Editorial

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Nanotechnology to nanomedicine: reconciling ethical implications and public health

Abstract

Current advances in nanotechnology and nanomedicine have demonstrated great promise in reducing the rates of morbidity and mortality of various diseases. As the science of nanotechnology and nanomedicine surge ahead, ethics, public health and policy are struggling to keep up. It is essential to simultaneously recognize contributions inimical to the ethical, social and regulatory aspects of this burgeoning technology in order to minimize its adverse impacts on the environment and public health. For example, the combination of cancer and cardiovascular diseases result in approximately half of all deaths in the United States every year. At present, the most significant concerns involve risk assessment and management, and a lack of a standardized protocol for the assessment of engineered nanomaterials. Although *ex vivo* and *in vivo* experiments can increase our understanding of the character of nanomaterials in biological systems, they cannot be certain in eliminating the risks associated with human exposure to nanomedicine products in clinical trials. Furthermore, continued use of engineered nanomaterials in nanomedicine has directed heightened attention to issues of ethical healthcare. The knowledge gaps regarding the potential health and safety implications of exposure to engineered nanomaterials, however, can be actively researched and addressed. Dynamic and socially responsible research across disciplines such as engineering, medicine, and public health will drive nanomedicine as it plays a transformative role in medicine and public health in the 21st century. This review looks at the burgeoning science of nanotechnology and nanomedicine, its applications and the ethical and the public health implications.

Keywords: nanotechnology, nanomedicine, clinical trials, risk, ethics, public health

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Introduction

"Nano" in science means one billionth, therefore one nanometer (nm) is one billionth of a meter. Nanotechnology is the study and application of nanostructures or nanosystems, and it involves the design, characterization, synthesis and application of materials by controlling the shapes and sizes at the nanoscale level. The nanomaterials are engineered at the molecular level to accomplish improved properties compared with the same materials at a larger size. Several nanotechnology applications to medicine (i.e. nanomedicine), have been generated to transform diagnostics, drug delivery, gene therapy and general therapeutics. With diabetes, scientists are creating effective nanosystems which would be able to identify only a drop in sugar levels, and restore the sugar levels automatically in patients without any self-injections. Current nanotechnology in cancer research aims at detecting potential cancer cells, and treating them before any deleterious organ damage. Further, nanotechnology involving the delivery of dopamine to the brain cells in Parkinson's disease has been developed. This drug is aimed at eliminating infection or any side effects.[1]

In the midst of the numerous benefits, environmentalists and boethicists have also raised several health concerns associated with nanotechnology. For example, even though nanoparticles are small enough to penetrate cell membranes, they are also large enough to obstruct the normal cell processes. Some have also argued that, the advent of nanotechnology could lead to loss of jobs in the manufacturing sector and other traditional occupations. Again, due to the skill and difficulty to manufacture, nanotechnology costs lots of money.[2]

Applications of nanotechnology to medicine

Nanomedicine is used for early detection, diagnosis, treatment and prevention of diseases like diabetes, infections, cancer, infectious diseases, cardiovascular diseases, musculoskeletal dysfunctions, and many more.[3]

Applications in cancer

Nanotechnology has been used to identify early stages of various illness by introducing nanoparticles composed of quantum dots (QDs) into the body. One of the most essential applications of QDs is a test developed by Johns Hopkins for cancer diagnosis. The test is based on the recognition of DNA methylation, a process that inhibits the migration of tumor-prohibiting proteins to ordinary cells, and rather allows the multiplication and diffusion of cancer cells. The QDs are subsequently used to remove the methyl group-containing DNA strands. This test has been effectively used to detect infected DNA molecules and stop the spread and damaging effects of tumors. A nanite is a robotic device containing gigabytes of computer memory for medical purposes. It is produced via nanotechnology by manipulating atoms at the molecular level. After injection into the cell nuclei, it accomplishes various tasks. When inactive, it is non-functional. When they are irradiated by X-rays to produce the active state, they produce electrons to destroy cancer cells.[4]

Delivery of medication

Nanotechnology may enhance targeted drug delivery into cancer cells[5] via two ways. Firstly, the use of nanoparticle-mediated chemotherapy into the cancer cells resulting in rapid and painless effects. Secondly, the use of nanoshells, where the heat from the infrared light is used to kill the cancer cells. Nanotechnology research has created a better way to deliver a vaccine. Protein fragments of the vaccine are stacked in many spherical lipid layers which increase the life span of the particles within the body. The protein vaccine remains in the lungs long enough for recognition by the immune cells, before presentation to T cells. This is essential to activate the memory T cells in response to future lung infections.[6] Another medical use of nanomaterials involves advanced drug delivery systems and therapies. With advanced nanotechnology in drug delivery, small-molecular-weight nanoparticle drugs, as well as peptides or genes, are delivered to the tissue of interest.[7]

The rapid innovations in nanotechnology have opened new frontiers for cardiovascular diseases. Some of the recent applications include devices for delivering drugs, bioactive molecules for lowering vesicular cholesterol, dissolving blood clots, as well as detection of specific signalling molecules for the onset of atherosclerosis.[8]

Wound healing

Medical gauze containing nanoparticles loaded with a drug called alumina-silicate helps the blood clot faster on open wounds.[9] Quell is a non-invasive neuro-stimulation technology that provides chronic pain relief in conditions such as degenerative knees and fibromyalgia. The small device is strapped onto the back of the patient's calf, and provides transcutaneous electrical nerve stimulation to the area of pain.[10] A dynamic research team is using nanotechnology to engineer the combination of polyester fibers, an antioxidant plus a porous biomaterial, and calcium nanocrystals to develop artificial Anterior Cruciate Ligament replacements. Even though success has been chalked in animal models, more empirical clinical studies are necessary to evaluate the potential use of the technology in humans. One big advantage if successful, would be the rapid healing of the ligament injury followed by a shorter rehabilitation period.[11]

Ethical implications

Nanotechnology is a fast developing branch of science which has generated significant research investigations. However, this new technological development has raised ethical issues, specifically regarding supervision, monitoring and regulation. The proponents of nanotechnology believe that it has the ability to dramatically transform lives, while opponents fear that the process may have negative consequences on human lives. A critical discussion of ethical issues surrounding nanotechnology, including nanobiotechnology and regulation of nanotechnology has been adequately presented.[12] Even though exposure to nanoparticles remains minuscule, it is generally believed that the consequences may be great. There is currently inconclusive evidence on the disastrous effect of nanoparticles on biological systems. However, the same feature of nanotechnology that facilitates the crossing of semi-impermeable membranes of cells for nanomedicine may also result in disastrous consequences.[13] Nanomedicine has risks and uncertainty. Certain nanotechnology formulations are believed to interact directly with part of the nervous system controlling behavior and movement. This uncertainty is one of the main reasons for the absence of specific regulations and tight controls regarding nanotechnology and nanomedicine.[13] Most of the potential toxic effects of nanoparticles are associated with *in vivo*, rather than *in vitro* experimental therapeutics, probably because *in vitro* therapeutics form the major component of laboratory diagnostics. Nevertheless, environmental concerns about nanoparticle pollution have arguably been the most discussed by scientists. Several studies are underway to unearth the combined effects of these 'pollutants' and those naturally available in the atmosphere. More studies on the response of living organisms to nanoparticles of varying sizes, chemical composition and surface characteristics is required to categorize the possible toxicity profiles of nanoparticle.

The final approval of *in vivo* nanomaterials for nanodiagnostics would be dependent on the empirical demonstration of nanoparticle safety in humans. Consequently, various public health committees have been set up to probe further into the toxicity issues associated with nanostructures.

Occupational and environmental health

Public and private sector investment in nanotechnology has grown exponentially worldwide. In the EU, nanotechnology has been earmarked to contribute significantly to achieving economic gains and individual benefits. This comes along the scientific debate, controversy and uncertainty about the safety of nanomaterials. The danger is that, uncertainty about safety may lower the unwillingness of businesses to invest any further. A clear regulatory framework to address the potential health impacts, within the wider context of monitoring, evaluating and assessment, must be an integral part of efforts towards nanotechnology innovation. Quite a number of studies on the effect of nanoparticles on human health have been carried out, but there is currently no acceptable protocol for safety assessment of nanomaterials. Therefore, a working group has been established to consider issues bordering on nanomaterial safety, focusing specifically on engineered nanomaterials. This initiative between the European Academies Science Advisory Council and the Joint Research Centre of the European Commission is the first of its kind. The term of reference for the working group was to assess the current methods for safety assessment, evaluate their relevance, assess the benefits and potential risks, and make recommendations for nanomaterial research. The report focuses on key nanotechnology issues that border on environmental effects and human health, rather than a comprehensive account of the science.

The revolution of nanotechnology in the global economy can also revolutionize public health. Sound occupational and public health programs implementing best practices are the grease for the engine of powerful economic engines. Information gleaned from such programs would sustain employers because accidents and disease are not only expensive, but wasteful. But what is the pragmatic line of action when arguably, there is a risk, but the details of that risk remain unknown?

Several international organizations that were set up in 2012 to produce initial steps towards international nanotechnology regulation, were met with an avalanche of criticisms from various stakeholders, but were nevertheless submitted to the World Health Organization. The generality of the criticisms bordered on steps for risk mitigation that are essential for sound programs to protect people exposed to nanoparticles, noting that the protocols as submitted, needed amendment before final submission and approval by the World Health Assembly.

Non-governmental organizations, governments and scientists agree that commercial nanotechnology poses several unanswered questions. International reports that have expressed this concern include the German Government Science Exploratory Commission, the Royal Commission on Environmental Pollution (UK 2008), the Swiss Precautionary Federation (2008), the Organisation for Economic Co-operation and Development (OECD) working group (since 2007), National Institute for Occupational Safety and Health,

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Public Testimonies sought by USA, and several non-governmental industrial organizations. Yet, reliable data to protect human lives and the ecological system lags behind industrial use. Commercial nanotechnology is expected to contribute about five trillion dollars to GDP by 2020. This quantum of economic gain by nanotechnology will change several obsolete industrial systems, and contribute to the scientific understanding, and ultimately, health care delivery systems. Therefore, prudent and rigorous research, leading to massive commercial investment in nanotechnology, should provide an overall societal benefit.

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Conflict of interest

The author declares no conflict of interest.

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