonly encountered skin diseases. Nanoliposomes, nanocapsules, nanoemulsions and nanoparticles are used to formulate cosmetic products, body lotions[18]. These materials diffuse through the stratum corneum part of the skin and does the needful. Sunscreen cosmetic materials are being formulated with titanium dioxide or zinc oxide nanoparticles, which are colourless and reflect or scatter UV light more efficiently than the normal sunscreen lotions containing larger particles[19]. Lipid nanoparticles are also added to cosmetics to enhance their film forming ability and also to hydrate the dry skin.

Nanomaterials have many more medical applications, but I restricted myself to only few of them keeping in view the length of the article.

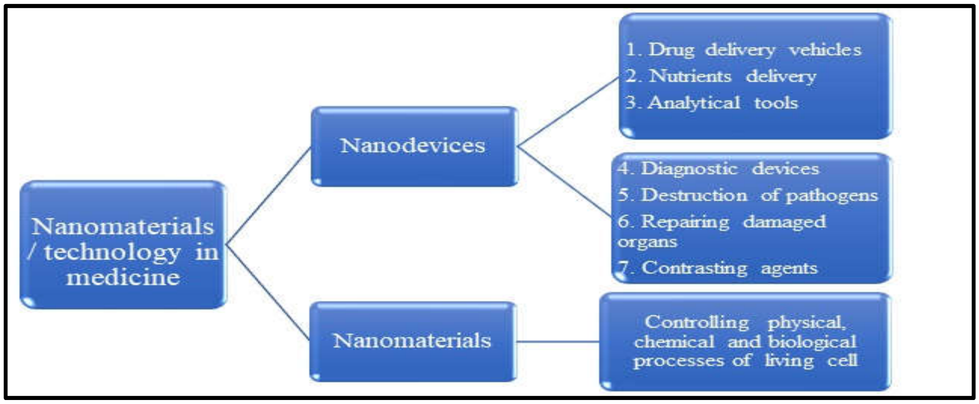

Figure No.1: Applications of nanomaterials

CONCLUSION

Nanomaterials have applications literally in every field. In this review, applications exclusively in medicine are explored in some detail. Lot more research need to be done in the field of biocompatible and biodegradable nanomaterials, but with a word of caution on toxicity. Because of the small size, nanoparticles find their way easily to enter the human body and cross the various biological barriers and may reach the most sensitive organs. Studies show that nanoparticles are distributed to the liver, heart, spleen and brain in addition to lungs and gastrointestinal tract in the body. During metabolism, some of the nanoparticles are congregated in the liver tissues and become toxic. Nanoparticles are more toxic to human health in comparison to large-sized particles of the same chemical substance. Hence, before bringing a nanoproduct for use, a detailed study should be done focusing on its toxic effects. If found satisfactory then only it should be used. An international body governing all these issues need to be established.

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CONFLICT OF INTEREST

We declare that we have no conflict of interest.

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