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Review Article

Current Research on Nanoparticles in Medicine and Future Obstacles

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ABSTRACT

Materials with overall dimensions in the nanoscale, or under 100 nm, are referred to as nanoparticles. These materials have recently become significant players in contemporary medicine, with therapeutic uses ranging from contrast agents in imaging to carriers for the transport of drugs and genes into malignancies. In fact, there are some situations where using nanoparticles makes it possible to perform studies and treatments that would otherwise be impossible. However, because of their toxicity in particular, nanoparticles pose special environmental and socioeconomic problems. This review will explore the societal and environmental implications of nanoparticle use as well as the significant contributions that nanoparticles have made to modern medicine.

Keywords: Nanoparticles; Drug delivery; Tumors; Toxicity

INTRODUCTION

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

Nanomaterials that are "zero-dimensional" are another name for nanoparticles. As opposed to two-dimensional nanomaterials, which have two dimensions larger than the nanoscale, and one-dimensional nanomaterials, which have one dimension larger than the nanoscale (such as nanowires and nanotubes), this definition is based on the fact that all of their dimensions are in the nanoscale. Nanoparticles have many advantages for contemporary medicine. In fact, there are some situations where using nanoparticles makes it possible to perform studies and treatments that would otherwise be impossible. However, because of their toxicity in particular, nanoparticles pose special environmental and socioeconomic problems. This review will explore the societal and environmental implications of nanoparticle use as well as the significant contributions that nanoparticles have made to modern medicine [1,2].

Instead of being a complete overview, this page serves as a general introduction to the use of nanoparticles in medicine. Additionally, this study will concentrate on innovations that have reached clinical application or in vivo testing. This discussion will go through several examples of medical applications within the broad categories of medical imaging and drug/gene delivery. When applicable, the reader will be directed to the many in-depth reviews that are currently accessible for each application area. The effects of using nanoparticles in contemporary medicine on society and the environment will also be covered [3].

Medical Imaging of Nanoparticles

Both conventional biological imaging of cells and tissues using fluorescence microscopy and contemporary magnetic resonance imaging (MRI) of various body locations can be significantly enhanced by nanoparticles. The nanoparticles utilised in these two processes differ in their chemical makeup [4].

Optical Imaging

By introducing organic dyes into the sample, conventional imaging of cell and tissue sections is accomplished. In order to preferentially bind to cells or cell components through ligand/receptor interactions, biomolecules such as rhodamine and fluorescein isocyanate (FITC) are frequently attached to dyes. Insufficient fluorescence intensity and photo bleaching are two issues that frequently occur in this way of imaging. The progressive reduction in fluorescence intensity that is frequently noticed over time as a result of permanent alterations to the chemical structure of the dye molecules that make them nonfluorescent is known as photobleaching [5].

Nanoparticles called quantum dots (QDs) are made of inorganic semiconductor molecules. Under ultraviolet (UV) lighting, these

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nanoparticles strongly fluoresce, and the wavelength (colour) of the fluorescence strongly varies with particle size. This size dependence is a distinctive feature of material the existence of a "band gap" is what gives inorganic semiconductor molecules their unique characteristics. The energy difference between the valence band (or energy level), where electrons are generally found, and the conduction band, where they can be "advanced" by the application of energy of a particular wavelength (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 (this is a term given to an energy level lacking an electron, and is not a physical feature). Electrons return to the valence band after the excitation is finished, releasing any remaining energy. With QDs, all of this energy is liberated as light. Larger QDs can absorb and release more energy because they have more electron-hole pairs. The wavelength of the light emitted decreases as QD size rises since energy and wavelength are inversely related (E = hc/). In comparison to typical organic dyes, QDs can emit light that is substantially more bright and significantly more stable against photobleaching. This is a significant benefit for 3-D tissue imaging, because photo bleaching during the acquisition of subsequent sections in the z-direction is a key worry. QDs cannot dissolve in water solutions since they are inorganic compounds. Therefore, coating QDs with a thin layer of a water-soluble substance is crucial to employing them in biological and medical applications. Usually, a substance that binds specifically to a certain cell or cell component is coated after this stage. There are numerous places on the surface of each QD where soluble and/or bioactive compounds can be attached. Each QD can also have more than one kind of molecule linked to it, giving it numerous functions. Michalet and colleagues have discussed several surface modification tactics, such as targeting and prolonged retention in the bloodstream, in a review of the application of QDs for live cell and in vivo imaging. Recently documented the mapping of lymph nodes in mice and pigs using oligomer phosphine-coated QDs. These QDs were constructed from CdTe with a CdSe cap, a material combination that emits light when excited in the near infrared. The accomplishment of this work is the non-invasive mapping of lymph nodes up to 1 cm below the skin's surface. The authors concluded that the quantities utilised were below known lethal thresholds despite the fact that the toxicity of the injected QDs was not evaluated in this investigation [6]

By covering the QD surface with the proper chemicals, QDs can be directed to particular body organs. by covering the QD surface with a peptide sequence that is known to bind to endothelial cells in lung blood arteries, it was shown that ZnS-capped CdSe QDs may be guided to the lungs of mice. Using the same technique, QDs were directed to blood or lymphatic arteries inside of mouse tumours. In both cases, the targeted cells ingested the QDs through endocytosis, while the cells in the surrounding tissue did not [7, 8].

Magnetic Resonance Imaging

The body can be scanned in 3-D without any harm using the magnetic resonance imaging (MRI) technique. The majority of brain, spine, and musculoskeletal problems are diagnosed and treated using this technique, which is widely employed in contemporary medicine. Hydrogen atoms that are naturally present in tissue are examined using MRI using magnetic resonance spectroscopy. A transverse radiofrequency (RF) pulse is used to ignite the magnetic dipoles within hydrogen nuclei in a sample that has been put inside of a potent static magnetic field. The spinning nuclei are lined up with the static field before the RF pulse. These nuclei receive additional energy from the RF pulse, which changes the frequency and direction (transverse) of their spin. Adhering to the RF pulse. The static magnetic field is aligned with the equilibrium state of the hydrogen nuclei as they "relax" or return to it. Two parameters known as T1 and T2 are commonly used to describe the relaxation process. T1 is the amount of time needed to get nuclear spins back in line with the static field, and T2 is the typical amount of time it takes for the nuclei's transverse magnetization to disappear. On the basis of various T1 and T2 relaxation durations, hydrogen nuclei and various types of tissue can be distinguished. Several pictures are gathered during MRI scans based on spatial position as well as weighting based on T1 or T2. In a T1-weighted picture, a sample with low T1 appears bright (Figure 1). The use of contrast chemicals is necessary in many therapeutic applications since the natural variations in relaxation times between regions of interest are minimal. Contrast agents are usually paramagnetic compounds that can change the relaxation times of particular bodily fluids, tissues, or areas. Gadolinium compounds have been successfully used as contrast agents for many years, allowing for the resolution of organs including the kidney and brain. Contrast agents made of gadolinium work by reducing T1. In addition to gadolinium-based agents, super paramagnetic iron oxide nanoparticles have lately gained popularity as efficient contrast agents for T2-weighting. For the imaging of the liver, lymph nodes, and bone marrow, T2 weighting is crucial. Super paramagnetic nanoparticles have considerably longer relaxation durations than ordinary magnetic nanoparticles [9].

Nanoparticles in Drug and Gene Delivery

Among the different application areas of nanoparticles, drug delivery is one of the most advanced. This is large part due to the success of polymer- and liposome-based drug delivery systems, many of which are in clinical use today. Polymeric drugs, polymer-protein conjugates, polymer-drug conjugates, and polymeric micelles are different types of polymer-based drug delivery methods. Additionally, polymers can be emulsified into nanometer-sized

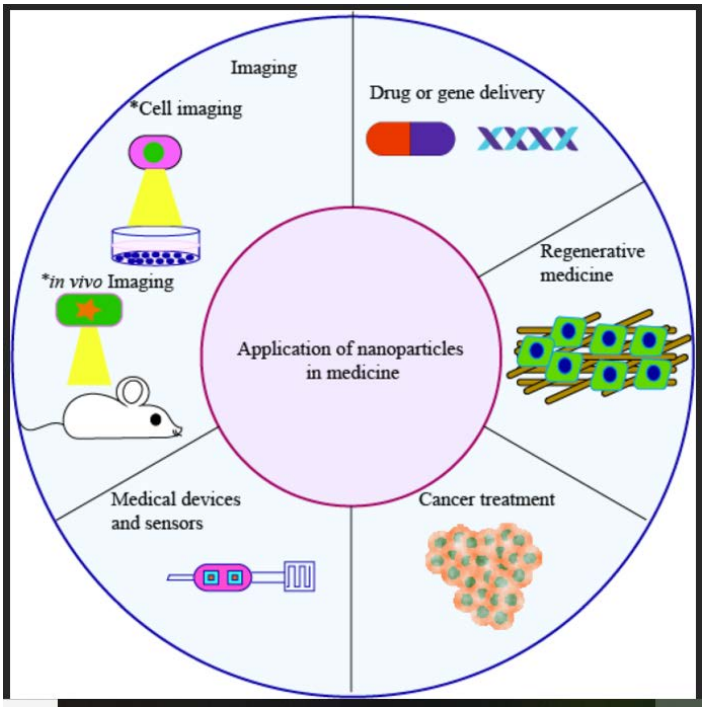

Figure 1: Carbon nanoparticles for medicine: Current and Future.

particles that can contain pharmaceuticals. Natural polymers with established antiviral or anticancer properties often make up polymeric medications. PEG is most frequently used in polymer-protein conjugates. PEG is well known for its high water solubility and outstanding biocompatibility; hence, the solubility of pharmaceuticals is boosted when PEG is attached to them. It is also known that PEG attachment increases receptor-mediated cell uptake and decreases drug renal clearance. Therefore, this strategy can be used to increase a drug's half life and decrease dose frequency. Low molecular weight medications' solubility and selectivity are improved through polymer-drug conjugation. Next is polymeric amphiphilic polymers are frequently used to make micelles, which are solutions of micelles that contain a medication [10].

Toxicity of Metallic Nanoparticles

Super paramagnetic iron oxide nanoparticles' toxicity in rats when utilised as MRI contrast agents. Either intracerebral inoculation or intraarterially injected nanoparticles were used to deliver them to the brain. Although the MRI signal strength decreased with time (weeks to months), normal rats' brain tissue showed no pathological abnormalities. These results are in line with Weissleder and colleagues' nearly 20-year-old toxicity investigation of iron oxide nanoparticles in mice and dogs (1989). The nanoparticles were given intravenously in this study, and neither blood tests nor histology of the targeted tissues revealed any signs of acute or subacute toxicity. Different iron oxide-based nanoparticles used in clinical contrast agents are known to be safe [11].

DISCUSSION

The toxicity of a variety of cadmium-based QDs utilising a primary rat hepatocyte in vitro model. Given that the liver is the main organ affected by Cd exposure, this cell type was chosen. At a QD concentration of 62.5 g/mL, it was shown that QDs with CdSe cores capped with mercaptoacetic acid (MAA) and TOPO were acutely cytotoxic. This behaviour was linked to the release of Cd^{2+} ions after air and ultraviolet (UV) light oxidised the CdSe lattice. ZnS coating of the CdSe particles completely prevented surface oxidation and cytotoxicity, and additional improvement was seen with polymer or protein coating on top of the ZnS. Although this was a positive outcome the in vivo toxicity of mice treated with CdSe/ZnS QDs coated with either amphiphilic poly(acrylic acid) or PEG. The mice received QDs at a concentration of 20 pmol/g of body weight [12]. Where the QDs were seen to deposit, in the liver, spleen, and bone marrow, no necrosis was seen, and when tissue analysis was done, the animals were still alive after 133 days. The two instances given above show how difficult it is to gauge the toxicity of QDs. Because of intrinsic changes in experimental design (QD concentration measurement is just one of many components of this), as well as differences in the organic coating, the in vitro and in vivo experiments cannot be directly compared

CONCLUSION

Nanoparticles have made major contributions to clinical medicine in the areas of medical imaging and drug/gene delivery. While several innovations such as iron oxide contrast agents and many drug delivery systems are by now well-established, newer technologies continue to emerge following the same basic concepts of design. As these innovations advance to clinical application, attention must be paid to environmental and societal implications, particularly in areas such as quantum dots

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