MINI REVIEW

# The present and future of nanotechnology in human healthcare

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**ABSTRACT**

Nanotechnology is a multidisciplinary field that encompasses a wide range of devices originating in engineering, physics, chemistry, and biology. Rapid breakthroughs in science and technology have opened up a blooming new sector of nanotechnology. Materials and technologies designed to interact with the body at subcellular (i.e., molecular) scales with a high degree of specificity are examples of nanotechnology applications in medicine and physiology. This could lead to targeted cellular and tissue-specific clinical applications aimed at achieving maximum treatment efficacy with the least amount of negative effects.

**Key Words:** *Nanotechnology; Nano medicine; Drug delivery; Nano diagnostic; Molecular imaging.*

## INTRODUCTION

The science of materials at the molecular or subatomic level is known as nanotechnology. It entails manipulating particles smaller than 100 nm, as well as producing materials or devices that are smaller than that – invisible to the naked eye and typically hundreds of times thinner than the diameter of a human hair. One of contemporary medicine's primary challenges is that the body does not absorb the complete pharmacological dose given to a patient. Scientists can use nanotechnology to ensure that pharmaceuticals are given to specific areas of the body with greater precision, and the drugs can be made so that the active ingredient penetrates cell membranes more effectively, lowering the required dose [1].

### Diagnostics and screening

There is an urgent need in the developing world for better disease diagnosis, and nanotechnology offers a multitude of options for detecting disease. One method is to use quantum dots, which are Nano-sized semiconductors that can be manipulated to fluoresce and can be used as biosensors to detect sickness. Quantum dots, also known as Nanocrystals, have several benefits over standard organic dyes, including the ability to adjust their luminescence to a wide range of frequencies and the fact that they degrade much more slowly in the body.

By making fluorescent quantum dots target the protein that creates a mesh in the inner membrane of blood cells, fluorescent quantum dots could be utilised to diagnose malaria. When cells are infected with malaria, the form of this protein network changes, allowing scientists to detect malaria infection based on the shape produced by the dots.Carbon nanotubes, as well as other nanoparticles like nanowires, have also been utilised as biosensors to detect diseases like HIV and cancer. Attaching nucleic acid probes to the ends of nanowires, for example, can be used to create cancer biosensors. These probes are made to bind to biomarkers like mutated RNA, which are used to detect cancer. Electric currents are created along the nanowire when altered RNA in a sample interacts with the probes, which are detected by the silicon chip in which the biosensor is housed.

Nanotechnology has the potential to transform medicine delivery by solving problems such as sustaining drug release in the body and increasing bioavailability (the number of active components per dosage).

### Drug Delivery

Nano vehicles' are currently being used to transport some medications. Liposomes, for example, have been used to encapsulate HIV medications like stavudine and zidovudine in vehicles ranging from 120 nm to 200 nm in size. Liposomes can deliver the drug payload by merging with cell membranes. Because both of these medications have limited half-lives, the liposome coating may help them stay active for longer. Fullerene 'Bucky ball' cages and branched Nano molecules termed dendrimers are two other Nano drug delivery techniques.

### Uses for nanotechnology in health

There are several developments in nanotechnology that can help improve health in developing countries.

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**Disease Diagnosis and Screening**

1. Nano litre systems (known as lab-on-a-chip): devices that automate a biological process using fluids at the Nano litre scale.
2. Quantum dots: Nano-sized semiconductors that can be used as biosensors to find disease. Because they fluoresce they can be used to tag diseased cells.
3. Magnetic nanoparticles: used as Nanosensors
4. Nanosensor arrays: grids of carbon nanotubes
5. Antibody-dendrimer conjugates: branched Nano molecules with antibodies on their ends for diagnosis of HIV and cancer
6. Carbon nanotubes and flatter, thin wires called Nano belts or nanowires as Nanosensors for disease diagnosis as they bond to biomarkers that indicate cancer such as mutated RNA
7. Nanoparticles as medical image enhancers: medical imaging relies on looking for contrasts in the way light is scattered in healthy tissue compared with diseased tissue. The sharper this contrast, the more accurate the diagnosis. Nanoparticles can give medical imaging techniques a sharper resolution, making it easier to identify diseases [2].

**Drug Delivery Systems**

The choice of system depends on the way they bind with the drug and the type of drug treatment.

1. Nanocapsules: these are pods that encapsulate drugs, which ensures the drugs are released more slowly and steadily in the body
2. Liposomes: artificial vesicles made up of a lipid bilayer so they can fuse with and penetrate membranes easily. These have been used to treat diseases such as cancer, fungal infections, hepatitis A, and influenza.
3. Dendrimers: tree-shaped synthetic Nano molecules that carry drugs in the tips of the branches.
4. Buckyballs: spherical nanoparticles can carry more than one drug at a time. They are useful in the treatment of diseases such as cancer and other diseases where monotherapy can lead to drug resistance
5. Nanobiomagnets carry drugs, for cancer for instance, into the body and are held at the target site by an external magnet. The purpose of this is to concentrate the drug at the tumour site for long enough for it to be absorbed.
6. Attapulgite clays with nanometre-sized pores are ideal for filtering out harmful bacteria from water
7. Nanotechnology can also provide alternatives to injectable vaccines if the inactive virus is bound up with nanoparticles to increase the immune response [3].

**Health Monitoring**

1. Nanotubes and nanoparticles can be used as glucose, carbon dioxide and cholesterol sensors and for in-situ monitoring of homeostasis, the process by which the body maintains metabolic equilibrium.
2. In the developed world, cancer is top of the list of diseases being targeted for Nanomedical treatment.
3. Cancer prevalence is rising fast in the developing world with 70 per cent of all cancer deaths, according to WHO.
4. In developing nations, the use of nanotechnology is also being explored in the fight against infectious diseases such as HIV and TB.

**Could nanotech help cure cancer?**

1. Advances in nanotechnology have largely been focused on cancer, primarily in terms of diagnostics and medicine administration.
2. The chemotherapies paclitaxel, which inhibits cell proliferation, and lonidamine, which lowers energy metabolism in cancer cells, have been utilised to treat multidrug-resistant breast and ovarian cancer with drugs transported by polymer-coated nanoparticles. The nanoparticles are designed to target an overexpressed epidermal growth factor receptor in tumour cells.
3. Early detection of cancer can have a substantial impact on survival rates. Scientists can detect as few as two cancer cells in one microliter of a biosample using magnetic nanoparticles in a small magnetic resonance sensor, dramatically increasing early detection [4].

**Tuberculosis and Nanotechnology**

1. The Indian government's Central Scientific Instruments Organisation has developed a nanotechnology-based tuberculosis detection kit that is currently being tested in clinical trials. This would reduce the cost and time required for TB tests, as well as the amount of blood required for testing.
2. Nanotechnology is also being employed to improve the treatment of tuberculosis. Existing TB treatment entails a lengthy drug regimen administered over several months. Many individuals do not take their medications properly or do not finish the course. Nanotechnology-based drug formulations degrade more slowly, allowing more of the active component to be administered with fewer doses.
3. Polylactide co-glycolide nanoparticles, a polymer commonly used to transport medications because it degrades efficiently and does not produce an immune reaction, have been successfully tested as tuberculosis medication carriers.
4. Nanoparticles could also be used to deliver an aerosolized tuberculosis vaccine. The vaccine is needle-free and hence does not require trained workers to give it. It is also stable at room temperatures, which is significant in rural areas where there is no reliable cold chain.

**Vaccines**

1. By giving alternatives to injectable vaccines for illnesses that impact the poor, nanotechnology could usher in a new age in immunisation.
2. In developing nations, particularly in rural regions, injectable vaccines must be delivered by healthcare professionals, who may be few.
3. Vaccines require consistent refrigeration throughout the delivery process. Scientists are developing an aerosol tuberculosis vaccine.
4. They're also looking into a nanotechnology-based skin patch that can protect against West Nile and Chikungunya viruses.
5. Injectable vaccines can be useful if the inactive virus is bound up with nanoparticles to increase the immune response. This method is being used to devise a vaccine against pandemic influenza [5].

**Positive Impact**

5. Nanoparticles provide a variety of health benefits; molecular imaging uses nanoparticles to detect, quantify, and display molecular and cellular changes in vitro and in vivo. Organic

dye-based fluorescent biological probes are commonly utilised in biology because of their inert properties and ability to interact without losing sensitivity in a range of cellular interactions.

2. Nanoparticles can be utilised as probes in vivo by connecting them to proteins, antibodies, and nucleic acid molecules. These nanoparticles can then be utilised to visualise and quantify chemical processes within the human body. They exhibit excellent photostability, brightness, and absorption coefficients over a wide spectrum range.
3. Nanoparticle-based site-specific targeted medication delivery is more effective for enhanced bioavailability, low side effects, reduced toxicity to other organs and is less expensive.
4. The development of tumour-specific thermal scalpels to heat and burn tumours is an attractive prospective application of nanoparticles in cancer treatment. It can be utilised to prevent tumour growth by utilising near infrared-absorbing polyethene-coated gold Nano shells of 130 nm.
5. Anti-wrinkle treatments, deodorants, and burn remedies contain gold and silver nanoparticles, which have powerful antifungal, antibacterial, and anti-inflammatory qualities. They are non-cytotoxic, inert, very stable, and biocompatible [6].

**Negative Impact**

1. Nanoparticle toxicity is determined by its surface characteristics, coating, structure, size, and aggregate ability. Nanoparticles with little solubility have the potential to cause cancer. Because nanoparticles have a higher surface area to volume ratio, their chemical and biological reactivity is increased.
2. Nanoparticles can enter the body in a variety of ways, including cutaneous absorption, ingestion, inhalation, injection, and implantation. When nanoparticles are included in skin care products, hair products, or lip balms, such as sunscreens and anti-wrinkle lotion, they enter the dermis.
3. Cosmetics do not require clinical testing; however, there are a large number of items containing nanoparticles. The cobalt and chromium nanoparticles in these items have been observed to produce erythema, and they breach the epidermal barrier and harm fibroblasts.
4. Many theories have been offered to explain the negative impacts of nanoparticles including cardiopulmonary morbidity and mortality. Nanoparticles have the potential to excite lung neurons, impacting the central nervous system and cardiovascular autonomic function. Because NPS is detected and identified as "invader" particles by the body's immune system, when they enter the circulation, they might cause an immediate inflammatory response.
5. When the body is exposed to foreign materials, the immune system begins to release cytokines, which are chemical substances. These particles, like any pollutant or inflammatory agent, produce a reaction in the lungs, influencing the reactive oxygen species (ROS) and, in extreme cases, triggering cardiac events [7].

**Conclusion**

1. Nanomedicine raises ethical concerns in developing countries, much like genetically engineered crops do. When people are in severe need of food or medicine does it make a difference how it gets there? Is it possible for illiterate or uneducated people to participate adequately in debates regarding the effects of new technology on society? Nanotechnology's invisibility makes it easy to 'hide' nanotech items, as well as infringe the privacy or perform operations requiring consent without the patient's knowledge. This is especially true in the case of Nano drug clinical trials conducted in developing countries.
2. Governments in developing countries will have to tread carefully. In the industrialised world, the capacity to conduct ethical clinical trials is typically limited, and introducing health products based on nanotechnology may necessitate a level of knowledge that is unavailable. Nanotechnology, like other health technologies, has no inherent positive or harmful qualities. It all depends on how it's put to use.
3. Advances in nanotechnology are being integrated with other technologies in the health field, such as information technology and biotechnology, to increase nanotechnology's potential to 'displace' health measures and systems that have been regulated for many years. The development of computer-controlled molecular instruments, for example, could eliminate the need for direct medical intervention. Alternatively, Nanosensors that measure and record medical information about a person may raise concerns regarding data storage, access, and use.
4. Even in affluent countries, research on legal, ethical, environmental, and equity issues lags behind breakthroughs in nanotechnology for health. Nanotechnology may not be as advanced in developing countries as it is in developed countries such as the United Kingdom and the United States, but China and India will catch up in no time. Developing countries should investigate the ethical and societal ramifications of technology before it arrives on their shores [8].

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