ISSN: 2582-5887; Peer-Reviewed Refereed International Journal (UIJES); Volume-5, Special Issue 2(January-2024); Impact Factor: 6.71(SJIF)

Nanoparticles in modern medicine

T.N. Bhavani[1] , G.Pavani[2],V.Rambabu[2],P.Vijay Kumar[2], T.V.V.Satyanarayana[2] ,V.Sanjeeva Kumar[2]and Dr.S.V.G.V.A.Prasad[3*]

[1]Lecturer in Physics, Govt.Jr.College ,Tadepalligudem, West Godavari,A.P.,India.
[2]Lecturer in Chemistry,Pithapur Rajah's Government Autonomous College,Kakinada-533001,A.P.,India.
[3]Lecturer in Physics and Electronics, Pithapur Rajah's Government Autonomous College,Kakinada-533001,A.P.,India.
*Corresponding Author e-mail Id:somarouthu13@yahoo.co.in

Abstract

Materials with overall dimensions in the nanoscale, or less than 100 nm, are referred to as nanoparticles. These materials have become significant actors in contemporary medicine in recent years, with clinical uses ranging from carriers of drugs and genes into tumors to contrast chemicals in imaging. In fact, there are some situations in which treatments and analyses made possible by nanoparticles are just not possible in other ways. But there are also certain environmental and societal issues that come with nanoparticles, especially when it comes to toxicity. The primary contributions of nanoparticles to contemporary medicine will be emphasized in this overview, together with a discussion of the socioeconomic and environmental implications of their use.

Keywords: nanoparticles, contrast agents, drug delivery, tumors, quantum dots, toxicity.

Introduction

Materials with overall dimensions in the nanoscale, or less than 100 nm, are referred to as nanoparticles. These materials have become significant players in contemporary medicine in recent years, with uses ranging from carriers of genes into particular cells to contrast chemicals in medical imaging. By virtue of their size, nanoparticles differ from bulk materials in a number of ways, including chemical reactivity, energy absorption, and biological mobility.

Another name for nanoparticles is "zero-dimensional" nanomaterials. This definition results from the fact that all of their dimensions are within the nanoscale, in contrast to two-dimensional and one-dimensional nanomaterials, which have two dimensions exceeding the nanoscale (e.g., self-assembled materials and nanowires, respectively), and one-dimensional nanomaterials, which have one dimension exceeding the nanoscale. Additionally talk on the societal and environmental effects of its use. There are many advantages of nanoparticles in contemporary medicine. In fact, there are situations in which treatments and analyses made possible by nanoparticles are just not possible in other ways. But there are also certain environmental and societal issues that come with nanoparticles, especially when it comes to toxicity. This analysis attempts to emphasize the significant advances that nanoparticles have made to contemporary medicine and

The purpose of this paper is to provide a general overview of the application of nanoparticles in medicine. Moreover, the technologies covered in this review will be those that have either already progressed to clinical application or in vivo experimentation. Examples of medical applications of nanoparticles will be covered in this paper, falling under the general categories of drug/gene delivery and medical imaging. The reader will be directed, whenever feasible, to the many in-depth reviews that are now accessible for each application area. Finally, the effects of using nanoparticles in modern medicine on society and the environment will also be covered.

Nanoparticles in medical imaging

Both contemporary magnetic resonance imaging (MRI) of different body regions and conventional biological imaging of cells and tissues using fluorescence microscopy can greatly benefit from the use of nanoparticles. The nanoparticles utilized in these two methods differ in terms of their chemical makeup. Table 1 provides an overview of the uses of nanoparticles in imaging.

Table 1

Summary of current nanoparticle technologies in medicine

Area	Nanoparticle type	Major in vivo applications	Significant characteristics	Selected references
Optical imaging	Quantum dots	Site-specific imaging in-vivo	Imaging of lymph nodes, lung blood vessels, and tumors. Greater intensity and resistance to photobleaching compared with conventional methods. Site-specific targeting via surface functionalization. Subcutaneous imaging without surgical incisions.	Akerman et al 2002; Gao et al 2004; Kim et al 2004
MRI	Superparamagnetic iron oxide nanoparticles	Cancer detection	Enhanced contrast for imaging of liver, lymph nodes, and bone marrow. Paramagnetic properties that can alter magnetic resonance relaxation times of selected regions or fluids **in vivo**.	Harisinghani et al 2003; Huh et al 2005
Drug and gene delivery	Polymer- and liposome-based nanoparticles	Cancer therapy	Targetted delivery by surface functionalization. Strategies for prolonging residence times in vivo (eg, PEG attachment). Strategies for solubilizing water-insoluble drugs (eg, paclitaxel). Multi-layer and multi-functional (eg, chemotherapeutic and anti-angiogenic).	Duncan 2003; Allen and Cullis 2004; Micha et al 2006; Sengupta et al 2005
		Neurodegenerative disease therapy	Transport across blood–brain barrier (eg, by PEG incorporation). Superior to direct drug administration. Therapies for diseases unresponsive to small molecule drugs (gene therapy).	Schlachetzki et al 2004; Garcia-Garcia et al 2005; Popovic and Brundin 2006
		HIV/AIDS therapy	Solubilizing water-insoluble drugs by emulsification. Ability to transfect cells by DNA incorporation in nanoparticle.	De Jaeghere et al 2000; Olbrich et al 2001; Tabatt et al 2004

Optical imaging

Organic dyes are added to the sample in order to accomplish conventional imaging of cells and tissue sections. Many dyes, like rhodamine and fluorescein isocyanate (FITC), are attached to biomolecules that connect to cells or their constituents in a specific way via ligand/receptor interactions. Insufficient fluorescence intensity and photobleaching are two issues that arise frequently with this imaging modality. The progressive loss of fluorescence intensity that is frequently noticed over time as a result of irreversible modifications to the dye molecules' chemical structure that make them nonfluorescent is known as photobleaching.

The nanoparticles known as quantum dots (QDs) are made of inorganic semiconductor molecules. When exposed to ultraviolet (UV) radiation, these nanoparticles release a bright fluorescent light, with the wavelength (color) of the light being sensitively correlated with the particle size. These materials are special in that they rely on size. A "band gap" gives inorganic semiconductor molecules their unique characteristics. The energy difference that separates the valence band, also known as the energy level, where electrons predominantly reside, from the conduction band, where they can be "promoted" by an energy source of a particular wavelength, or "excitation," typically in the form of a photon, is known as the band gap. A "hole" is left behind when an electron transitions from the valence band to the conduction band.

Being inorganic materials, QDs are insoluble in aqueous solutions. An essential part of using QDs in biological and medical applications is therefore coating them with a thin layer of a water-soluble material. Typically, this step is followed by coating with a material that binds preferentially to a particular cell or cell component. The surface of each QD has a large number of sites onto which soluble and/or bioactive molecules can be tethered. Furthermore, more than one type of molecule can be attached to each QD, giving it multiple functionalities. In a review of the application of QDs for live cell and in vivo imaging, Michalet and colleagues (2005) have described different surface modification strategies such as targeting and prolonged retention in the bloodstream. Akerman and colleagues (2002) ,Gao and colleagues (2004)

Nanoparticles are also used in the following fields:

1.Magnetic resonance imaging Mornet et al 2004

2.Huh and colleagues (2005) recently described how SPIO nanoparticles can be used to detect cancer in vivo using a mouse xenograft model.

SPIO nanoparticles can also be used to visualize features that would not otherwise be detectable by conventional MRI. Harisinghani and colleagues (2003) utilized SPIO nanoparticles in human patients with prostate cancer to detect small metastases in the lymph node.

Nanoparticles in drug and gene delivery

3.Cancer

Nanoparticles have made a tremendous impact in the treatment of various types of cancer, as evidenced by the numerous nanoparticle-based drugs and delivery systems that are in clinical use. Examples of numerous liposome- and polymer-based drugs or therapeutic agents have been presented in recent reviews (Duncan 2003; Allen and Cullis 2004).

4.Neurodegenerative diseases

Drug delivery to the central nervous system remains a challenge in developing effective treatments for neurodegenerative diseases (Garcia-Garcia et al 2005; Popovic and Brundin 2006).

5HIV/AIDS

De Jaeghere and colleagues (2000) investigated the delivery of an HIV-1 protease inhibitor, CGP 70726, using pH-sensitive nanoparticles made from a copolymer of methacrylic acid) and ethyl acrylate.

6.Ocular diseases

The primary motivation for using nanoparticle-based drug delivery systems in ophthalmic applications is the ability to prolong drug residence times by trapping the drug in the ocular mucus layer (Ludwig 2005).

Certain disease conditions, such as cytomegalovirus (CMV) retinitis require administration of drugs to the retinal region of the eye.

7.Respiratory diseases

The application of nanoparticle-based drug delivery approaches in respiratory diseases has been somewhat limited (Pison et al 2006

Environmental and societal considerations in recent years, there has been a lot of attention paid to the effects of nanomaterials on the environment and public health. But much more work needs to be done as advances in nanomedicine and nanotechnology as a whole evolve. This is because different nanomaterials carry different kinds of dangers. The sorts of nanoparticles mentioned in the preceding applications will be the main topic of this section. In vivo investigations will receive special focus, as in the previous sections, but noteworthy in vitro work will also be discussed.

Toxicity of quantum dots

QDs are inorganic nanoparticles that are usually coated with an organic material, which makes them biocompatible or bioactive, as was discussed in the section on medical imaging. The exposure of the inorganic core due to organic layer breakdown is the primary toxicological danger linked to QD use in vivo. Numerous inorganic-metal complexes, including CdSe, ZnS, CdTe, InP, InAs, and GaAs, to mention a few, can be used to create QDs. These compounds each have distinct chemical characteristics that can have a significant impact on their toxicology. Even though there isn't a lot of research on these chemicals' toxicity in vivo, several papers raise important issues and show how much more needs to be done. Recently, a thorough analysis of quantum dot toxicity was published.

Table 2

Toxicological effects of nanoparticles associated with medical applications

Nanoparticle type	Toxicological effects	References
Quantum dots	Potential for exposure to inorganic core (eg, cadmium) and resulting cytotoxic effects (eg, liver damage).	Derfus et al 2004
	Toxicity risk greatly reduced by coating with ZnS and soluble polymers (such as PEG).	Ballou et al 2004
	Risks associated with production, handling, and storage of QDs need to be evaluated.	Oberdorster et al 2005; Hardman 2006
Metallic	Iron oxide and gold nanoparticles are not toxic.	Weissleder et al 1989; Connor et al 2005; Muldoon et al 2005; Hainfeld et al 2006;.
	Surface functionalization may influence toxicity.	Goodman et al 2004
Polymeric/liposomal	Not toxic since these nanoparticles have natural or highly biocompatible components (eg, chitosan, PEG).	Alonso 2004; de Campos et al 2004

Advantages of Nanomaterials

The properties of nanomaterials, particularly their size, offer various different advantages compared to the bulk-form of the materials, and their versatility in terms of the ability to tailor them for specific requirements accentuates their usefulness. An additional advantage is their high porosity, which again increases demand for their use in a multitude of industries.

In the energy sector, the use of nanomaterials is advantageous in that they can make the existing methods of generating energy - such as solar panels - more efficient and cost-effective, as well as opening up new ways in which to both harness and store energy.

Nanomaterials are also set to introduce a number of advantages in the electronics and computing industry. Their use will permit an increase in the accuracy of the construction of electronic circuits on an atomic level, assisting in the development of numerous electronic products.

The very large surface-to-volume ratio of nanomaterials is especially useful in their use in the medical field, which permits the bonding of cells and active ingredients. This results in the obvious advantage of an increase in the likelihood of successfully combatting various diseases.

Disadvantages of Nanomaterials

Alongside their benefits, there are also a number of disadvantages associated with nanomaterial use. Due to the relative novelty of the widespread use of nanomaterials, there is not a large amount of information on the health and safety aspects of exposure to the materials.

Currently, one of the main disadvantages associated with nanomaterials is considered to be inhalation exposure. This concern arises from animal studies, the results of which suggested that nanomaterials such as carbon nanotubes and nanofibers may cause detrimental pulmonary effects, such as pulmonary fibrosis. Further possible health risks are ingestion exposure and dust explosion hazards.

Additionally, there are still knowledge gaps regarding nanomaterials, meaning the manufacturing process can often be complex and difficult. The overall process is also expensive, requiring optimum results - especially regarding their use in consumer goods - in order to avoid financial losses.

Risk analyses for possible environmental impacts show that after being rinsed off, nanoparticles used in skin-care products like sunscreen have the potential to wind up in aquatic environments. Engineered nanomaterials may also find their way into bodies of water like lakes and rivers, where they may accumulate to form larger-sized particles. This could lead to a decrease in life functions including growth and reproduction, which could endanger freshwater animals like snails. It is possible that the materials in such freshwater habitats also generate problems for marine ecosystems. An further worry is the build-up of nanomaterials in other environmental components, like soils, through sewage sludge.

References:

Akerman et al 2002; Gao et al 2004; Kim et al 2004

Duncan 2003; Allen and Cullis 2004; Micha et al 2006; Sengupta et al 2005

Schlachetzki et al 2004; Garcia-Garcia et al 2005; Popovic and Brundin 2006

De Jaeghere et al 2000; Olbrich et al 2001; Tabatt et al 2004

Pignatello et al 2002, 2002b; Ludwig 2005

Derfus et al 2004

Ballou et al 2004