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Nanorobots: A Future Medical Device in Diagnosis and Treatment

Meena Kharwade*, Monika Nijhawan, and Sheela Modani

Gokaraju Rangaraju College of pharmacy, Osmania University, Hyderabad, Andhra Pradesh, India.

ABSTRACT

Nanorobotics is emerging field of a nanotechnology having nanoscale dimensions and is predictable to work at an atomic, molecular and cellular level. Nanorobot skeleton is made up of carbon and its toolkit contains components like medicine cavity containing medicine, microcamera, payload, capacitor and swimming tail. As nanorobots have special sensors i.e. physical or chemical which detect the target molecules in the human body can be used for the diagnosis and treatment of various vital diseases i.e. cancer, diabetes, atherosclerosis, hemophilia, kidney stones, etc. Nanorobots till date are under the line of investigation, but some primary molecular models of these medically programmable machines have been tested. This review on nanorobots presents the various aspects allied i.e. introduction, definition, basis for the development, ideal characteristics, tool kit recognition and retrieval from the body, application considering diagnosis and treatment.

Keywords: nanorobots, nanomedicines, nanosensors, nanodevice.

**Corresponding author*

INTRODUCTION

In recent years, nanotechnology provides a wide range of new technologies for optimizing the drug delivery of pharmaceutical products. Nanotechnology raises hopes for the patients that suffer from chronic diseases like cancer, multiple sclerosis, cardiovascular diseases etc. Nanotechnology is a part of applied science whose theme is to control the matter on atomic and molecular scale. Nanomedicine is a subfield of nanotechnology referred to the repair, construction and control of human biological systems using devices built upon nanotechnology standards [1]. The full potential of nanomedicine is unlikely to arrive until after complex, high-sophisticated, medically programmable nanomachines and nanorobots are developed. Nanomedicine would make use of these nanorobots introduced into the body, to repair or detect damages and infections [2-4].

A nanorobot is a theoretical tiny machine designed to perform a specific task or tasks with precision at nanoscale dimensions of 1-100 nm with or without working machine of size 0.5 to 3 µ in diameter [5]. Nanorobots are expected to work at the atomic, molecular and cellular level to perform tasks in both medical and industrial fields. The some speculative claims about the possibility of using nanorobots in medicine would totally change the world of medicine once it is realized [6].

Scientific studies report that the exterior of a nanorobot will likely be constructed of carbon atoms in a diamondoid structure because of its inert properties and strength. Super-smooth surfaces will lessen the likelihood of triggering the body's immune system allowing to act in a specific site. Nanomachines are largely in the research and development phase, but some primitive molecular machines had been tested [3, 7-9].

Basis for Development of Nanorobots

In the last decade, there has been remarkable progress in developing nano sized drug delivery systems such as antibody-conjugates, liposomes and polymer-conjugates stem [4]. Each has its own advantages and disadvantages. Antibodies have immense potential for selective targeting but can be immunogenic. Liposomes have high drug-carrying capacity, but can either release drug too quickly or entrap it too strongly and are prone to capture by the reticuloendothelial system (RES), even when polymer coated. Similarly, it is difficult to keep nanoparticles away from the RES after intravenous injection. The ideal delivery system often merges benefits of two or more technologies. As we mark the birth of nanomedicine, it is worth reflecting on the revolution it could bring to healthcare. Considering the properties of nanorobots to navigate as blood borne devices, they can help important treatment processes of complex diseases in early diagnosis and smart drug delivery [10-12, 14].

Ideal Characteristics

- Nanorobots must have size between 0.5 to 3 microns large with 1-100 nm parts. Nanorobots of larger size than the above will block capillary flow.
- It will prevent itself, from being attacked by the immune system by having a passive, diamond exterior.

- It will communicate with the doctor by encoding messages to acoustic signals at carrier wave frequencies of 1-100 MHz.
- It might produce multiple copies of it to replace worn-out units, a process called self-replication.
- After the completion of the task, it can be retrieved by allowing it to exfuse themselves via the usual human excretory channels or can also be removed by active scavenger systems [4, 13].

Building

There are two main approaches to build the nanorobots at the nanometre scale:

Positional assembly: Investigators make use of some devices such as the arm of a miniature robot or a microscopic set to pick up molecules one by one and assemble them manually.

Self assembly: It makes use of the natural tendency of certain molecules to seek one another out. In this investigators have to put billions of them into a beaker and let their natural affinities join them automatically into the desired configurations [4, 14, 15].

Tool Kit

The skeleton of nanorobots is made up of carbon, probably in the form of diamond or Diamondoid / fullerene nanocomposites. Many other light elements such as hydrogen, sulfur, oxygen, nitrogen, fluorine, silicon, etc. can be used for special purposes.

Medicine cavity: A void section inside the nanorobot can hold small doses of medicine or chemicals. The robot could release medication directly to the site of injury or infection.

Microcamera: Nanorobots may include a miniature television camera. An operator at a console will be able to steer the device while watching a live video feed, navigating it through the body manually.

Payload: A nanorobot with mounted electrodes could form a battery using the electrolytes found in blood. Another option is to create chemical reactions with blood to burn it for energy. It would hold a small supply of chemicals that would become a fuel source when combined with blood.

Capacitor: Capacitors are used to generate magnetic fields that would pull conductive fluids through one end of an electromagnetic pump and shoot it out the back end. The nanorobot would move around like a jet airplane. The non-conductive materials like Mica, Ceramic, Cellulose, Porcelain, Mylar, Teflon and even air are used.

Swimming tail: A nanorobot will need a means of propulsion to get around the body because it may have to travel against the flow of blood. The arms are manipulated by creating magnetic fields outside the patient's body. The magnetic fields cause the robot's arms to vibrate, pushing it further through the blood vessels [4, 5, 16-18].

Recognition of Target Site and Their Communication with the Machines

The nanorobot design includes integrated nanoelectronics which involves use of mobile phones. It uses RFID (radio frequency identification device) CMOS (complementary metal oxide semiconductor) transponder system for *in vivo* positioning, using well established communication protocol which allows track information about its positioning.

There are three approaches to recognize the target site-First, as a point of comparison; the scientists use nanorobots small Brownian motions to find the target by random search. In a second method, it monitors for chemical concentration significantly above the background level. After detecting the signal, it estimates the concentration gradient and moves toward higher concentrations until it reaches the target. In the third approach, nanorobots at the target release another chemical, which others use as an additional guiding signal to the target. With these signal concentrations, only it passes within a few microns of the target is likely to detect the signal.

Most recently, the use of RFID for *in vivo* data collecting and transmission was successfully tested for electroencephalograms. For communication in liquid workspaces, depending on the application, acoustic, light, RF, and chemical signals may be considered as possible choices for communication and data transmission.

One of the simplest ways to send broadcast-type messages into the body, to be received by *in vivo* nanorobots, is aural messaging. A device similar to an ultrasound probe would encode messages on aural carrier waves at frequencies between 1-10 MHz. Thus the supervising physician can easily send new commands or parameters to nanorobots already at work inside the body. Each nanorobot has its own power supply, computer, and sensorium, thus can receive the physician's messages via aural sensors, then compute and implement the appropriate response. The other half of the process is getting messages back out of the body, from the working nanodevices out to the physician [11, 19-21].

Retrieval of Nanorobots from the Body

Once a therapeutic function is completed, the extraction of artificial devices from circulation is must. Some nanodevices will be able to exfuse themselves from the body via the usual human excretory channels, others will be exfused by medical personnel using aphaeresis-like processes (commonly called nanapheresis) or active scavenger systems.

Onboard water ballast control is extremely useful during nanorobot's exfusion from the blood. Blood to be cleared may be passed from the patient to a specialized centrifugation apparatus where aural transmitters command nanorobots to establish neutral buoyancy. No other solid blood component can maintain exact neutral buoyancy, hence those other components precipitate outward during gentle centrifugation and added back to filtered plasma on the other side of the apparatus. Meanwhile, after a period of centrifugation, the plasma, containing mostly suspended nanorobots but few other solids, is drawn off through a 1-micron filter, removing the nanorobots. Filtered plasma is recombined with centrifuged solid components and returned undamaged to the patient's body [4, 22].

Applications- Diagnosis and Treatment

Medical nanorobots can perform a vast array of diagnostic, testing and monitoring functions, both in tissues and in the bloodstream. These devices could continuously record and report all vital signs including temperature, pressure, chemical composition, and immune system activity, from all different parts of the body.

Cancer Therapy

Nanorobots with embedded chemical biosensors can be used to perform detection of tumor cells in early stages of development inside the patient's body. These nanorobots would search out and identify the cancer affected cells using certain molecular as they could be introduced into the blood stream. Medical nanorobots would then destroy these cells. Nanorobots with chemical nanobiosensors can be programmed to detect different levels of E-cadherin and beta-catenin as medical targets in primary and metastatic phases, helping target identification and drug delivery. Integrated nanosensors can be utilized for such a job in order to find intensity of E-cadherin signals. Nanorobots could also carry the chemicals used in chemotherapy to treat the cancer directly at the site [11, 14, 20, 23, 24].

Diabetes

The protein hSGLT3 has an important influence in maintaining proper gastrointestinal cholinergic nerve and skeletal muscle function activities, regulating extra cellular glucose concentration. The hSGLT3 molecule can serve to define the glucose levels and serves as a sensor to identify glucose for diabetes patients. For the glucose monitoring the nanorobot uses embedded chemosensor that involves the modulation of hSGLT3 protein glucosensor activity. Through its onboard chemical sensor, the nanorobot can thus effectively determine if the patient needs to inject insulin or take any further action, such as any medication clinically prescribed. They flow with the RBCs through the bloodstream detecting the glucose levels. In the medical nanorobot architecture, the significant measured data can be then transferred automatically through the RF signals to the mobile phone carried by the patient. At any time, if the glucose achieves critical levels, the nanorobot emits an alarm through the mobile phone [3, 4, 25-27].

Surgery

Surgical nanorobots could be introduced into the body through the vascular system or at the ends of catheters into various vessels and other cavities in the human body. A surgical nanorobot, programmed or guided by a human surgeon, could act as a semiautonomous on-site surgeon inside the human body. It performs various functions such as searching for pathology and then diagnosing and correcting lesions by nanomanipulation, coordinated by an on-board computer while maintaining contact with the supervising surgeon via coded ultrasound signals. The earliest forms of cellular nanosurgery are already being explored today [3, 28-30].

As a Artificial Oxygen Carrier

The artificial mechanical red cell, "Respirocyte" is an imaginary nanorobot, floats all along in the blood stream. The Respirocyte is basically a tiny pressure tank that can be pumped full of oxygen (O_2) and carbon dioxide (CO_2) molecules. These gases can be released from the tiny tank in a controlled manner.

When the nanorobot passes through the lung capillaries, O_2 partial pressure is high and CO_2 partial pressure is low, so the onboard computer tells the sorting rotors to load the tanks with oxygen and to dump the CO_2. When the device later finds itself in the oxygen-starved peripheral tissues, the sensor readings are reversed. CO_2 partial pressure is relatively high and O_2 partial pressure relatively low, so the onboard computer commands the sorting rotors to release O_2 and to absorb CO_2. Respirocytes mimic the action of the natural haemoglobin-filled red blood cells and can deliver 236 times more oxygen per unit volume than a natural red cell [4, 22, 31, 22].

As Artificial Phagocyte (Microbivore)

Microbivore is an artificial mechanical phagocyte of microscopic size whose primary function is to destroy microbiological pathogens found in the human bloodstream, using the "digest and discharge" protocol. The chief function of microbivore is to wipe out microbiological pathogens found in the human bloodstream, using the "digest and discharge" procedure. Microbivores upon given intravenously (I.V) would achieve complete clearance of the most severe septicemic infections in hours or less, far better than the weeks or months needed for antibiotic-assisted natural phagocytic defenses. The nanorobots do not boost the risk of sepsis or septic shock because the pathogens are completely digested into harmless simple sugars, monoresidue amino acids, mononucleotides, free fatty acids and glycerol, which are the biologically inactive effluents from the nanorobot [4, 33, 34].

As Artificial Neurons

Nanorobots can be employed in replacing every neuron in one’s brain with nanorobot which is designed to function just like normal, everyday, natural neurons. The nanotech neurons are functionally equivalent. They connect to the same synapses of the original neuron, and they perform the same functional roles [35].

Atherosclerosis

Medical nanorobots have the ability to locate atherosclerotic lesions in blood vessels, mainly in the coronary circulation, and treat them either mechanically, chemically or pharmacologically [4, 36, 37].

Cell Repair and Lysis

An interesting utilization of nanorobots may be their attachment to transmigrating inflammatory cells or white blood cells, to reach swollen tissues and assist in their healing process. Mobile cell-repair nanorobot capable of limited vascular surface travel into the capillary bed of the targeted tissue or organ, followed by extravasation, histonatation, cytopenetration, and complete chromatin replacement in the nucleus of one target cell, and ending with a return to the bloodstream and subsequent extraction of the device from the body, completing the cell repair mission [4, 27, 38, 39].

Hemophilia

One particular kind of nanorobot is the clottocyte or artificial platelet. The clottocyte carries a small mesh net that dissolves into a sticky membrane upon contact with blood plasma. According to Robert A. Freitas, Jr., the man who designed the clottocyte, clotting could be up to 1,000 times faster than the body's natural clotting mechanism [40].

Gout

Gout is a situation where the kidneys lose the ability to remove waste from the breakdown of fats from the bloodstream. This waste sometimes crystallizes at points near joints like the knees and ankles. A nanorobot could break up the crystalline structures at the joints, providing relief from the symptoms, though it wouldn't be able to reverse the state permanently [41, 42].

Kidney Stones

Kidney stones can be intensely painful the larger the stone the more difficult it is to pass. A nanorobot could break up kidney stones using a small laser.

Cleaning Wounds

Nanorobots could help remove debris from wounds, decreasing the likelihood of infection. They would be particularly useful in cases of puncture wounds, where it can be difficult to treat using more conventional methods [16, 43].

Gene Therapy

Medical nanorobots can readily treat genetic diseases by comparing the molecular structures of both DNA and proteins found in the cell to known or desired reference structures. Any irregularities can then be corrected, or desired modifications can be edited in place. In some cases, chromosomal replacement therapy is more efficient than in cytorepair [44, 45].

Limitations

- The design of the nanorobot is a very complicated one and costly.
- Electrical nanorobots are susceptible to electrical interference from external sources such as RF or electric fields, EMP pulses, and stray fields from other in vivo electrical devices.

- Nanorobots can cause a brutal risk in the field of terrorism, can make use of nanorobots as a new form of torturing the communities as nanotechnology and has the capability of destructing the human body at the molecular level.
- Nanorobots manufacturing should be restricted to in-vitro replication because the replication in the body is dangerous because it can go out of control.

- Privacy is the other potential risk involved with Nanorobots. As Nanorobots deals with the designing of compact and minute devices, there are chances for more eavesdropping than that already exists [3, 4, 46].

CONCLUSION

Considering the severe side effects of the existing therapies like radiation and chemotherapy the nanorobots from the field of nanomedicine can be an innovative, supportive and optimistic machine technology for patients in the treatment and diagnosis of life threatening diseases. In future, the main emphasis in medicine will shift from medical science to medical engineering, where nanorobotic technology will be the revolution. This dawn of medical sciences will again expand extremely the effectiveness, comfort and speed of future medical treatments while significantly reducing their risk, cost, and invasiveness. Nanorobotics has strong potential to diagnose and treat disease as now it might sound like a fiction.

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